Paper 4
AGRONOMY OF BARLEY PRODUCTION

J.P. Millner
MAF, Private Bag, Palmerston North

INTRODUCTION

With any cereal, yield can be expressed as the product of the yield components: head numbers in a given area, average number of grains in each head, and average size or weight of a grain. Many combinations of these components are possible, even without variation in total yield, because of the range of environmental conditions which will influence them. These conditions can be modified in an attempt to obtain an ideal set of yield components, and provide the greatest economic return to the farmer, particularly by his choice of sowing rates, fertilisers, and irrigation applications. In this paper the main topical problems of barley production are discussed.

CULTIVARS

This is an area where we have good knowledge. Following a co-ordinated evaluation programme by the MAF, DSIR and commercial firms, we can recommend cultivars best suited to any area. Farmer experience further refines this system. Variation in soil type and availability of irrigation water may affect the performance of some cultivars in localised areas. (The 1983 Recommended List appears in Paper 12 — Eds.)

CULTIVATION

Cultivation absorbs the greater part of the time and energy required to produce a cereal crop. Ploughing is normally the first step in cultivation and its principal function is to help in producing a good weed-free seedbed. A great variety of implements may be used after ploughing to produce the seedbed, but whichever we use, the aim should be to achieve the desired result with as few passes as possible. Some implements can produce a seedbed with a single pass. Among the best are P.T.O.-driven rotary harrows and crumbler. They are best suited to lighter textured soils, but will perform well in heavier soils if the ground is not too wet. Ploughing should be done as early in the spring as possible to ensure a reasonable length of fallow, which if coming out of pasture should be at least 4 weeks. This ensures good organic breakdown if the soil is not too cold, and reduces numbers of pests such as Argentine Stem Weevil.

There is much interest in direct drilling as an alternative to conventional cultivation. In the past one of the biggest factors causing apprehension amongst farmers was the cost of the systemic herbicide glyphosate. The chemical remains expensive, but has been married off to C.D.A. spraying; application rates have dropped substantially without a decrease in effectiveness. There is no doubt that the technique is beneficial in labour and energy efficiency, and improved soil structure. Establishing a crop takes a quarter of the time using direct drilling rather than conventional cultivation. This also means savings in fuel, and longer tractor life. However, costs are incurred with the spraying rig required, glyphosate, extra nitrogenous fertiliser and insecticides, and there can be problems with spray drift.

The question of which method is the easier or more cost effective is not the most important. Whether yields and overall reliability are the same must be considered. Under ideal soil conditions in terms of moisture and soil-seed contact, direct drilling has proven reliable and capable of producing yields as high as conventional cultivation. However, when conditions are less than ideal, as with soil that is too wet, too dry, or compacted, yields are often much reduced because of poor emergence. A problem surfacing in the North Island is the difficulty of obtaining a good burn after direct drilled crops. The presence of weeds, particularly summer grass, is sometimes making this almost impossible. Direct drilling is quite acceptable when conditions are suitable, but is more likely to fail (compared to conventional methods) when conditions deviate from the ideal.

SOWING

Barley should be sown early enough so as to allow the crop to grow under adequate moisture conditions for as long as possible. Researchers have found that October-sown crops yield better than November-sown crops, which in turn yield far better than those sown in December. September sowings offer little advantage over October sowings, and may even result in less yield. Presumably low soil temperatures are likely to affect a September-sown crop.

The most important factor determining yield in barley is head numbers, and up to a certain limit the more heads we have the greater the yield. Obviously the sowing rate is directly related to the number of plants per hectare, but heads per plant, grains per head, and grain weight, and hence yield and screening losses, are inter-related. The question of optimum sowing rate is one which has always been around but never seems to be fully answered. The following is a summary of some of the local research on sowing rates.

From 1969 to 1971 G.W. Nixon (1975) did a series of trials comparing four different sowing rates on light-medium land (Seddon silt loam) and also on medium-heavy land (Kaiapoi series).

The three-year average yields are shown in Figure 1.

For both soil types successive increases in sowing rate gave economic increases in yield, except for the highest (140 kg/ha) sowing rate in the light soil, where a slight yield depression occurred. Nixon (1975) concluded that sowing rates in Marlborough should be 112 kg/ha on lighter land, while 140 kg/ha was most economical on heavier land.

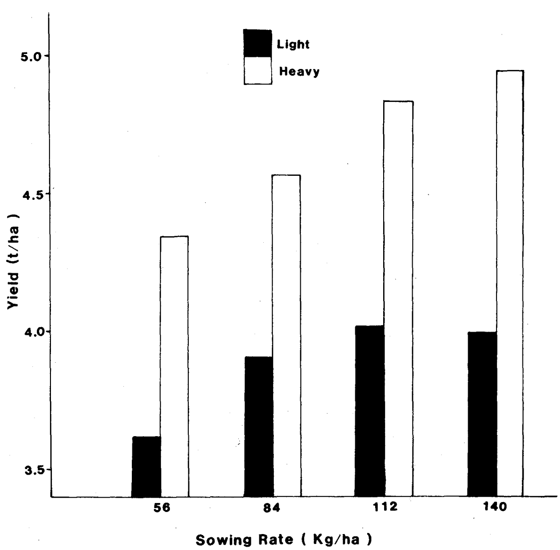

Figure 1: Effect of sowing rate on yield, Marlborough, 1969-1971.

A series of eight trials was conducted by C.C. McLeod (MAF, Timaru) from 1974 through to 1977. Again there were two main soil classes:

(a) Moisture retentive alluvial flats — Temuka and Waitohi silt loams

(b) Dry downlands — Claremont and Timaru silt loams

The eight-trial average results in Table 1 show that increasing the sowing rate up to the maximum used gave a series of increases in yield. However, on the basis of economic return it was recommended that for South Canterbury there was no benefit in using seeding rates over 100 kg/ha. Rates above this did not produce enough revenue to cover the cost of the extra seed, even on the better land (McLeod, unpub.).

TABLE 1: Effect of sowing rate on yield and yield components (4 yr av.).

Sowing Rate kg/ha	Plants per m^2	Heads per m^2	Grains per hd	Seed wt (mg)	Yield t/ha
50	112	488	21.2	46.1	3.96
75	163	529	19.9	45.1	4.26
100	202	549	19.2	44.7	4.38
125	241	561	18.4	43.4	4.41
150	291	582	17.9	42.8	4.47

However, the plant populations obtained when 100 kg/ha seed was sown were very variable, ranging from $152/m^2$ to $240/m^2$. If the trials on light and heavy land are compared, a more uniform picture emerges, with the most profitable sowing rates on the heavy land producing about 250 plants/m^2 and on lighter and drier land about $200/m^2$.

There were five trials on the downlands and three on the flats. Taking comparisons a step further, plotting the sowing rates against the average yields for the trials in the two soil classes, a similar result to that from the Blenheim work is obtained (Figure 2).

While the overall effect of increasing sowing rates was to increase yield, only head numbers among the yield components showed an increase. Both grains per head and average grain weight decreased with each increase in sowing rate. Obviously the decrease in the latter two yield components was not enough to offset the increase in head numbers. Head numbers were the most important determinant of yield.

The present consensus is that plant populations should be about $200/m^2$ for light land and $250/m^2$ for heavier land. By finding out the 1000 seed weight of the seed we are using and assuming a likely seedling emergence, we can calculate the required sowing rate. The following formula is used.

$$\text{Sowing rate (kg/ha)} = \frac{\text{desired plant No/m}^2 \times \text{1000 seed weight (g)}}{\text{\% establishment}}$$

For example assume a 1000 seed weight of 45 g and an emergence of 85% — typical for spring-sown cereals.

Say we want to establish 200 plants/m^2,

$$200 \times \frac{45}{85} = 106 \text{ kg/ha}$$

To get 250 plants/m^2, $250 \times \frac{45}{85} = 132$ kg/ha sowing rate

TABLE 2: Yields from fertiliser treatments (t/ha)

Fert	74/75	75/76	76/77	77/78	78/79	79/80	80/81	81/82	Av
Control	3.33	6.54	5.53	5.45	3.92	4.30	4.14	3.62	4.60
P Alone	3.56	6.50	5.63	5.72	4.30	4.49	4.60	3.90	4.84
N Alone	3.28	6.16	5.83	6.43	4.46	5.02	3.92	4.22	4.92
N + P	3.44	6.24	5.77	6.86	4.80	5.27	4.66	4.40	5.18

N — 250 kg/ha ammonium sulphate: P — 250 kg/ha superphosphate

Alternatively, having decided on the sowing rate, we can calculate establishment if the plant population is known.

$$\% \text{ establishment} = \frac{\text{plant no/m}^2 \times 1000 \text{ seed weight (g)}}{\text{sowing rate (kg/ha)}}$$

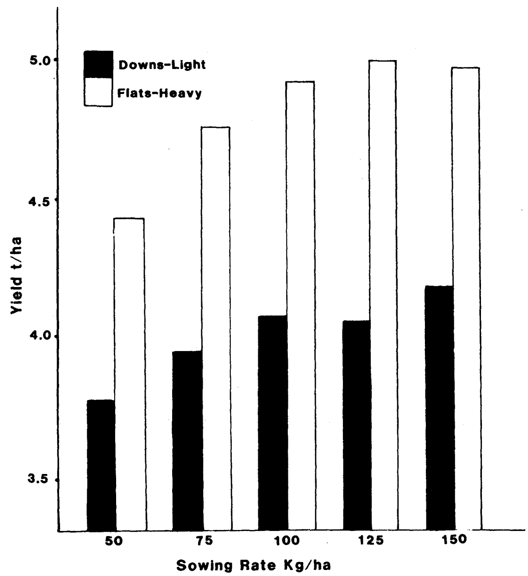

Figure 2: Effect of sowing rate on yield, South Canterbury, 1974-1977.

FERTILISERS

In the past, much has been said about the need for fertilisers, particularly nitrogen, on malting barley crops. N was quite likely to result in higher screenings and higher grain N, especially in the absence of irrigation or adequate rainfall. The percentage of screenings produced is of significance as it has a large bearing on price. However, the grain N content and its affect on malting quality are of no interest to farmers, simply because they have no effect on returns.

The two most important elements are phosphorus and nitrogen. C.C. McLeod has been running a series of trials for eight years on the effects of N and P on the yield of Zephyr barley (Table 2).

TABLE 3: Rates of nitrogen and time of application and their effect on yield (t/ha)

Nitrogen	Heads/m²		Yield	
	L	M	L	M
Control	545	669	3.80	6.16
25 kg N/ha	623	740	4.13	6.43
50 kg N/ha	645	780	4.36	6.74
Early Tillering	622	736	4.30	6.67
Late Tillering	646	784	4.19	6.49

M = Milford site — Waimakariri sandy loam, ex wheat, one irrigation
L = Lyalldale site — Timaru silt loam, not irrigated (16th successive crop)

Although the pattern does vary from year to year, these results show conclusively that economic yield increases can be expected from the addition of N and P even on the drought-prone downland soils in South Canterbury. In the 1980/81 season the response to N was negative — the result of a dry December during 1980. The principal reason for this was a drop in average grain weight with additional N. The plants were unable to fulfil a yield potential determined earlier in the life cycle when growing conditions were nearer optimum. This is one of the perennial problems of applying N to barley crops in drought-risk soils.

In general both N and P increased head numbers, with N having the greater effect. The same pattern is exhibited with grains/head. N and P tended to increase average grain weights, except in abnormally dry years.

In a more detailed trial McLeod has studied three rates of N and different application times on two soil types in South Canterbury.

The results, in Table 3, show economic response to N at both rates on both sites. Yield increments were fairly consistent for each additional 25 kg N for both soil types, yet the pattern was different for head numbers. There was a large increase from the first 25 kg N, but a much smaller increase for the second 25 kg N. Presumably the corresponding decreases in average grain weight and grains per head were higher over the first 25 kg N.

Of interest is the benefit of early rather than late application. Even though applying N at late tillering increased head numbers, yield was decreased. A possible explanation for this is that late N increased tiller survival

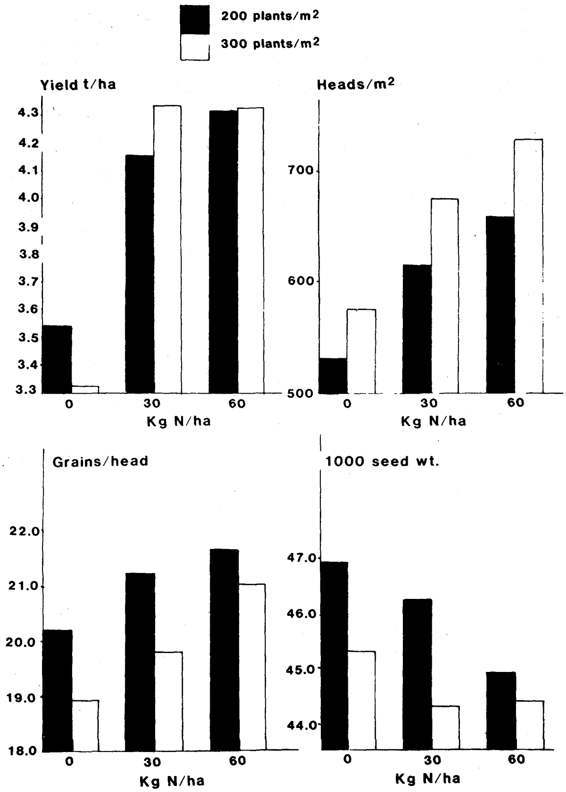

Figure 3: Effect of nitrogen fertiliser on yield and its components, Palmerston North, 1982.

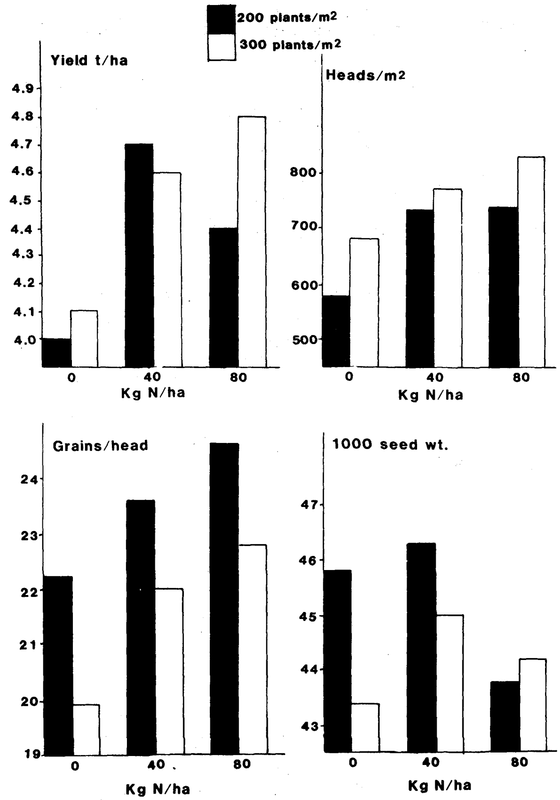

Figure 4: Effect of nitrogen fertiliser on yield and its components, Lincoln, 1981.

but did not become available to the plant in time to benefit head size, which is determined late in tillering at the end of spikelet initiation. Early N boosted tiller numbers and head size but subsequent tiller death took head numbers back down again once the availability of the added N decreased.

A trial Millner carried out at Palmerston North also shows similar interactions. This trial compared three rates of N (urea at early tillering) and two plant populations. The results have been plotted (Figure 3). In another trial at Lincoln, which received irrigation, the results were similar (Figure 4).

The effects of N on the yield and yield components were similar in these two experiments, with increases in head numbers and grains per head. The only difference is that grain weight at Lincoln was highest at 40 kg N, while at Palmerston North N decreased grain weight. This is reflected in yield, which for the lower sowing rate at Lincoln was highest at 40 kg N. The probable reason for this is that the Lincoln trial received irrigation, which helped increase the grain weight with 40 kg N. The lower plant population produced fewer heads, but more grains per head, and except for the Lincoln plots with 80 kg N it produced heavier grains.

FURTHER RECOMMENDATIONS

Potassic fertiliser has not been shown to be beneficial to barley yields in New Zealand. Although standard tests may indicate deficiencies, most soils have large natural reserves of this element, which are being continually, slowly, released. N and P are the nutrients most required for fertiliser applications to barley crops. The recommendation for P is that as 15-20 kg of P/ha are removed with a barley crop, this amount should be applied simply to maintain soil reserves. From a survey in the southern part of the North Island, Unwin and Cornforth (unpublished) concluded that if soil test figures for P are below 10 then a yield increase from added P is likely. Above 10 responses are less likely, and above 20 they are unlikely. It is reasonable to utilise high soil P reserves by not applying any when soil test figures are this high, Yields would not be affected but soil reserves would decline.

How much N to apply is a more difficult question to answer. We know that about 25 kg of N are required to produce 1 tonne of barley. After pasture there will be ample N-releasing organic matter to supply the crop's needs. In subsequent years, when this organic matter has decayed, N supplementation will be needed. The decline in barley yields with each subsequent crop is well documented.

Small shortages of N will be tolerated by a barley crop and are reflected in lower N levels in the grain — considered desirable by maltsters. The damage caused through N deficiency is expressed in yield reduction. Yield potential is set soon after sowing, through tillering and then by the formation of spikelets at the growing points of each tiller, soon after tillering is finished. This will ultimately decide how many heads the crop will have and how big they are. N deficiency will restrict tillering, decrease tiller survival and reduce head size, therefore reducing yield. P has also been shown to benefit tillering. Because all this occurs from around growth stage 2 to stage 5 the most convenient time to apply any fertiliser will be at sowing, down the drill. The fertiliser will become available at about the time the barley plants start to require it.

The benefits of N are often closely related to the amount of moisture available to the crop during grain fill. The more reliable the moisture supply the more reliable the response to N. Total yield is not necessarily affected; however, there will almost certainly be a large proportion of screenings in those crops receiving N and suffering from dryness later on. If N is not used then irrigating at 10% available soil moisture gives the best results. However, to obtain the full value of applied N, irrigation needs to be at 15% available soil moisture.

It is unfortunate that there is no way of deciding exactly how much N should be applied to a particular paddock. There is hope that a soil test being developed at Winchmore Research Station will be able to do this. Researchers in Canterbury have obtained economic yield increases from adding up to 50 kg N/ha, even on drought-prone soils (see Papers 15 and 16 of this Volume). Winchmore has obtained good yield increases to adding 50 kg N/ha, but only with irrigation. Farmers need to consider applying up to this amount once they have gone past the first year out of grass.

The best fertiliser is the cheapest. For phosphatic fertilisers, the cheapest source of P alone will be superphosphate. The following is a price list of various fertilisers quoted from Ravensdown (Hornby) in autumn 1982.

Super-bags (7.5% citric soluble P)	$136.85/tonne or $1.82/kgP
D.A.P. (18:20)	$424/tonne
Urea (46% N)	$438.35/tonne or $1.05/kgN
Ammonium Sulphate (21% N)	$216.65/tonne or $1.03/kgN
Crop Mix (6:6:5:13)	$165.15/tonne

DAP is very economical in supplying both N and P, which are present in about the same quantity. It would be useful for applying say 15-20 kg P/ha plus a small dressing of 15-20 kg N/ha the second year out of grass. Taking out the cost of P at $1.82/kg then the N is only 33 cents/kg compared with over $1/kg for straight nitrogenous fertilisers. However, later on the crop will require more N than can be supplied by D.A.P. without putting on excess P. What is required is a fertiliser with say a 3:1 ratio of N to P. None of these fertilisers fit into this category. We can mix various fertilisers to get what is required. The following are two examples with costings.

1. 50:50 mix of Super + Ammonium Sulphate
   100 kg of this mix will contain
   50 kg of Super @ 7.5% P = 3.75 kg P
   50 kg of Ammonium Sulphate @ 21% N = 10.5 kg N

So the analysis will be 10.5 : 3.75 or approx 11:4. One tonne of this mix will cost .5 × $136.85
plus .5 × $216.65 = $176.75/tonne
By applying 400 kg/ha we are applying:
42 kg N/ha
15 kg P/ha cost = $70/ha

2. 40:60 mix of D.A.P. + Ammonium Sulphate
   100 kg of this mix will contain
   40 kg of D.A.P. @ 18% N = 7.2 kg N
   @ 20% P = 8.0 kg P
   60 kg of Ammonium Sulphate @ 21% N = 12.6 kg N

So the analysis will be 12.6 + 7.2 : 8
= 19.8 : 8 or approximately 20:8
One tonne of the mix will cost .4 × $424
plus .6 × $216.65 = $299.59/tonne
By applying 200 kg/ha we supply:
40 kg N/ha
16 Kg P/ha Cost = $60/ha

Obviously the second mixture is more desirable both because it costs less and because you only need to transport half as much around. When thinking about fertilisers, first decide what is required, how much of each element you are going to apply and which fertilisers supply them. Finally the best value for money, based on the cost per kg of nutrient you want to apply, should determine which fertiliser or mix you use. There is no benefit from taking account of sundry elements which may be present in some fertilisers, such as potassium or sulphur.

WEED CONTROL

Spraying for weeds is now a standard procedure in nearly all cereal crops. The commonly used broadleaf sprays do a good job. However, many paddocks, mainly those out of pasture, are being sprayed without first being inspected to determine whether or not they need spraying. Many first-year crops do not require herbicides; if there are few weeds present at the time the crop is due to be sprayed there will be no benefits from spraying.

There were many reports of herbicide damage in the 1981 and 1982 seasons from both the North and South Islands. Most of the effects were temporary, but crops sprayed too late suffered quite severely. Plants were stunted, the heads often failed to emerge and the flag leaf was twisted around the stem. Obviously it is vital to spray at the correct time, especially in extra-dry years when the plants are likely to take in more chemical.

IRRIGATION

With some soils, obtaining reliable yields will depend on the use of irrigation. Most of the work done on irrigation has been at Winchmore on the dry Lismore soils. Although irrigation is just another variable input, along with fertiliser for example, it is probably one of the easiest to manipulate. If it doesn't rain and it's getting dry then you irrigate. Studies of irrigation response are given in Papers 13 and 14 of this Volume.

DISCUSSION

Barley is enjoying considerable popularity at present and this is likely to continue. The traditional approach to growing the crop involves sowing two bushels of seed with about one cwt of super. I think we know enough to be able to recommend those plant populations most likely to give us the highest economic returns for particular circumstances. For dry ground — 200 plants/m², from 100-110 kg/ha of seed; and for ground holding more moisture, or with more reliable rainfall or irrigation available — 250 plants/m² (125-140 kg/ha). By assuming the most likely emergence and taking account of seed size we should calculate the best sowing rate. Applying a standard weight of seed is only going to give us what we want "on average", some years there will be too many plants, and in others too few. Neither situation is good for profits.

Having established the crop, preferably in October, the next stage is the determination of yield potential. This mainly happens through tillering which determines head numbers — the most important yield component in determining final yield and profit. Head numbers also have a large bearing on the next most important component — grain weight — as this component not only helps determine yield but often also determines the price received for the grain. The size of the heads, or number of grains per head, is determined when the plant goes reproductive at the end of tillering.

Just what the desirable head number is will depend on conditions. The better they are, the more heads can be supported. Typical head populations in farmers' paddocks were obtained just before harvest in a survey in the Darfield area (Table 4).

The paddock with 40% screenings shows a problem which is characteristic of barley. Yield potential has not been realised with shrivelled grain the result. Except for 1000 seed weight, yield potential is set by the finish of tillering. If it has been set too high, small grains will be the result. This contrasts to the yield mechanism for wheat. The grains/head component is not set until flowering. This is much closer to the critical grain-fill period — which normally means a more realistic yield potential is set.

TABLE 4: Head density and yield in six paddocks in the Darfield area (1982)

Heads (per m²)	Yield (t/ha)
600	3.6
650	6.3
720	7.5
730	5.3
750	5.7
940	5.4*

*40% screenings

Lack of moisture, which may or may not have been compounded by the excessive use of nitrogen to increase yield potential, is the most likely cause of shrivelling. The ideal is to obtain a yield potential which matches the capability of the land to sustain it. However, achieving this normally means predicting the weather, unless irrigation is available. This simply means growers in less favourable conditions need to be more conservative with their crop inputs (e.g. seed + fertiliser) while growers in the more ideal areas can expect economic yield increases from using higher inputs.

ACKNOWLEDGEMENTS

Thanks to C.C. McLeod, MAF, Timaru for the offer and use of unpublished data and S. White, MAF, Darfield, for material from the Darfield survey.

REFERENCES

Drewitt, E.G., Smart, J.G., Thompson, W.J., 1974. Malting barley yield and quality responses to irrigation. *Proceedings Agronomy Society of N.Z. 4:* 41-44.

Drewitt, E.G., Smart, J.G., 1981. Effect of irrigation and nitrogen fertiliser on the yield and malting quality of barley. *Proceedings Agronomy Society of N.Z. 11:* 23-28.

Martin, R.J., 1979. Irrigation and sowing date of cereals. Annual Report of the Agricultural Research Division of Ministry of Agriculture and Fisheries.

Martin, R.J., 1980. Effect of irrigation and sowing date on cereals. Annual Report of the Agricultural Research Division of Ministry of Agriculture and Fisheries.

National Ammo-phos barley and wheat grower of the year 1981 — Results and Information.

Nixon, G.W., 1975. Seeding rates of barley. *N.Z. Journal of Agriculture. 130 (3):* 63-65.

Wauchop, P., Field-Dodgson, J., 1978. Response of malting barley cultivars to different levels of P with and without N supplement, in the Southern North Island. *Proceedings Agronomy Society of N.Z. 8:* 11-13.

DISCUSSION

Robertson: Will you have to change your recommend ations on seeding rate with the new high tillering cultivars?

Millner: No; experiments with Triumph, which is a newer cultivar, support these recommendations.

Coles: I think perhaps the new cultivars tiller less than the older ones.