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Alternative techniques of nitrogen application to irrigated wheat: a review

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Summary

The nitrogen and phosphorus fertiliser requirements of irrigated wheat at Emerald, Queensland were recently reported, from studies involving applications of nitrogen at planting. Since the efficiency of such dressings is low, research comparing alternative techniques of nitrogen application may be productive. In this paper, the literature was reviewed to determine what further research may be worthwhile, with respect to irrigated wheat at Emerald, where the crop is generally grown by furrow irrigation on cracking clay soils.

It was concluded that planting was a more appropriate time to apply nitrogen than later in the life cycle in order to optimise returns, but that reduced nitrogen availability may restrict yields under the current furrow irrigation system. Local experimental validation of these conclusions was considered desirable.

INTRODUCTION

The nitrogen and phosphorus fertiliser requirements of irrigated wheat at Emerald, Queensland were recently reported (Wade and Tonks 1986) from studies involving applications of nitrogen at planting. Since the efficiency of such dressings is low (Strong 1981), research comparing alternative techniques of nitrogen application may be productive. The recovery of applied fertiliser nitrogen may be improved by altering the timing and method of nitrogen application. Deep placement or earlier application of the pre-planting dressing may improve the distribution of applied nitrogen in the soil profile (Strong and Cooper 1980). Split applications of nitrogen may be employed to increase the efficiency of utilisation and to increase grain yield and protein (Reeves 1954; Littler 1963; Sadaphal and Das 1966). Post-planting dressings of nitrogen may involve soil or foliar applications, or alternatively nitrogen may be applied in the irrigation water.

In this paper, the literature was reviewed to determine what further research may be worthwhile, with respect to irrigated wheat at Emerald, where the crop is generally grown by furrow irrigation on cracking clay soils (Keefer *et al.* 1977). The literature was considered with respect to two specific objectives:

1. The consequences of alternative techniques of nitrogen application for yield enhancement, by varying the timing and method of application of an equivalent total dressing of nitrogen, at a rate considered sufficient for the requirements of the crop.
2. The consequences of alternative techniques of nitrogen application for the maintenance of yield potential, through the alleviation of nitrogen availability problems in furrow irrigation systems, following a pre-planting dressing considered sufficient for the nitrogen requirements of the crop.

REVIEW OF LITERATURE

Yield enhancement through alternative techniques of nitrogen application

Pre-planting dressings

Earlier application of the pre-planting dressing may improve the distribution of applied nitrogen through the profile, due to rainfall or pre-irrigation, leaching some of the applied nitrogen out of the topsoil. Nitrogen applied before April could be lost due to denitrification as a result of heavy storm rains and high soil temperatures (Strong 1981).

Deep placement may overcome unavailability of nitrogen due to drying of the topsoil between irrigations (Strong and Cooper 1980), and may reduce the accumulation of nitrate in the ridge in furrow irrigation systems. Wetselaar *et al.* (1972) reported that for a given amount of fertiliser for a given area of soil, the rate of nitrate formation may be controlled by banding the fertiliser and by varying the band spacing. Bands of nitrogen placed higher in the soil profile than the effective depth of the furrow would be flushed directly to the surface of the bed, while bands deeper than the furrow would be flushed downwards through the soil profile. Deep placement would normally require a separate operation, which should be conducted as close to planting as possible.Thus the placement of bands of nitrogen applied before or at planting could have important consequences for subsequent nitrogen availability during crop growth.

Timing of application of post-planting dressings

Wheat yield enhancement by split application of nitrogen would be dependent upon the availability of nitrogen in the soil, the amount and distribution of seasonal rainfall (Cooper 1974) or irrigation, and the timing of application relative to the development stage of the crop (Strong 1982). Since response would only be possible in components of yield whose final value had not already been set in the life cycle of the crop (Adams 1967), the longer the application was delayed the less benefit there would be to yield and the more benefit there would be to grain protein content (Cooper 1974).

Thus Strong (1982) reported yield increases due to applications at boot stage, but no yield response from applications after flowering. Nevertheless, the boot stage dressing resulted in lower yields than when the equivalent total dressing was applied at planting. Greater responses would be expected from applications earlier in the life cycle, such as mid-tillering (Dougherty *et al.* 1979; Hedditch 1982).

Strong and Cooper (1982) compared five application strategies at three nitrogen levels. Only one split application strategy (50% at planting, 25% at tillering and 25% at boot) was able to produce grain yields equal to that in which all of the fertiliser was applied at planting. Split applications did not result in yield enhancement. Strong (1982) reported that applications from flowering onwards may result in increased grain protein. Split applications may only be economically justified for yield responses however, and not for increasing grain protein *per se*, since the premium for high protein wheat does not cover the expenditure required.

Strong (1982) reported similar quantities of nitrogen assimilation whether the entire nitrogen application was applied at planting or was split between planting and applications prior to flowering. Similarly, Strong and Cooper (1982) found that splitting the fertiliser application did not increase crop response or fertiliser uptake. Strong (1982) concluded that the results demonstrated unequivocally that planting was a more appropriate time to apply nitrogen than later to optimise returns. Thus on the basis of this literature review yield enhancement by split nitrogen application would not be expected.

Method of application of post-planting dressings

Post-planting dressings of nitrogen may involve soil or foliar applications, or alternatively nitrogen may be applied in the irrigation water. Urea solutions have been used as foliar sprays with little or no injury, even with nearly saturated solutions at rates up to 67 kg N/ha (Chesnin and Shafer 1953; Littler 1963), and may be applied with herbicides or insecticides (Reeves 1954). Since it appeared that the major portion of foliar applied nitrogen utilised by the plant was via the roots (Thorne 1956), the utilisation of foliar nitrogen sprays was largely dependent upon subsequent rainfall (Littler 1963; Hanley *et al.* 1966). Because of the unreliability of rainfall during the growing season (Robinson and

Mawson 1975), the benefits of foliar application might be considered to be questionable for yield enhancement.

Cooper (1974) reported that utilisation by plants of top-dressed nitrogenous solids was also largely dependent on subsequent rainfall. Thus even with the benefit of furrow irrigation, aerial top dressing may be a dubious proposition, since the movement of water in the soil would tend to keep the nitrogen at the soil surface, where it is generally unavailable to the plant due to drying of the topsoil between irrigations (Strong and Cooper 1980). Losses due to ammonia volatilisation may also be significant in these circumstances (Musa 1968). Side-dressing nitrogen by drilling alongside the row would minimise these problems, but would be impracticable in a sward crop with close row spacings. Drilling the fertiliser into the furrow may be effective, but its value for the whole crop would rely on lateral movement across the beds.

Application of nitrogen in the irrigation water would seem to be a more effective technique for splitting nitrogen applications (Beth 1981). At mid-tillering, the time the dressing would be expected to be most beneficial for yield, little water would have been extracted from the soil, and most of the irrigation water would be moving to shallow soil layers likely to dry out between irrigations.

Where spray irrigation facilities were available the placement difficulties considered above would not arise, since water movement would tend to take fertiliser into the root zone. Nevertheless, at the optimum time of application only the upper portion of the soil would be dry, so nitrogen would only enter the topsoil, where surface drying would soon render it unavailable. Furthermore, growers could be caught with a crop having less than the full complement of nitrogen if rainfall delayed or prevented the post-planting dressing. This possibility would be increased if split applications were used in a climate of variable rainfall pattern, such as the Central Highlands.

Discussion

There appears to be little evidence from comparable environments that split applications of nitrogen would provide any yield enhancement compared to the application of an equivalent total dressing sufficient for the crop's requirements at or prior to planting. This dressing should be banded at a depth greater than the intended depth of the furrow in order to minimise movement of nitrate to the surface of the ridge.

Split applications have not been shown to increase the efficiency of utilisation of applied nitrogen in comparable environments. The effectiveness of split application techniques depends upon rainfall or irrigation for movement of applied nitrogen to the root zone and for its continued availability there. All of the techniques have problems.

Split applications may be useful in situations in which either an insufficient initial rate of nitrogen was employed or the pre-planting dressing was not applied at all. These circumstances may arise if the weather pre-planting is unfavourable, or if the crop rotation or tillage system utilised precludes fertiliser application. Split applications may also have a role if seasonal conditions improve during the crop's growth, so that a higher yield goal than that originally intended may be achieved with additional nitrogen.

Nevertheless, it is concluded that planting is a more appropriate time to apply nitrogen than later in the life cycle in order to optimise returns. This conclusion has not been tested locally.

The maintenance of yield potential through the alleviation of nitrogen availability problems in furrow irrigation systems

Nitrogen availability in furrow irrigation systems

The availability of the pre-planting dressing of nitrogen declines with time (Wetselaar *et al.* 1972), through the influence of leaching of nitrate (Wright 1982), ammonia volatilisation (Musa 1968), and denitrification (Craswell and Martin 1974).Short term availability problems associated with transient waterlogging in each furrow irrigation have recently been reported (Hodgson and Chan 1982).The importance attributed to each of these factors and the methods used to alleviate them have varied considerably.

Lower yields have been reported for furrow irrigated crops than for equivalent sprinkler irrigated crops.Wright (1982) found that nitrate accumulation in the top five centimeters of the ridge in furrow irrigation systems resulted in seedling mortality, nitrogen deficiency symptoms and reduced yields at high rates of soil applied nitrogen in grain sorghum on the heavy cracking clays in the Ord Irrigation Area. In contrast, the downward movement of water under the sprinkler system recycled surface accumulated nitrate back to the root zone of the crop.

Craswell and Martin (1974) reported that denitrification may reduce the availability of applied nitrogen in clay soils at water contents reached during furrow irrigation.Muirhead (1980) considered that if denitrification was responsible for significant nitrogen losses, then large applications of nitrogen before sowing should be avoided.From studies with irrigated maize at Griffith in New South Wales, Muirhead and Melhuish (1980) and Muirhead *et al.* (1985) concluded that the application of urea in the irrigation water during the growth of the crop was desirable.

Chan and Hodgson (1981) reported poor aeration after every furrow irrigation on a self mulching grey clay in the Namoi Valley in New South Wales.Increasing the inundation period increased the duration of waterlogging, decreased soil nitrogen uptake and reduced cotton lint yields (Hodgson and Chan 1982).The duration of waterlogging was found to be critical, rather than the period in which the syphons were running (Hodgson 1983).Rapid application of the irrigation water would reduce the problem, but its severity was ultimately dependent upon the rate of drainage, which was essentially a function of slope and furrow geometry.Hodgson (1982) obtained significantly higher cotton lint yields when foliar sprays of urea were applied just prior to each irrigation. The adverse effects of inundation period on waterlogging, yield and nitrogen uptake have recently been confirmed by Wright (1985*a*, *b*) for furrow irrigated grain sorghum grown on Cununurra clay in the Ord Irrigation Area.

Discussion

Problems associated with reduced nitrogen availability under furrow irrigation systems have been reported from a range of locations, soil types and crops, with the cause being variously attributed to the flushing of nitrate to the surface of the ridge (Wright 1982), denitrification in fine textured soils (Muirhead and Melhuish 1980), and reduced aeration (Chan and Hodgson 1981; Wright 1985*a*).The relative importance of each of these processes in each situation may be difficult to determine, but some appreciation of their respective roles may be valuable in defining methods for the alleviation of the problem. Techniques which have received attention include deep banding of the pre-plant dressing (Wetselaar *et al.* 1972), the use of alternative irrigation systems (Mason *et al.* 1982), the application of urea in the irrigation water (Muirhead *et al.* 1985) and the application of foliar sprays of urea just prior to each irrigation (Hodgson 1982). No direct comparison of the value of each of these techniques for the alleviation of nitrogen availability problems in furrow irrigation systems has been reported.

Furthermore, it is not known whether the yields of irrigated wheat at Emerald may be restricted by reduced nitrogen availability as a result of the problems associated with furrow irrigation discussed. Compared with conditions in the Namoi Valley, at Griffith and at Kununurra, the slopes being commercially irrigated on the basaltic cracking clays at Emerald are shorter and steeper. Therefore these problems may be less during furrow irrigation at Emerald so that significant yield responses to these techniques may not be obtained. Crops on the gently sloping grey alluvial cracking clays at Emerald may be more likely to respond favourably than crops on the basaltic cracking clays. These conclusions have not been tested locally.

CONCLUSION

Application of the full nitrogen requirement of the crop in deep bands at planting was more appropriate than later in the life cycle in order to optimise returns. Local experimental validation of this conclusion would be desirable, by comparing the full dressing at planting with a similar total dressing split between planting and the application of urea in the irrigation water. Reduced nitrogen availability due to flushing of nitrate, denitrification and waterlogging may be restricting the yield under the current irrigation system to a level less than the potential expected from the pre-planting dressing. This could be tested by including treatments involving foliar nitrogen sprays applied just before each irrigation for both of the fertiliser regimes considered above. A comparison of spray and furrow systems may also be productive.

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