GROWTH PATTERNS OF SIX WHEAT CULTIVARS

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ABSTRACT

Three semi-dwarf and three standard height wheat cultivars were grown on Lismore stony silt loan under border-strip irrigation. Irrigation was applied at 25% available soil moisture and fertiliser nitrogen was applied at the second node stage.

Growth and development were earlier in the semi-dwarf cultivars and within the two groups there was difference of seven days between the first and last cultivar to reach anthesis. All cultivars reached maturity within a six day period.

Total above-ground plant weight at the booting stage was similar for all six cultivars but after ear emergence the growth of the leaves, stems and ears varied with cultivar. Large cultivar differences in the amount of dry matter lost from the stem + leaf between anthesis and harvest were explained by differences in growth rate and duration following anthesis. In the same period, increase in ear weight of all cultivars was much less variable. Additional fertiliser N applied to small scale sub-plots at late anthesis increased ear weight and reduced the rate of loss of dry weight from the stem + leaf.

Grain yield and harvest indices of two of the standard height cultivars were comparatively low, mainly because of low mean grain weight. Agreement between calculated yield, derived from component data, and the yield from 1m² varied considerably with cultivars.

INTRODUCTION

Two cultivars recently released for commercial use (Oroua and Rongotea) and two cultivars under pre-release testing at C.R.D. Lincoln (Pahau and Wakanui) were compared with two standard cultivars (Karamu and Kopara) in a spring- sown trial to evaluate their performance on Lismore stony silt loam under border-strip irrigation in the 1978-79 season. Karamu is a Mexican semi-dwarf selection (McEwan *et al.*, 1972) and both Oroua and Rongotea involve crosses between semi-dwarf and high quality wheats of conventional stature (McEwan and Vizer, 1979). Karamu and Oroua are short-strawed and Rongotea has straw of medium length; all three are fully awned. These three cultivars are recommended for spring sowing, although Karamu and Rongotea are suitable for winter sowing in some districts. Kopara, Pahau and Wakanui were recommended for winter sowing. Wakanui has similar growth characteristics to Kopara, both are tip-awned only. Pahau is fully awned and has slightly shorter straw than Kopara. Both Pahau and Wakanui have since been withdrawn, at least temporarily, from official testing.

The growth, nitrogen uptake and yield of the six cultivars in this experiment have previously been described (Quin and Drewitt, 1979). This paper describes the growth patterns of the individual cultivars with particular reference to the dry weight changes occurring in the leaf, stem + leaf and ear. Yield parameters are also discussed.

In England, Pearman *et al.* (1978) found that the pattern of ear growth after anthesis and loss of weight from the stem + leaf between anthesis and harvest did not differ between semi-dwarf and standard cultivars. However, Austin *et al.* (1977) recorded significant differences among six cultivars in the amount of dry weight lost from the stem + leaf between anthesis and harvest; loss of carbohydrate from the stem + leaf was similar to the loss of dry weight and the amount of carbohydrate translocated to the grain also differed between the cultivars. Other factors affecting the contribution of translocated carbohydrate to grain yield include the demands of the respiratory processes (Austin *et al.*, 1977), leaf area duration (Pearman *et al.*, 1978), climate and soil moisture (Gallagher *et al.*, 1975) and fertility (Murata, 1969).

Spring-sown wheat yields on the light soils in Canterbury are increased by irrigation and fertiliser nitrogen and the interaction may be significant on low fertility areas (Drewitt, 1979). Results presented in this report are for that section of a cultivar x irrigation factorial experiment in which a soil moisture deficit sufficient to restrict growth was not allowed to occur and fertiliser nitrogen was applied at the second node stage. The effects of a late application of nitrogen are also discussed.

MATERIALS AND METHODS

The experiment was carried out on Lismore stony silt loam (300-450 mm overlaying gravels) as a first cereal crop following oats/ryegrass greenfeed, which had been sown after several years in pasture. Soil "Quick Test" analysis of the top 150 mm at time of drilling (18 August) was pH 5.5, P 12, Ca 8, and K 8. Seed sowing rates (kg/ha) and weight (mg) were Kopara 170, 48; Pahau 155, 50; Wakanui 160, 44; Karamu 140, 44; Oroua 170, 45; Rongotea 170, 53. Superphosphate at 21 kg/ha was applied with the seed, and nitrogen was applied at 54 kg N/ha (as ammonium sulphate) at the second node stage (27 October). An additional 40 kg N/ha was applied to small sub plots at late anthesis.

The experiment was a split plot design with three irrigation treatments occupying main plots (70 x 9m) and six cultivars on split plots (35 x 2.4m). There were five replicates. In this report, only the results of the highest yielding irrigation treatment are presented - results of this main plot treatment were analysed as a randomised block. Full details of all treatments, nitrogen uptake and grain yield were given by Quin and Drewitt (1979). Irrigation was applied by the border-strip method when soil moisture in the top 150 mm of soil fell to approximately 25% available soil moisture. Two irrigations were required, they were applied on 23 November and 21 January.

Plant samples were taken at approximately two-weekly intervals from 15 November (early booting) until harvest. Quadrats 300 x 300 mm were taken from each replicate and bulked before separation into shallow roots, stems (including sheath), leaves (live and dead) and ears for dry matter determination. Leaves were classified dead when all green colouring had disappeared from the leaf. At harvest, plant sampling was carried out on a plot basis on 1m² samples. After removal of 50 ears (25 for chaff and grain separation and 25 for component analysis); those remaining were machine threshed for grain yield determination.

For component analysis the total number of ears in the 1m² sample was counted. The number of fertile spikelets per ear was counted on a sub-sample of 25 ears and after threshing the number of grains per spikelet was calculated from the total number of grains in the 25 ears. Mean grain weight was measured on a sub-sample of 300 grains.

RESULTS

Plant development

The dates of the major growth development stages are given in Table 1. The three cultivars recommended for spring sowing, Karamu, Oroua and Rongotea emerged five days earlier than the three winter cultivars, Kopara, Pahau and Wakanui. Ear emergence was also earlier on the spring cultivars, with Karamu the first to reach anthesis.

TABLE 1: Dates of growth stages according to the Feekes scale.

Cultivar	Feekes 1 emerg.	2 tillering	10.1 ear emerg.	10.5.1 anthesis	11.4 maturity
Kopara	12 Sept.	3 Oct.*	24 Nov.	1 Dec.	27 Jan.
Pahau	12 Sept.	3 Oct.	27 Nov.	8 Dec.	30 Jan.
Wakanui	12 Sept.	3 Oct.	29 Nov.	8 Dec.	1 Feb.
Karamu	7 Sept.	3 Oct.	17 Nov.	27 Nov.	27 Jan.
Oroua	7 Sept.	3 Oct.	19 Nov.	1 Dec.	27 Jan.
Rongotea	7 Sept.	3 Oct.	21 Nov.	4 Dec.	29 Jan.

*The start of tillering was not monitored — all cultivars were in the early stages of tillering when examined on 3 October.

Leaf and stem dry weight

When plant sampling began on 15 November (early boot) the combined leaf + stem dry weight was very similar on all six cultivars, averaging 230 g/m². Slightly more than half the plant material was stem and of the leaf fraction approximately 10% was classified dead (Fig. 1). Dry weight of the live leaves generally increased slightly at the second sampling (ear emergence) but thereafter decreased until the fifth sampling (soft dough) when all leaves were classified dead. Total leaf dry weight generally decreased with time but differences between samplings were quite small. Wakanui produced the highest and Karamu the lowest peak of total leaf dry weight. At the final sampling total leaf dry weight was similar on all six cultivars. No account was taken of fallen leaves.

The highest recorded stem + leaf weight of Rongotea occurred at the third sampling (Fig. 2), but in all other cultivars the highest stem + leaf weight occurred at the fourth sampling. Wakanui produced the highest, and Karamu the lowest peak of stem + leaf dry weight. At the final sampling stem + leaf weight of Karamu (250 g/m²) was much lower than the other five cultivars which averaged 320 g/m² (Table 2).

TABLE 2: Dry weight (g/m²) of the stem + leaf at anthesis and at harvest.

Cultivar	Anthesis	Harvest	s.e. mean at harvest	Weight loss between anthesis and harvest
Kopara	420	330	8.9	90
Pahau	500	300	19.6	200
Wakanui	580	330	36.3	250
Karamu	330	250	18.9	80
Oroua	420	310	26.6	110
Rongotea	500	320	17.8	180

Figure 1: Dry weight g/m², of live leaf (•---•) and total leaf (○—○)

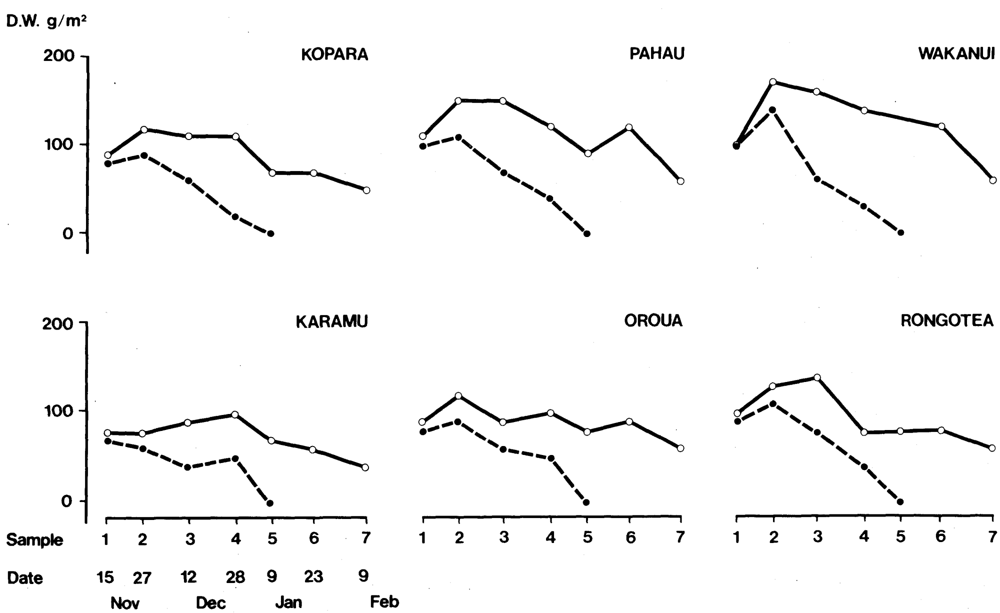
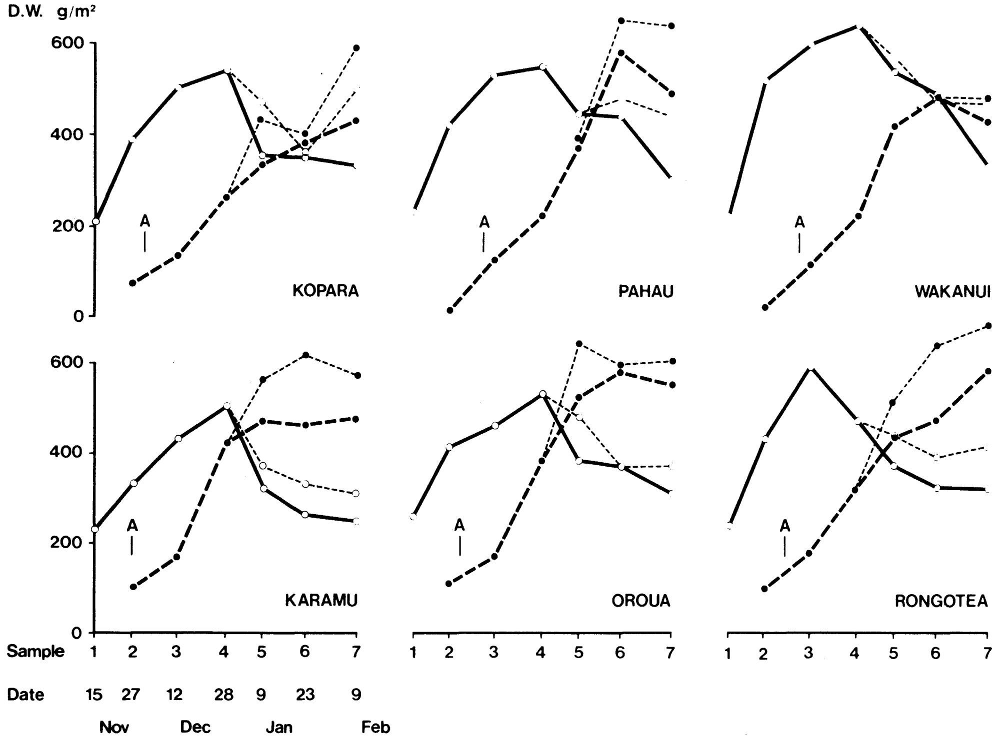


Figure 2. Dry weight of stem + leaf (○—○) and ear (•---•). 40 kg N/ha at late anthesis (----). Anthesis (A)



Ear dry weight

Ear dry weight increased rapidly following anthesis and on two cultivars, Kopara and Rongotea, it reached the highest level at the final sampling (Fig. 2). Maximum ear weight was reached at the sixth sampling on Pahau, Wakanui and Oroua but in Karamu, ear weight levelled off after the fifth sampling. At the final sampling, ear weight of Kopara and Wakanui was comparatively low while that of Oroua and Rongotea was well above the mean (Table 3).

TABLE 3: Dry weight (g/m²) of the ear at anthesis and at harvest.

Cultivar	Anthesis	Harvest	s.e. mean at harvest	Weight gain between anthesis and harvest.
Kopara	90	430	15.8	340
Pahau	90	490	30.2	400
Wakanui	90	430	18.9	340
Karamu	100	470	37.4	370
Oroua	120	550	34.6	430
Rongotea	140	580	30.8	440

Changes in stem + leaf and ear dry weight between anthesis and harvest.

Dry weights of stem + leaves and ears at anthesis were estimated from the plotted line between the second and third plant sampling (Fig. 2.). The loss of weight from the stem + leaf between anthesis and harvest varied considerably with the cultivars, ranging from 80 g/m² for Karamu to 250 g/m² for Pahau (Table 2). Increase in ear weight between anthesis and harvest did not vary so much between cultivars, averaging 390 g/m² (Table 3).

Grain yield

The fraction of grain as a percentage of total ear weight was comparatively low on Kopara and Wakanui and consequently grain yield and harvest index (fraction of total above ground dry weight in the grain), were lowest on these two cultivars (Table 4). Karamu had the highest harvest index and the grain yield of this cultivar equalled that of Pahau, Oroua and Rongotea.

TABLE 4: Dry weight (g/m²) of total plant, ears and grain at harvest, and harvest index.

Cultivars	Total Plant	Ears	Grain	Harvest index
Kopara	750	430	230	31
Pahau	800	490	340	42
Wakanui	760	430	230	30
Karamu	710	470	350	49
Oroua	850	550	360	42
Rongotea	900	580	370	41

Number of ears at harvest

The number of ears/m² at harvest varied with cultivar (Table 5), partly because of variability in the seeding rate and probably also because of differences between cultivars in tiller production and tiller survival, neither of which was recorded in this trial. The ratio of ears/m² to seed sown was slightly more than one for the three spring cultivars, slightly less than one for Kopara and Pahau and rather lower for Wakanui (0.82). Oroua had the highest number of ears at harvest and Pahau and Wakanui the lowest.

Number of grains per ear

Kopara, Pahau and Karamu produced approximately the same number of grains per ear, there being only small differences in the number of spikelets per ear and grains per spikelet (Table 5). Wakanui produced slightly more grains per ear mainly because of above average spikelets per ear. Oroua and Rongotea produced fewer grains per ear; Oroua because of lower than average spikelets per ear and Rongotea because of comparatively low grains per spikelet.

TABLE 5: Yield components and calculated grain yield at 12% moisture.

	Ears/m²	Spikelets/ ear	Grains/ spikelet	Grain wt.mg.	Grain yield g/m² calc.
Kopara	342	13.5	2.55	36.9	435
Pahau	284	13.2	2.63	48.3	479
Wakanui	294	14.8	2.48	35.7	385
Karamu	330	12.5	2.65	44.7	491
Oroua	425	11.6	2.55	41.2	526
Rongotea	335	13.7	2.17	53.6	533
LSD 5%	50	1.0	0.20	1.5	98

Grain size

There was a large variation in grain size among the cultivars (Table 5). Kopara and Wakanui produced the smallest grains and there were significant differences between each of the other four cultivars. Mean grain weight of the cultivar with the largest grain (Rongotea) exceeded that of the smallest (Wakanui) by 50%. Grain size was not consistently related to the number of grains to be filled, either on a per ear or per unit area basis.

Calculated and 1m² grain yield

Calculated grain yield, i.e. the number of ears/m² x spikelet/ear x grain/spikelet x grain weight, exceeded the yield obtained from 1 m² by variable amounts (Table 6). Agreement between the two yield estimates was particularly poor for Kopara and Wakanui where calculated yield exceeded 1m² by 63% and 50% respectively.

TABLE 6: Grain yield: from 1m² and calculated g/m² at 12% moisture.

	1 m²	Calculated	Excess of calculated over 1m²	Excess %
Kopara	267	435	168	63
Pahau	390	479	89	19
Wakanui	257	385	128	50
Karamu	404	491	87	21
Oroua	409	526	117	29
Rongotea	418	533	115	27
LSD 5%	62	98	58	

DISCUSSION

When regular plant sampling began, the total plant dry weight of the six cultivars was similar even though the three 'spring' cultivars, Karamu, Oroua and Rongotea were in a more advanced stage of development. Thereafter, distinct growth patterns became evident, especially in the levels of dry matter in the stem and leaves and the accumulation of dry matter in the ear. The accumulation of dry matter in the ear after anthesis is predominantly that of grain filling and the two sources of assimilate (mainly carbohydrate) are photosynthesis after anthesis and translocated dry matter formed before anthesis and temporarily stored in the stem and leaves. The contribution of translocated assimilate from the stem and leaves to the ear has been widely studied. In controlled conditions Rawson and Evans (1971) found that translocated stem reserves contributed from 2.7 to 12.2% of the grain weight of six wheat cultivars while Gallagher *et al.* (1975) estimated that up to 70% of the grain weight of barley could have been translocated from the stem and leaves.

In this experiment no measurements were made of the fate of dry matter lost from the stem and leaves through translocation, respiration, leaf-fall or tiller mortality. Furthermore, the separation of grain from the rest of the ear was carried out only on the final sampling, therefore changes in the dry weight of the different parts of the plant cannot be attributed to any particular activity. However, a balance can be drawn up between dry matter lost from the stem + leaves and the increase in ear weight.

The mean weight loss from the stem + leaves for the six cultivars between anthesis and harvest was 150 g/m² but there was a factor difference of more than three between the cultivar with the smallest loss (Karamu, 80 g/m²) and the largest (Wakanui, 250 g/m²) (Table 2). Austin *et al.* (1977) measured similar absolute levels of dry matter losses and cultivar differences, and their results, supported by carbon-14 labelling and respiration measurements, showed that translocation of dry matter from the stem and leaves to the grain was greatest in those cultivars which lost the most dry matter from the stem and leaves.

On the first six sampling occasions plant material from the five replicates was bulked and therefore the accuracy of the data points cannot be determined. Standard errors of the means for the final sampling are shown in Tables 2 and 3. There is a smooth progression from point to point and the growth patterns illustrated in Fig. 2 are probably a reasonably accurate representation of the changes occurring in the dry weight of the stem + leaf and ear with time. These growth patterns help to explain the large cultivar differences in the amount of dry weight lost from the stem + leaf between anthesis and harvest by showing the rate of dry weight increase and decline in the stem + leaf and the rate of dry weight accumulation in the ear. Dry weight of the stem + leaf continued to increase after anthesis on all cultivars and did not decrease until after the fourth sampling (20-30 days later) on five of them (Fig. 2). On the other cultivar, Rongotea, stem + leaf dry weight decreased after the third sampling, which was shortly after the start of anthesis. In the early stages of ear development the ears of Rongotea were, therefore, competing against increasing stem and leaf growth for a much shorter period than the other five cultivars. The effect of competition for nutrients between the developing ear and stem + leaf growth following anthesis would be difficult to measure. Any advantage Rongotea may have gained from the shorter period of competition did not result in superior grain yield. In contrast, ear weight increase in Karamu was more rapid than Rongotea and was accompanied almost throughout by increasing stem + leaf weight, there being very little addition to ear weight after stem + leaf weight began to decline (Fig. 2).

The decrease in stem + leaf weight once the peak had been reached was primarily due to translocation of assimilate to the grain and to losses through respiration; leaf-fall was negligible. Low levels of nitrogen available to the plant were detected after ear emergence (Quin and Drewitt, 1979); conditions which could lead to carbohydrate being translocated to the roots (Murata, 1969) but as the root weight of all cultivars decreased throughout the fourth and fifth sampling periods it is unlikely there was much mobilisation to the roots. The absence of any further increase in total plant nitrogen (Quin and Drewitt,

1979) following ear emergence could have affected the distribution of assimilates within the plant (Murata, 1969). Photosynthesis in the leaves would have ceased by the fifth sampling as indicated by the absence of any green leaf material at that time (Fig. 1). The later stages of grain filling would therefore have been dependent on photosynthesis in the upper part of the stem and the ear and to translocated assimilate stored in the stem and leaves.

When a shortage of available nitrogen became apparent 40 kgN/ha was applied to small indicator plots on 17 December (late anthesis). Plant sampling was carried out on these plots concurrently with the main trial but because the plots were sampled on three occasions there was insufficient material left to allow a full yield composition analysis at the final sampling. This late applied nitrogen generally slightly increased the longevity of live (green) leaf, slowed the rate of stem + leaf weight decrease and increased ear weight at harvest of Kopara and Pahau by 160 g/m^2, Karamu and Rongotea by 100 g/m^2 and Wakanui and Oroua by 50 g/m^2 (Fig. 2). Although no grain yield estimate was possible on these samples it is suggested that most of the increased weight was located in the grains.

These results illustrate the extent to which a shortage of plant nitrogen may limit carbohydrate assimilation during the later stages of crop development of some cultivars, despite the presence of an adequate supply and crop content of nitrogen during the earlier stages of development. Quin and Drewitt (1979) and Quin (1980) suggested that apparent deficits in nitrogen budgets could be due to large-scale atmospheric losses of volatile nitrogen compounds from the wheat plant itself. Scott (1980) suggested that poor wheat yields in Canterbury compared to Southland and the U.K. may be associated with the much higher evaporation during the critical grain filling period in Canterbury. Further, high transpiration losses or physiological drought are not fully alleviated by plentiful water supply (Dougherty, 1973). Losses of nitrogen from several crop plants have been demonstrated to increase even more rapidly than transpiration losses with increasing temperature (Stutte and Weiland, 1978). It seems reasonable to assume therefore that excessive transpiration and nitrogen losses during grain filling may be imposing major yield limitations in New Zealand, and in Canterbury in particular. The large variations between cultivars in the pattern of crop development, and in the response to later nitrogen applications suggest that there is an urgent need for research into the physiology of nitrogen and water stress in the New Zealand environment.

It is well known that cultivars with semi-dwarf characteristics have a higher harvest index than standard height cultivars but there is no general agreement on how it is achieved. Because of unequal plant density our data do not permit a critical analysis of the importance of grain number per unit area or grain number per ear in determing harvest index. Large differences in mean grain weight suggest that some cultivars have greater ability than others to fill the grains for, although the two cultivars (Pahau and Rongotea) with the least number of grains /m^2 had the heaviest grain, grain weight and grain number were not closely related. On the four equally high yielding cultivars, Pahau, Karamu, Oroua and Rongotea, in which mean grain weight ranged from 41.2 to 53.6 mg. the fraction of ear weight to total plant was almost identical (mean 64%, Table 4). The superior harvest index of Karamu was due to a higher fraction of grain in the total ear weight. On the lower yielding cultivars mean grain weight and harvest index were very low and the fraction of ear to total plant was 57%.

The method of measuring yield components in this experiment was consistent with the methods used elsewhere. The calculated grain yield from 25 ears extracted from the total ear population of 1m^2 grossly overestimated the yield obtained by machine threshing 1m^2, especially on Kopara and Wakanui. A probable explanation for the overestimate of yield from the 25 ears is that the sub-sample was drawn in a non-random manner and there may have been a tendency to unconsciously extract the larger ears. While the method may be adequate to differentiate between agronomic treatments within a cultivar these results show that it is not sensitive enough for comparisons between cultivars, especially when awned and awnless types are included. A study of the sub-sampling requirements for determining the yield structure of different cultivars is warranted.

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