THE EFFECTS OF STARTER FERTILISER AND METHODS OF APPLICATION ON DIRECT SEEDED CROPS

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ABSTRACT

Four methods of applying nitrogenous fertiliser to fodder raddish and barley under continuous double crop rotation were tested at two sites over a three year period. The four methods of applying fertilizer were:

- Subsurface placement close to, but not in contact with the seed.
- Subsurface placement alongside the seed.
- Surface broadcasting.
- Subsurface placement every third row in a skip-row fashion (150 mm between rows of seed).

A treatment with no fertiliser was used as a control.

The plant population and yield of fodder radish, and yield of barley were significantly higher on a silt loam than on a sandy soil. Mixing fertilizer (subsurface placement alongside the seed) significantly reduced the plant population of the fodder radish but the other fertilizer treatments had no effects on the population of either crop. Application of 24 kg N/ha had no effects on the yield of fodder radish, except, when the fertilizer was placed alongside the seed, the yield was reduced. In barley, application of 36 kg N/ha significantly increased the yield with all methods of fertilizer application except when fertilizer was applied in every third row (skip-row).

Further analyses suggested that barley grain yield and fodder radish DM yield had no association with plant population although the barley yield had strong association with ear density.

Key Words: Direct drilling, starter fertilizer, fertilizer application methods, barley, fodder radish, plant density, grain yield, DM.

INTRODUCTION

There appears to be little information on fertilizer practices used with direct drilling (zero-tillage). Cropping in temperate New Zealand has usually involved returning paddocks to pasture at regular intervals in the rotation and most of the information on fertilizers is based on this. Intensive continuous double cropping is not widely practised in New Zealand, but in any case has usually required application of chemical fertilizers with both crops. Little is known, however, about similar fertilizer needs and use-efficiency in continuous direct-drilled double-cropping systems.

In New Zealand cropping fertilizers are usually applied either by surface broadcasting or, more commonly, by mixing it with the seed at drilling. These methods have been chosen because they are relatively easy to use and equipment is cheap. Carter (1969) and Baker and Afzal (1986) suggested that fertilizers were more toxic to plants when soil moisture was medium to low. This was because dissolution of the fertilizer was reduced resulting in more osmotic or chemical effects on the germinating seeds. The more toxic fertilizers that had been mixed with seed or banded close to seed, such as quick-release nitrogenous forms, were suggested to have adverse effects on seed germination.

On the other hand R.A. Morris (International Rice Research Institute, Philippines, pers. comm.) claimed that a course textured soil such as sand normally had a lower water holding capacity and did not necessarily behave in the same way as dry soil. Ionic activity is lower in coarse soils and applied fertilizers are therefore dissolves and deactivated more slowly, resulting in less damage to germinating seeds than in loams and clays.

Young (1982) suggested that fertilizers which were surface applied (broadcast) in direct drilling gave no yield advantages compared with fertilizers which were incorporated. Payton *et al* (1979) and Baker and Afzal (1981) however, suggested that in direct drilling placement of concentrated bands of fertilizer below the seed had given higher uptake by plants and resulted in increased crop production. Several workers (Wilkins *et al*, 1982; Rasmussen *et al*, 1980; and Noori-Fard and Bolton, (1981) noted root burning, and delayed or reduced emergence in conventionally tilled soils when fertilizer was poorly separated from the seeds.

Baker and Afzal (1986) also demonstrated that seedling emergence increased when fertilizers were separated horizontally from the sown seed by 10-20 mm (rather than vertically) in an untilled soil. In their experiments, germination of rape seed (*Brassica napus* L.) was reduced significantly when seeds and fertilizers were mixed together in the soil grooves. Because rape seed is particularly sensitive to fertilizer (Mason, 1971) the size of the response may not be as great as with other crops in double cropping systems.

Little data describing the effects of methods of fertilizer application on establishment, growth and yield in sequentially direct drilled crops is available. The objective of the present study was to determine the relative performance of a number of methods of applying starter fertilizer in direct drilled double-crops which are common in the mixed cropping and sheep farming systems of the Manawatu and Rangitikei regions.

MATERIALS AND METHODS

Four methods of applying starter fertilizer were compared over the 1983, 1984 and 1985 seasons. The methods of applying fertilizer were:

Fertilizer placed horizontally separate from the seeds in the groove;

Fertilizer mixed with seed in the groove;

Fertilizer surface broadcast at the time of seeding;
Fertilizer drilled alone in every third row giving two rows of seed and one row of fertilizer i.e. skip row.
A control treatment where no fertilizer was applied.

A prototype direct drill, designed and developed at Massey University, was used to drill the seed. This drill used an inverted-T opener (Baker *et al*, 1979) in which seeds and fertilizer were placed in the groove horizontally separted from each other by about 20 mm (Baker and Afzal, 1986). The drill was temporarily modified to apply surface broadcast and skip row (SR) fertilizer treatments. In another treatment, the seed and fertilizer were mixed together less than half an hour before drilling. A pilot experiment showed no effect from such "last-minute" mixing on seed viability.

The crop rotation was barley (*Hordium vulgare*, cv. Gold marker), which could be sown in winter or spring, and fodder radish (*Raphanus sativus*, cv. Burton), a fodder crop which could be sown in late summer or early autumn depending on field and ambient conditions. The reasons for choosing these crops was they would be combined into a rotation frequently found on mixed cropping and sheep farms in the Manawatu and Rangitikei regions, and that the barley was considered to be less sensitive to damage from chemical fertilizers than fodder radish.

Fertilizer rates for barley were 36 kg N/ha and 40 kg P/ha in the form of diammonium phosphate (18-20-0-0), and, for fodder radish, 24 kg N/ha, 20 kg P/ha, 20 kg K/ha and 2 kg K/ha and 2 kg S/ha in the form of "Nitrophoska" (12-10-10-1).

The experiments were conducted at two sites, both of which were of low fertility and in permanent pasture. The sites, at Tiritea and Flock House, were selected so that any plant responses to fertilizer would be high-lighted. A soil test taken before drilling at Flock House showed pH, 6.2; Ca, 8; K, 4; S, 9; and Mg, 14, but soil tests for the site at Tiritea were not available. The soil at Tiritea was a yellow grey earth and at Flock House was a yellow brown light sandy soil.

Existing vegetation was sprayed with 3-4 l/ha of glyphosate a few days prior to drilling. The experiment had a randomised block design with 4 replicates and used small plots 20 m in length by 4.8 m wide. The seeding rates used were 140 kg/ha for barley and 8 kg/ha for fodder radish. Seed was drilled when the soil moisture was adequate for seed germination.

Measurements made on barley included seedling counts taken 3 weeks after drilling, dry matter (DM) yield, and ear density and grain yield. The Dry Matter yield was measured when visual differences due to fertilizer treatments in plant growth and leaf colour showed. These samples were usually taken after 6-8

Table 1. Overall effect of site on plant population and yield of barley and fodder radish (1983-86).

Sites	Barley		Fodder radish	
	Plants (m^{-2})	Grain Yield ($kg\ ha^{-1}$)	Plants (m^{-2})	DM ($kg\ ha^{-1}$)
Flock House	268.7	1876.3	13.9	2431.3
Tiritea	283.6	2941.3	38.9	4793.9
% increase at Tiritea	5	57	280	97

Table 2. Monthly rainfall data from the Metereological stations at Flock House and Tiritea (1983-1986)*.

	Rainfall (mm)									
	Flock House					Tiritea				
Months	1983	1984	1985	1986	**Mean**	1983	1984	1985	1986	**Mean**
January	41	39	151	116	**87**	66	34	123	128	**88**
February	39	61	44	163	**77**	32	84	169	116	**75**
March	28	108	29	26	**48**	56	120	54	18	**62**
April	77	60	54	46	**59**	87	60	59	57	**66**
May	72	67	25	77	**60**	90	96	39	70	**74**
June	68	57	76	79	**70**	97	107	108	76	**97**
July	27	107	74	109	**79**	41	95	148	135	**105**
August	68	73	52	86	**70**	73	60	83	98	**79**
September	119	57	47	59	**71**	138	68	43	78	**82**
October	54	38	48	63	**51**	70	50	75	108	**76**
November	38	82	82	55	**64**	59	96	116	32	**76**
December	79	89	134	24	**81**	77	105	-	12	**68**

* Data from the New Zealand Meterorological Service

Table 3. Effects of season on plant population and yield of barley and fodder radish (1983-1986)*.

Seasons	Barley		Fodder radish	
	Plants (m^{-2})	Grain Yield (kg/ha^{-1})	Plants (m^{-2})	DM (kg/ha^{-1})
Year I (1983-84)	298.3 a	1697.6 b	25.2 b	2564.6 b
Year II (1984-85)	263.3 b	3290.8 a	28.4 a	4480.5 a
Year III[1] (1985-86)	250.3 b	1534.7 b	12.2 c	2791.2 b

[1] = Data from the Flock House site only

Unlike letters following values in each column show significant differences at $P < 0.05$.

Table 4. Effects of fertilizer application methods on plant density and yield of barley and fodder radish (1983-1986).

Treatments	Barley		Fodder radish	
	Plants (m^{-2})	Grain Yield (kg/ha^{-1})	Plants (m^{-2})	DM (kg/ha^{-1})
Control	274.2 a	1889.4 b	25.9 a	3239.9 ab
Placed in groove	262.1 a	2580.1 a	26.4 a	3763.1 a
Mixed with seed	270.9 a	2538.7 a	13.6 a	2809.7 b
Surface broadcast	284.3a	2431.7 a	26.2 a	3542.6 a
Skip row	282.1 a	2071.6 b	27.2 a	3526.3 a

Unlike letters following values in each column show significant differences at $P < 0.05$.

Table 5. Simple correlations between yield and selected yield components.

	Tiritea			Flock House		
	Plants (m^{-2})	Ears (m^{-2})	G. Yield ($kg\ ha^{-1}$)	Plants (m^{-2})	Ears (m^{-2})	G. Yield ($kg\ ha^{-1}$)
Barley						
Plants (m^{-2})	-	-	+0.52	-	-	-0.47
Ears (m^{-2})	-0.18	-	+0.93	-	-	-

	Tiritea		Flock House	
	Plants (m^{-2})	DM ($kg\ ha^{-1}$)	Plants (m^{-2})	DM ($kg\ ha^{-1}$)
Fodder radish				
Plants (m^{-2})	-	-0.0005	-	+0.23

weeks of growth. At the Tiritea site, the density of ears in the barley crop was sampled as there was a danger of yields being reduced by birds. As plant population was thought to influence the size of the fodder radish plants and as the fertilizer might have influenced populations of the different treatments, DM samples were taken twice during growth. Four quadrats of 0.5 m^2 were taken from each plot, and the number of plants and ears counted and Dry Matter measured. An area of 20 m x 1.3 m was harvested from each plot of barley using a 1.3 m wide plot combine harvester and grain yield estimated. Results were analysed using a 'SAS' statistical package.

RESULTS AND DISCUSSION

Site effects

Table 1 shows the overall site effects on the plant population and yield of barley and fodder radish. There were no differences between the barley plant population at both sites although grain yield at the Tiritea site was higher than that at the Flock House site.

The population of fodder radish plants at the Tiritea site was 2.8 times higher than that at the Flock House site. Differences in plant numbers were also reflected in the Dry Matter yield obtained from fodder radish at the Tiritea site which was approximately twice that of the Flock House site. This occurred partly because the fodder radish demonstrated compensatory growth and at the Flock House site, where plants were low in numbers, vegetative growth was much more vigorous. Vegetative growth at the Tiritea site was also higher because environmental conditions were more favourable (Table 2) and the water holding capacity of the silt loam higher than that of the light sandy soil at Flock House.

Seasonal effects

There were seasonal differences in plant numbers and yield of barley and fodder radish (Table 3). Plant numbers and yield of fodder radish were generally higher in 1984/85 than the previous or subsequent years and although the plant population of barley was similar in this year, yields were also higher. Further analysis suggested that barley grain was affected by weather conditions at the coastal site at Flock House, where moisture stress can occur during establishment, tillering and grain filling. The cumulative rainfall for the months of September, October and November was approximately 25% higher at the Tiritea site than at the Flock House site (Table 2). In the year 1983/84 the barley crop was spring sown and yields were adversely affected by drought despite the application of 20 mm of irrigation. In the 1984 and 1985 season the barley crop at Flock House was winter sown to reduce these problems. In 1985 data was only available from the Flock House site (Table 3). A problem with weed control due to a late and unexpected germination of barnyard grass (*Echinochloa crus -galli L.* Bauv) meant that grain yield of the barley could not be measured. Therefore care is needed in interpreting seasonal comparisons.

Fertilizer effects

Table 4 shows the effects of the methods of fertilizer application on plant population and yield of barley and fodder radish over the three years (1983-86). No differences in counts of established barley plants were found although there were differences in grain yield.

Plant population of fodder radish was reduced when fertilizer was mixed with the seed in the groove. The DM yield was also reduced and was similar to that of the control plot.

Overall, the data for the three year period indicated that barley grain yield increased when fertilizer was applied but no differences in grain yield were apparent when fertilizer was applied below the soil surface either mixed with the seed or without contact with the seed or was broadcast on to the soil surface at drilling. This could be partly because grain yields in these experiments were low compared with the average yields in the Manawatu/Rangitikei region measured by Withers and Pringle (1981).

It was somewhat surprising to note that the grain yield obtained when fertilizer was horizontally separated from the sown seed was similar to that obtained when fertilizer was broadcast on the soil surface as this is contrary to earlier results of Baker and Afzal (1981) who had found yields reponses to sub-surface placement of fertilizer in a continuous rotation of maize and winter oats. However, present results agree with the findings of Wilkins *et al* (1981) who had suggested that fertilizer placed below the seed sometimes increased yields of wheat but compared with broadcast fertilizer never reduced yields.

The addition of fertilizer increased yields above that of the control in all treatments except when fertilizer was applied to the skip row plots which was partly attributable to plant competition from the weeds which grew in the unseeded rows in these plots. It was also possible the fertilizer applied in the treatment leached before it became available to the plants as it was placed 150 mm away from the seeded row. However, quantitative measurements of weed competition or the fate of applied fertilizer were not made and so these hypotheses can not be confirmed.

When Nitrophoska fertilizer was used with seeds of fodder radish, a 'sensitive' seed, mixing fertilizer and seeds and sowing them "down-the-spout" caused seedling mortality. At the Flock House site, the Dry Matter of the fodder radish sown in this way was 53% less than when fertilizer was placed in the groove horizontally separate from the seeds and 65% less than when the fertilizer was surface broadcast. At the Tiritea site yields were reduced by 23 and 5% respectively although these differences were not significant. Fertilizer applied in the skip-row method did not increase crop yields.

Data pooled over the three years suggested that there was a weak correlation between plant density and grain yield of barley grown at the Tiritea site (Table 5). However, a strong positive correlation was found between ear number and grain yield at the Tiritea site. Withers and Pringle (1981) surveyed a large number of wheat paddocks in the Manawatu/Rangitikei district and reported similar results.

There was a weak negative relationship between the plant density of barley and grain yield at the Flock House site which appeared to relate to the low soil fertility and soil moisture at this site and suggests that plant competition might have reduced grain yield.

Correlations between plant density and the Dry Matter yield of fodder radish were inconsistent (Table 5). A weak correlation was found at the Flock House site, while no correlations were found at the Tiritea site. Plant populations were low (13.9 plants/m^2) at the Flock House site so that there was little competition between plants and the yield of Dry Matter was directly related to plant population. At the Tiritea site, plant populations and DM yields were higher (38.9 plants/m^2 and 4794 kg/ha respectively) and about twice those at the Flock House site. Intraspecific competition appeared to be more intense, possibly resulting in growth compensation in the plants sown at low plant densities.

CONCLUSIONS

Overall yields of both barley and fodder radish from the Tiritea site on the silt loam were 57% and 97% more than those from the Flock House site on a light sandy soil.

The continuous rotation of barley and fodder radish which ran for three years indicated that plant population of barley was not affected by starter fertilizer applied as diammonium phosphate at a rate of 200 kg/ha. No responses were found in the Dry Matter yields of fodder radish to applied fertilizer or the way in which it was applied, except when seed and fertilizer were mixed the yield was reduced markedly. The plant population of fodder radish and the Dry Matter yield were significantly reduced when 200 kg/ha of Nitrophoska was mixed with seed in the grooves. This was more so in the light sandy soil where plant population was low than in the silt loam where plant population was high.

Grain yields of barley were significantly increased when fertilizer was applied and were similar where fertilizer was placed alongside the seed, mixed with it or broadcast on the surface. No increase in grain yields occurred when fertilizer was applied in the skip-row fashion, presumably because of competition from weeds or leaching of fertilizer occurred.

These results suggest that placing fertilizer under the soil surface close to seed would be a better farming practice than broadcasting it or mixing it with seed when seed is direct drilled particularly if the seed species sown are prone to toxicity.

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