Sowing depth and nitrogen effects on emergence of a range of New Zealand wheat cultivars

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Abstract

Effects of sowing depth and additional nitrogen (N) on emergence percentage of six New Zealand wheat (*Triticum aestivum* L.) cultivars were examined under field conditions. Two milling cultivars (Batten and Otane), two biscuit cultivars (Bounty and Brock) and two feed cultivars (Pernel and Sapphire) were compared.

In field experiments carried out in 1989 and 1990, Batten and Otane were compared. For both cultivars, emergence percentage decreased with increased sowing depth in the range 30 to 90 mm. The decrease was greater for Otane than for Batten. For example, in 1990, emergence percentage for Batten decreased from 80 to 71% with increased sowing depth 30 to 90 mm; comparable values for Otane were 72 and 41% respectively. In a field experiment carried out in 1991, all six cultivars were compared. In this experiment, emergence percentage from 85 mm sowing depth was greater for Batten and Sapphire than for all other cultivars. Coleoptile length was also greater for Batten and Sapphire than for all other cultivars. For all cultivars in all field experiments, additional N (100-300 kg N/ha) did not affect emergence percentage.

Under controlled environment conditions, all cultivars showed >95% emergence at 30 mm sowing depth. Emergence percentage of all cultivars decreased with increased sowing depth 30 to 90 mm. At 90 mm sowing depth, emergence percentage decreased with cultivar in the order Batten = Sapphire > Otane > Bounty = Brock > Pernel. Germination percentage of all cultivars was not affected by sowing depth. Emergence percentage at 90 mm sowing depth was postively correlated (correlation co-efficient = 95%) with mean coleoptile length.

Additional key words: Triticum aestivum *L., seedling growth, coleoptile length*

Introduction

Increased sowing depth and additional nitrogen (N) can cause decreased emergence percentage of wheat (*Triticum aestivum* L.). Three reasons have been proposed for poor emergence with increased sowing depth. Firstly, decreased aeration with increased soil depth results in decreased germination (Bremner *et al.*, 1963). Secondly, seed reserves become depleted before the shoot reaches the soil surface (Wibberley, 1989). Thirdly, the first leaf emerges from the coleoptile underground and although the leaf continues to extend, it is less rigid than the coleoptile and hence folds more easily and often is unable to push up through the soil (Allan *et al.*, 1962; Sunderman, 1964). Several workers, using a wide range of wheat genotypes have found a strong positive correlation between final coleoptile length and emergence percentage from deep sowings (Sunderman, 1964; Whan, 1976). Usually, decreased emergence percentage with additional N has been related to decreased soil water potential resulting in dehydration of seedlings (Varvel, 1982; Radford *et al.*, 1989). This occurs when N is placed with the seed. Placement of N with the seed has also been found to decrease coleoptile length (Radford *et al.*, 1989).

At present, Otane is the wheat cultivar most commonly grown in New Zealand. Under controlled environment conditions, emergence percentage of Otane decreased with increased sowing depth from 30 to 60 mm (Andrews *et al.*, 1991). This effect appeared to be due to emergence of leaf 1 from the coleoptile within the substrate. Decreased emergence of Otane with increased sowing depth was greater with additional nitrate (NO_3^-). In contrast with previous reports, this effect was associated with greater uptake of water. It was proposed that decreased emergence with additional NO_3^- was due to increased expansion of leaf 1 within the substrate resulting in greater folding and damage of the leaf (Andrews *et al.*, 1991). The major part of the NO_3^- effect occurred with increased applied NO_3^- concentration to 1.0 mol/m^3. In the field, NO_3^- concentration in the interstitial water of non-fertilised agricultural soil in temperate regions is likely to be higher than 1 mol/m^3 after cultivation and hence during seedling development (Barber, 1984; Haynes *et al.*, 1986; Wild, 1988). It was argued that endogenous soil NO_3^- concentration is likely to be high enough to cause the NO_3^- effect on emergence and that additional N, if mixed into the soil, is likely to have little further effect (Andrews *et al.*, 1990, 1991).

In the present study, the effects of increased sowing depth and additional N on emergence percentage of six New Zealand wheat cultivars were examined under field and controlled environment conditions. Also, the correlation between emergence percentage and coleoptile length was determined.

Materials and Methods

Plant material

Six wheat cultivars were compared. Seed of Sapphire, Bounty and Brock was obtained from Challenge Seeds Ltd., Christchurch, New Zealand, Otane and Pernel from Elders Pastoral, Christchurch, New Zealand and Batten from Crop Research Division, Department of Science and Industrial Research, Lincoln, Canterbury, New Zealand. Batten and Otane are milling cultivars, Bounty and Brock are biscuit cultivars and Pernel and Sapphire are feed cultivars. Seed from all sources showed >90% germination. Seed used in field experiments was treated with Baytan F17.

Field experiments

All experiments were carried out on a Templeton silt loam at the Lincoln University Research Farm, Lincoln. In experiment 1 (1989), the previous crop on the site was field bean (*Vicia faba* L.). The experimental design was a two cultivar x two seed weight x two sowing depths x three rates of N, factorial, randomised, complete block design with five replicates. Lines of Otane and Batten with a thousand seed weight (TSW) of 46 and 41 g respectively, were used. This seed is described as normal sized seed. Seed from these lines was sieved to produce lines with a TSW of 31 and 32 g for Otane and Batten respectively (small seed). Coulters were set at 30 and 60 mm sowing depths. Actual sowing depths were measured as 41 ± 6 and 67 ± 6 mm. The N treatments were 0, 100 and 300 kg/ha applied as calcium ammonium nitrate. Nitrogen was broadcast out of a conventional drill on to the plots prior to drilling. The site was ploughed, Dutch harrowed and rolled prior to sowing. Seed was sown on 9 June 1989. Five hundred viable seeds per plot were drilled with an Oyjord drill in rows 15 cm apart. The plot size was 3.0 x 1.4 m. Emerged seedlings were counted at the 2 - 3 leaf stage.

In experiment 2 (1990), the previous crop was annual ryegrass (*Lolium multiflorum* Lam.). The experimental design was a two cultivar x three sowing depths x three rates of N, randomised, complete block design with five replicates. The two cultivars were Otane and Batten. Coulters were set at 30, 60 and 90 mm. Actual sowing depths were not determined. Nitrogen treatments were as in experiment 1. The seed bed was prepared as in experiment 1 and seed was sown on 21 September 1990. Two hundred viable seeds per plot were drilled into plots 3.0 x 1.5 m. Measurements were as in experiment 1.

In experiment 3 (1991), the previous crop on the site was dwarf bean (*Phaseolus vulgaris* L.). Preparation of the seed bed, plot size and number of seeds per plot were as in experiment 1. The experimental design was a six cultivar x two sowing depths x two rates of N, randomised, complete block, design with five replicates. The cultivars are described above. Coulters were set at 60 and 90 mm. Actual sowing depths were determined as 59 ± 5 and 85 ± 7 mm. Nitrogen treatments were 0 and 100 kg N/ha applied as in experiments 1 and 2. Seed was sown on 14 May 1991. Emergence percentage for all treatments was determined as in experiment 1. In addition, ten emerged and ten non-emerged plants were sampled randomly from each plot for measurement of coleoptile length.

Controlled environment experiment

Seed used in the controlled environment experiment was of mean seed weight ± 5%. The experimental design was a six cultivar (as above) x two sowing depths, randomised, complete block design with six replicates. Seed of all cultivars was sown at 30 or 90 mm depth in 100 mm diameter, 200 mm tall pots (5 per pot) containing a vermiculite/perlite (1:1) mixture soaked with basal nutrient solution (Andrews *et al.*, 1989) containing 5 mol/m^3 potassium nitrate. Plants were grown in the dark in a controlled environment chamber. The temperature ranged from 5-10°C during each 24 hour period. All pots were flushed twice weekly with the appropriate nutrient solution. Emerged plants were counted each week after planting. Emergence from each pot was taken as complete either when all plants had emerged or when no further plants emerged during a 3 week period after emergence of at least ten plants from that particular sowing depth. On completion of the experiment, seed which failed to produce emerged seedlings was examined to determine if germination had occurred and coleoptile length of all seedlings was measured.

Analysis of data

An analysis of variance was carried out on all data. All effects discussed have an F ratio with a probability of $P<0.01$. Means stated as significantly different are on the basis of an LSD ($p<0.05$) test.

Results

In experiment 1, monthly mean values for daily air and soil temperature ranged from 5.4 - 8.3°C and 3.1 - 6.0°C respectively (Table 1). At such temperatures, germination and seedling growth of wheat are slow and it took approximately 2 months for Otane and Batten to reach the 2-3 leaf stage. Regardless of seed size or sowing depth, N did not affect emergence percentage of either cultivar. For both cultivars, emergence percentage decreased with decreased seed size and increased sowing depth (Table 2). The decrease in emergence percentage with increased sowing depth was greater for Otane than for Batten.

Monthly mean values for daily air and soil temperatures ranged from 8.3 - 11.1°C and 6.1 - 9.3°C respectively, in experiment 2. At these temperatures, both Otane and Batten reached the 2-3 leaf stage in approximately 4 weeks. As in experiment 1, emergence percentage of both cultivars was not affected by N but

Table 1. Monthly mean values for mean daily air temperature, grass minimum temperature, soil temperature at 10 cm depth, rainfall and solar radiation during the periods of study, compared with long term means[1].

	Air Temperature (°C)		Grass Minimum (°C)		Soil Temperature (°C)		Rainfall (mm)		Solar Radiation ($MJ/m^2/day$)	
Month	Actual	Mean	Actual	Mean	Actual	Mean	Actual	Mean	Actual	Mean
1989										
June	7.3	6.2	0.8	-1.6	5.0	4.5	1.7	2.0	-[2]	5.5
July	5.4	5.7	-2.0	-1.3	3.1	4.0	1.6	2.3	-[2]	6.3
August	8.3	6.7	3.2	-0.6	6.0	5.2	1.5	2.0	-[2]	9.6
1990										
October	11.1	11.7	4.4	2.6	9.3	10.8	1.3	1.6	-[2]	18.0
1991										
May	8.8	8.7	1.1	0.9	6.0	6.9	0.5	2.3	-[2]	7.3
June	5.5	6.2	-0.9	-1.6	2.8	4.5	3.5	2.0	-[2]	5.5
July	3.8	5.7	-4.1	-1.3	0.9	4.0	1.3	2.3	-[2]	6.3

[1] Long term means are for period 1967-77 in case of air temperature, 1976-86 for grass minimum temperature, soil temperature and solar radiation and 1930-81 for rainfall.

[2] Values not available.

Table 2. Effects of seed size and sowing depth (41 and 67 mm) on emergence percentage of wheat cvs. Otane and Batten. Seed was sown on 9 June 1989. Emergence percentage was determined at the 2-3 leaf stage.

	Emergence (%)			
	Normal Seed		Small Seed	
Cultivar	41 mm	67 mm	41 mm	67 mm
Otane	66	52	58	46
Batten	89	85	88	80
SEM		1.2		

Table 3. Effect of sowing depth (30, 60 and 90 mm) on emergence percentage of wheat cvs. Otane and Batten. Seed was sown on 21 September 1990. Emergence percentage was determined at the 2-3 leaf stage.

	Emergence (%)		
Cultivar	30 mm	60 mm	90 mm
Otane	72	52	41
Batten	80	77	71
SEM		2.2	

decreased with increased sowing depth (Table 3). Again, this decrease was greater for Otane than for Batten.

At a sowing depth of around 60 mm, emergence percentage for Batten was lower in experiment 3 (Table 4) than in experiments 1 or 2 (Tables 2,3). This effect does not appear to be related to weather conditions as temperatures and rainfall during June/July 1989 and May/June 1991 were similar (Table 1). Nitrogen did not affect emergence percentage or coleoptile length of any cultivar in experiment 3. For all cultivars except Batten and Sapphire, emergence percentage decreased with increased sowing depth (Table 4). At 59 mm sowing depth, emergence percentage was greater for Batten than for all other cultivars except Sapphire. At 85 mm sowing depth, emergence percentage was greater for Batten and Sapphire than for all other cultivars. In general, for all cultivars in experiment 3, coleoptile length increased with increased sowing depth and at each sowing depth was greater for emerged than non-emerged plants (Table 5). For emerged plants at 59 and 85 mm sowing depths and non-emerged plants at 59 mm sowing depth, coleoptile length was greater for Batten and Sapphire than for all other cultivars.

Under controlled environment conditions, all cultivars showed 96% or greater emergence from a sowing depth of 30 mm (Table 6). This value was similar to germination percentage. For all cultivars, germination percentage was not affected by sowing depth but emergence percentage decreased with increased sowing depth. At 90 mm sowing depth, emergence percentage decreased with cultivar in the order Batten = Sapphire > Otane > Bounty = Brock > Pernel. Emergence percentage was positively correlated (correlation coefficient = 95%) with coleoptile length (Table 6).

Table 4. Effect of sowing depth (59 and 85 mm) on emergence percentage of six wheat cultivars. Seed was sown on 14 May 1991. Emergence percentage was determined at the 2-3 leaf stage.

	Emergence (%)	
Cultivar	59 mm	85 mm
Batten	64	63
Sapphire	62	59
Otane	54	45
Bounty	58	46
Brock	52	46
Pernel	59	45
SEM	1.6	

Discussion

Andrews *et al.* (1991) found that under controlled environment conditions, emergence percentage of Otane from sowing depths of 60-120 mm decreased with increased applied NO_3^- from 0 to 5.0 mol/m^3 then changed little with increased NO_3^- to 20 mol/m^3. The major part of the NO_3^- effect occurred with increased concentration to 1.0 mol m^{-3}. As NO_3^- concentration in non-fertilised soils is likely to be greater than 1.0 mo/m^3

Table 5. Coleoptile length of emerged and non-emerged seedlings of six wheat cultivars sown at different depths (59 and 85 mm). Seed was sown on 14 May 1991. Plants were sampled when emerged plants were at the 2-3 leaf stage.

	Coleoptile Length (mm)			
	Emerged		Non-emerged	
Cultivar	59 mm	85 mm	59 mm	85 mm
Batten	63	85	56	57
Sapphire	59	74	55	55
Otane	54	63	46	54
Bounty	55	62	47	57
Brock	53	64	37	46
Pernel	53	60	35	44
SEM	1.4		2.4	

Table 6. Effect of sowing depth (30 and 90 mm) on emergence percentage of six wheat cultivars and mean coleoptile length of these cultivars at 90 mm sowing depth.

	Emergence (%)		Coleoptile Length
Cultivars	30 mm	90 mm	(mm)
Sapphire	100	77	67
Batten	97	76	60
Otane	96	58	53
Bounty	100	33	49
Brock	98	31	48
Pernel	99	22	40
SEM	6.0		2.1

after cultivation, then additional N, if mixed into the soil, is likely to have little effect on emergence percentage (Andrews *et al.*, 1990, 1991). This was found to be the case here, as for all cultivars, in all field experiments, additional N did not affect emergence percentage regardless of sowing depth. Placement of N with the seed has been found to decrease coleoptile length of wheat (Radford *et al.*, 1989). However, under controlled environment conditions, applied NO_3^- up to 20 mol/m^3 did not affect coleoptile length of Otane, indicating that if additional N is mixed into the soil, coleoptile length is unlikely to be affected (Andrews *et al.*, 1991). This was found to be the case in experiment 3 here, as for all cultivars, regardless of sowing depth, additional N did not affect coleoptile length.

For all cultivars, emergence percentage decreased with increased sowing depth from 30-40 mm to around 60 mm (Tables 2,3,4,6). The magnitude of the decrease was dependent on cultivar. With regard to the two milling cultivars, the decrease in emergence percentage with increased sowing depth was always greater for Otane than Batten. However, only Batten and Sapphire had greater emergence percentages from deeper sowings than Otane, indicating that Otane is not exceptional in its susceptibility to deeper sowings. Previously, cultivar differences with respect to emergence percentage from deeper sowings were shown to be related to coleoptile length (Allan *et al.*, 1962; Sunderman, 1964; Whan, 1976). This appears to be the case in the present study also, as at 60 and 90 mm sowing depth in the field, coleoptile length and emergence percentage were greater for Batten and Sapphire than for all other cultivars. Also, at 90 mm sowing depth under controlled environment conditions, emergence percentage was positively correlated (correlation coefficient = 95%) with coleoptile length (Table 6). For Batten, Sapphire and Otane at 90 mm sowing depth, emergence percentage was greater under controlled environment conditions than in the field but for Bounty, Brock and Pernel, the converse was the case (Tables 4,6). Because of these differences, ranking of cultivars with respect to emergence percentage was different in the two environments. In the field, emergence percentage was greater for Batten and Sapphire than for all other cultivars but in the growth cabinet there were four groupings; Batten = Sapphire > Otane > Bounty = Brock > Pernel (Tables 4,6). For Bounty, Brock and Pernel, decreased emergence percentage in the growth cabinet in comparison with the field was associated with shorter coleoptiles (Tables 4-6). These data emphasise that although emergence percentage from deep sowings is dependent on cultivar and cultivar differences are positively correlated with coleoptile length, environmental conditions other than sowing depth can affect emergence percentage and coleoptile length (Allen *et al.*, 1962; Whan, 1976).

Conclusions

1. Additional N is unlikely to affect emergence percentage of wheat if incorporated into the soil.
2. Emergence percentage from deep sowings is dependent on cultivar.
3. Cultivar differences are positively correlated with coleoptile length.
4. Sowing depths greater than 30 mm are likely to cause a substantial reduction in emergence percentage of Otane, Bounty, Brock and Pernel.

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