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THE RELATIONSHIP OF COLEOPTILE LENGTH AND PLANT HEIGHT WITH ESTABLISHMENT OF CEREALS UNDER ZERO-TILLAGE

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ABSTRACT

Seedling establishment of cereals in four zero-tilled (direct-drilled) seedbeds was found to be positively related to the length of the 'coleoptile' and the ultimate straw length or height of the cultivar. 'Coleoptile length' was defined as the distance between the scutellum and the apex of the plumule as determined in seedlings deep sown in pots. Ten to twenty-five percent more seedlings were established in plots of the tallest cereals compared to the shortest cereals. In the zero-tilled seedbeds seedling establishment ranged from 18% to 78% of total seeds sown, indicating that the factors which often reduce seedling establishment in zero-tillage were also working in our trials.

Tall cereals tended to develop longer coleoptiles than semi-dwarf cereals, which suggests that tall cultivars have more seedling vigor. Coleoptile length was not correlated with seed weight. An 'emergence rate index', weighted to favour seedlings which emerged more quickly, was not found to be useful in predicting final stands of seedlings. Establishment was not associated with the emergence rate index, cultivars which emerged more slowly sometimes produced higher final plant populations than cultivars which emerged more quickly.

When a range of cultivars were grown in both zero-tilled and conventionally cultivated seedbeds, plant populations produced in the zero-tilled seedbed were lower than in the conventionally cultivated seedbed.This was not correlated with cultivar height.

We conclude that in improving seedling establishment in zero cultivation there is more to be gained in solving the engineering problems associated with the technique than in breeding plants with better seedling establishment.

Key words: Seedlings, cereal genotype, dwarfing genes, cultivation, wheat, barley, oat, triticale, straw length.

INTRODUCTION

In New Zealand zero-tillage or conservation techniques are not widely accepted although their use is slowly expanding. In the U.S.A., some surveys estimate that over 30% of the total cropping area is now planted using conservation tillage techniques of one sort or another.

One of the main concerns when considering zero-tillage is the low or variable seedling establishment. The most popular view is that poor crop establishment is largely an engineering problem. For example the coulter on seed-drills can have a large effect on seed-soil contact, moisture in the seed environment, and mechanical impedence to roots (Choudhary & Baker, 1980). Another possibility is that poor seedling emergence is caused by characteristics of seedlings which can be modified. Relationships between cereal genotype and seedling establishment do exist (Allan, 1980). This suggests that the problem might be able to be improved by plant breeding.

Generally seedlings with long coleoptiles emerge more rapidly and from a greater depth than do those with short coleoptiles (Allan *et al*, 1965). Selections which emerge rapidly generally produce better stands than those which emerge slowly or erratically (Allan *et al* 1962, Burleigh *et al*, 1965). However this does not always occur. Kaufmann (1968) concluded from his experiments that the emergence success of barley, but not of oats or wheat, was related to coleoptile length.

A rough relationship between coleoptile and culm lengths in wheat was demonstrated by Allan *et al*, (1961a). Seedling emergence has also been observed to be greater in 'standard-height' wheats than with semi-dwarf wheats (Fick & Qualset, 1976). However Barcaltchuk & Ullrich (1983) found that although semi-dwarf wheats with short coleoptiles have been associated with poor plant establishment, some short stemmed cultivars of barley had long coleoptiles and produced the best plant populations.

Plant breeders in New Zealand have been selecting short stemmed wheat and barley cultivars for commercial production in recent years. These modern genotypes are usually selected in cultivated seedbeds with little consideration given to seedling vigor. There is a possibility that taller genotypes would grow better in zero-cultivated seedbeds.

The objectives of the experiments reported here were to see if variation in seedling vigor exists in a small representative range of N.Z. cereals and to determine if modern short cultivars produce lower seedling stands than tall cultivars in zero-tilled seedbeds.

METHODS

Seedling vigor

Seedlines were selected and 100 seed weights determined. A measure of their phenotypic characteristics was obtained by placing fifteen seeds of each line in gallon pots in a glasshouse and covering them with 140 mm of a mixture of uncompacted pumice and peat. The pots were watered and after 14 days at 14-23 C, each seedling was removed and its length (scutellum to apex of the plumule) measured. When sown at this depth only two seedlings, one of Okawa oat and one of HR 59,01 barley emerged. All other seedlings had stopped growing before reaching the surface.

Field trials

In the spring of 1983 and 1984 seeds of representative genotypes were sown into field trials (Table 1). Genotypes sown were representative of a wide range of commonly used or previously used cultivars. Seedbeds were sown at a rate of 300

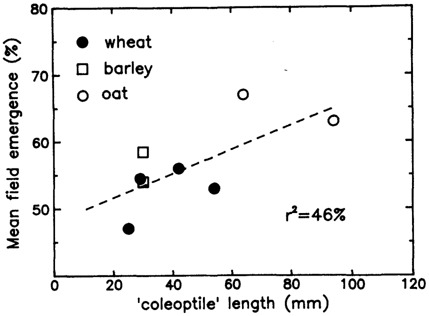

Figure 1. Mean seedling establishment (% seeds sown) in four zero-tilled seedbeds as a function of coleoptile length.

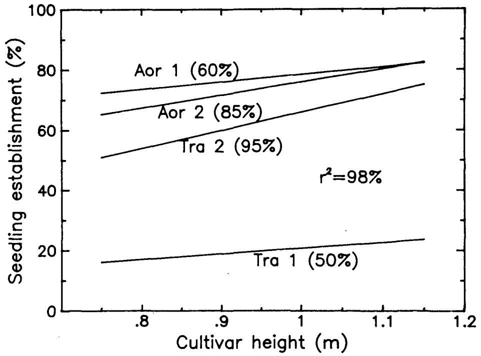

Figure 2. Seedling establishment in four zero-cultivated seedbeds (% seeds sown) as a function of genotype as distinguished by height (m). The lines are fitted regression lines to data, the means of which are shown in Table 4. The statistical probability of the slope of each line differing from zero is shown in brackets.

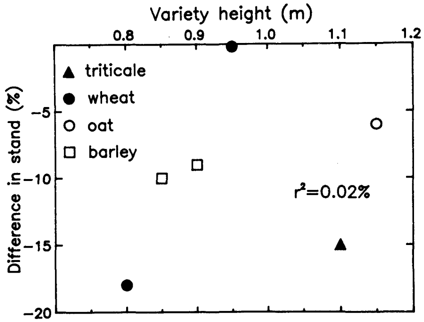

Figure 3. The difference in numbers of seedlings established between cultivated and zero-cultivated seedbeds (% cultivated stand) as a function of variety height (m).

live seeds/m^2 with a 16-row direct-drilling machine built by the Agricultural Mechanisation Unit at Massey University, and fitted with winged openers (Baker *et al*, 1979). Four cone seeders were temporarily mounted above the seed-box, each split three ways so that four plots of three 150 mm rows were sown at each pass. A blank row was left beside each plot. The average height of each cultivar was not measured at the trial sites but was obtained from records held by Crop Research Division (Dr. J.M. McEwan pers comm).

The trial sites in 1983 were located on a Tokomaru silt loam at the Tiritea Research Area near Palmerston North, and approximately 15 km East of this at Aorangi, the D.S.I.R. farm, on a Kairanga fine sandy loam. In the trial sown in 1984 zero-cultivating and ploughing were compared using six cultivars. Each trial was of a randomised complete block design in which cereal cultivars were treatments with four replicates.

Weather data were taken from Metorological stations near the Aorangi site (EO 5343) and at Palmerston North (EO 5363), about 2 km from the Tiritea site.

The method of evaluating relative performance of seedlines was similar to that described by Allan *et al,* (1962). An 'emergence rate index' (ERI) was calculated by counting the seedlings which had emerged in three 1.5 m lengths of row chosen at random from each plot. Counts started on the first day seedlings were seen (Table 1) and were made until no new seedlings emerged. Three or four counts were made on each trial. The counts made on each day were weighted to account for early emergence – the first days count was multiplied by four, the second day's count by three, and the third by two. The ERI was calculated by summing these scores. If three counts were made the weighting factors were three, two and one respectively. To make comparisons easier all ERI data were 'normalised' and adjusted to a common mean of 100 over all trials.

Table 1. Details of the field trials, sown in 1983 and 1984.

Site	Treatment	Sowing date	First count	Final count
Tiritea	zero-cult	2/9/83	21/9/83	26/9/83
Aorangi	zero-cult	1/9/83	15/9/83	26/9/83
Tiritea	zero-cult	25/11/83	2/12/83	9/12/83
Aorangi	zero-cult	28/11/83	5/12/83	12/12/83
Aorangi	zero-cult vs plough	17/9/84	27/9/84	5/10/84

Table 2. Summary of weather data recorded at the Aorangi site, and at Palmerston North (2km from the Tiritea trial site) between dates of sowing and final seedling counts (Table 1).

Trial site	Start date	Total rain (mm)	Mean daily airtemp(C)	Mean 10cm soil temp. (C)
Palm. Nth	2/9/83	113	11.6	9.9
Aorangi	1/9/83	109	11.3	10.0
Palm. Nth	25/11/83	24	15.8	15.8
Aorangi	28/11/83	28	15.5	16.8
Aorangi	17/9/84	38	10.3	10.2

Analysis of results

A SAS statistical programme was used to test two models (Council & Sall, 1982). The first model fitted regressed lines of seedling establishment against cultivar height, for each of the zero-tilled trials conducted in 1983. Each line was tested to determine the probability that their slopes differed from zero. Comparisons were made of the slopes of the lines obtained from the four trials. In the second model data were combined from all trials so that one regression line was fitted independent of the four different environments. In each case the least squares residuals were found to be normally distributed and had a mean of zero.

Table 3. Typical cultivar heights under 'average' conditions in the field, coleoptile lengths of seedlings (S.E.s in brackets) grown in deep pots and 1000 seed weights.

Cultivar	Height (m)	Coleptile length (mm)	1000 seed weight (g)
Wheats			
Gamenya	0.95	54 (2.4)	41.6
Takahe	0.95	42 (3.7)	40.4
Oroua	0.80	25 (2.2)	32.2
Karamu	0.80	29 (1.1)	30.2
Barleys			
Koru	0.75	30 (2.5)	40.7
Hassan	0.90	30 (2.6)	44.8
Triumph	0.85	28 (2.8)	51.2
HR 59,01	0.90	45 (3.3)	38.0
Oats			
CDA 4,02	1.00	64 (5.2)	44.0
Okawa	0.90	94 (6.3)	39.6
Awapuni	1.15	57 (4.3)	39.3
Triticale			
Aranui	1.10	56 (3.7)	40.4

Table 4. Final seedling stands (% of seeds sown) and normalised Emergence rate index (100 = mean) at four zero-cultivated sites in 1983.

Cultivar	Site & date sown							
	Tiritea (2/9/83)		Aorangi (1/9/83)		Tiritea (25/11/83)		Aorangi (28/11/83)	
	FS	ERI	FS	ERI	FS	ERI	FS	ERI
Gamenya	16	70	75	82	48	66	74	85
Takahe	28	120	73	38	57	84	64	84
Oroua	12	70	77	89	41	77	59	93
Koru	12	103	60	142	69	144	74	124
Hassan	11	83	76	162	59	99	88	134
Karamu	24	147	84	99	50	105	60	101
CDA 4, 02	21	76	82	97	83	127	83	98
Okawa	22	131	82	91	73	98	75	81
L.S.D 5% between cultivars:	15	71	18	40	19	40	22	37

Table 5. Final stands (% of seeds sown) and normalised Emergence rate index (100 = mean) for the zero-cultivated vs trial at Aorangi in 1984.

Variety	Treatment			
	zero-cult		cult	
	FS	ERI	FS	ERI
Gamenya	55	46	56	72
Aranui	66	63	78	104
HR 59,01	69	65	76	89
Awapuni	77	88	82	137
Oroua	65	94	79	125
Triumph	74	139	82	178
L.S.D 5%	12	19	11	20

RESULTS AND DISCUSSION

The weather during and after sowing the four 1983 zero-tilled seedbeds is summarised in Table 2. In the cool temperatures during September 1983, it took 19 days for the first seedlings to emerge at Tiritea and 15 days at the Aorangi site. In the warmer November and December weather it took seven days for the first seedlings to emerge at both sites. The cold wet seedbed at the Tiritea site in September resulted in the establishment of only 18 percent of the seeds sown, while 76 percent of the seed sown in September established at the better drained Aorangi site. The four environments tested in 1983 provide a relatively wide range of seedbed environments and can be regarded as a good testing ground for our general hypothesis that seedling genotype affects emergence rate.

Coleoptiles

Coleoptile lengths (Table 3) and cultivar height (Table 3) were only weakly correlated ($r^2 = 27\%$), which confirms previous work by Allan *et al*, (1961a).

When coleoptile lengths (Table 3) were plotted against final population of the four zero-tilled seedbeds (Table 4) an r^2 value of 46% was obtained (Figure 1). Considerably more data would need to be obtained to determine if similar relationships occurred within the three individual species of wheat, barley and oats. Allan *et al*, (1961a) has suggested that the reason for a positive relationship between plant height and seedling emergence may be related to seedling coleoptile length. Ceccarelli & Pegiati (1980) attributed the sub-optimal emergence of semi-dwarf wheats to the failure of the coleoptiles to reach the soil surface before the seedling leaves emerge through the top of the coleoptile.

The length of the coleoptile is unlikely to be the factor which determined emergence success in our trials, because in New Zealand zero-tilled crops are generally sown the same depth as cultivated crops. However the length of the coleoptile may well be a strong indicator of the presence of other characteristics which increase the vigor of seedlings and enable them to establish in otherwise unfavourable environments. For example slow emerging wheat cultivars could be stimulated to emerge rapidly with gibberellic acid, without stimulating coleoptile elongation (Alan *et al*, 1961b).

Genotype and seedling emergence

In the field the barley cultivars tended to germinate quickly, and emerge and gain high ERI scores, while the oat cultivars emerged more slowly, and tended to gain lower ERI scores, although their plant population was eventually higher. There was no relationship found between ERI and final stand (Table 4).

The result of most interest was the interaction between height (culm or straw length) of the cultivars (Table 3) and seedling stand. The model chosen to best illustrate the results is presented in Figure 2. The heights of the plants at maturity and the final stands of seedlings in the four zero-tilled seedbeds are positively related (r^2=98%).

Although the environment had a major effect on overall plant populations, interactions (as demonstrated in the slopes of the lines in Figure 2) between the four environments, and the plant height and seedling stand relationship were insignificant.

The consistent trends in our results in zero-tilled seedbeds indicate that the straw length is almost certainly correlated with establishment. Both seedling (coleoptile length) and mature plant (straw length) characteristics are correlated with populations of seedlings. This would be of value to plant breeders if they were selecting cultivars for zero-tillage.

The problem of slow or poor emergence is most often observed in the Northern Hemisphere in autumn sown crops. In the U.S.A. seed is usually sown in hot dry conditions and needs to be planted 100-125 mm deep in order to be placed in moist soil. In New Zealand seeds are not usually sown deeply when crops are established using zero-tillage techniques, so short coleoptile length of some cultivars should not influence emergence unless it is also associated with reductions in seedling vigor.

Cultivation versus zero-cultivation

There were no obvious interactions between cultivation treatments and final plant counts or ERIs (Table 5). Gamenya wheat, Aranui triticale and HR 59,01 barley which are all standard height cultivars had low ERI scores, and Awapuni oat, Oroua wheat (a semi-dwarf cultivar) and Triumph barley were the three best in both seedbeds. The characteristic lower stands in the zero-cultivated seedbed (i.e. a mean of 68% compared with 75% in the cultivated seedbed) illustrates that the factors often working to the detriment of zero-cultivated crops were also working at this trial site.

The relationship between plant height and the relative seedling performances of the seedlines in zero-cultivated and cultivated seedbeds is illustrated in Figure 3. The lack of any interaction suggests that if a cultivar is selected to perform well in cultivated seedbeds, it will also perform well in zero-cultivated seedbeds, and vice-versa. A much larger trial or survey would be required to test this convincingly. However it does appear that interactions between genotype responses and seedbed types are not large or of immediate concern to plant breeders. This means that unless major gains in seedling vigor can be obtained solving the engineering problems associated with preparing the seedling environment is likely to bring greater gains than from plant breeding.

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