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Effects of crop residues, soil type and temperature on emergence and early growth of wheat

R. S. JESSOP and L. W. STEWART
Department of Agronomy and Soil Science, University of New England, Armidale. N.S.W. 2351 Australia

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Summary Two controlled environment experiments were conducted to examine the germination and early growth of wheat (*Triticum aestivum* L. cv. Songlen) growing under crop residues of rape, sorghum, field pea and wheat. Additional treatments also included were soil type (Lithic Vertic Ustochrept and Plinthustalf) and temperature (8°C and 24°C to simulate winter and autumn sowing conditions). At low temperature, wheat and sorghum residues produced the most adverse effects on germination with all residues reducing emergence at high temperatures. Shoot lengths were also reduced by most residues at high temperatures whilst root lengths and shoot and root dry weights were unaffected by residue treatments. These results suggest major phytotoxic effects of residues during early growth (up to 14 days after sowing) with, in general, few interactions with soil type or temperature.

Introduction

Stubble retention cropping systems, initially adopted in areas of high erosion risk, are finding increasing acceptance in a range of climatic zones and cropping systems. Many beneficial effects following stubble retention have been identified; these include increased water infiltration[5], improved soil structure and the control of soil erosion[2,7,11], plus the minimisation of both absolute levels of, and fluctuation in, soil temperature[10,13]. Important negative effects of stubble retention include immobilisation of mineral nitrogen[6], reduced winter/spring soil temperatures[14] and possible phytotoxic effects[4].

Whilst both positive and negative effects of stubble residues have been widely reported in the literature, the individual crop response will depend on treatment differences such as residue type and temperature regime. This paper reports two experiments to examine the influence of a range of crop residues on wheat germination and early growth. In view of the paucity of comparative information on soil type in stubble retention systems, two soil types and two temperature levels (to simulate different times of sowing) were included to determine if either parameter alters any effect of the crop residues.

Methods

Two concurrent experiments were conducted using controlled environment growth cabinets. Each experiment was designed as a randomised block trial with 2 soil types and 5 varieties (4 residues, 1 non-residue control), with 4 replicates. The only variation in procedure between the two experiments was the temperature setting; temperatures were set at a constant 8°C and 24°C for experiments 1 and 2, respectively. The temperatures were selected to be close to temperatures experienced by a winter and a late summer/autumn wheat crop during germination. Each cabinet was programmed for a simulated day length of 14 hours using incandescent and fluorescent lighting to provide a light intensity of 400 μE m^{-2} s^{-1} (400–700 nm).

Two soils with distinctly different surface parameters were selected (Table 1). Each soil was passed through a 100-mesh sieve and had visible, non-decayed plant material manually removed.

Table 1. Major chemical and physical soil parameters

Soil group	Depth cm	pH*	O.M.**	% Oven dry weight N	P	K	S	% Particle size† CS	FS	S	C	Field capacity (%, v/v)
Chocolate (clay) (Lithic Vertic Ustochrept)	0–10	5.5	4.6	0.23	0.18	0.79	0.05	6	11	10	71	39
Lateritic podzolic (Plinthustalf)	0–20	5.6	1.4	0.06	0.02	0.21	0.01	36	39	13	10	11

* pH – 0.1 *M* $CaCl_2$, 1:2.5

** O.M. – Organic matter percentage

† CS – Coarse sand; FS – fine sand; S – silt; C – clay.

The four crop residues used were oilseed rape (*Brassica napus* L.), field pea (*Pisum sativum* L.), grain sorghum (*Sorghum bicolor* L.), and wheat (*Triticum aestivum* L.). Each residue was collected from a mature crop which was dried, threshed to remove seed and reduced to less than 10-cm lengths.

A 2.5-cm layer of soil was evenly spread in free-draining 29 × 17 cm plastic trays. Twenty seeds of spring wheat (cv. Songlen) were placed on the soil in a 5 × 4 row design. Another 2.5 cm of soil was mixed with a crop residue and evenly spread over the seed. Application rates for the residues were equivalent to 8570 kg ha^{-1}. Control trays had a total of 5 cm of soil and no residues.

The 40 trays were arranged in blocks randomised within each growth cabinet and watered to field capacity. An estimate of field capacity was obtained through watering, followed by moisture determination after 48 hours drainage. Water status was monitored twice daily by weighing and all treatments were maintained close to field capacity. No fertilisers were applied.

Measurements taken

Trays were monitored at twelve-hourly intervals for seedling emergence; the plant harvest for each experiment was performed at the expiration of the twelve-hourly period in which 75 per cent seedling emergence had occurred in all control (non-residue) trays. For experiments 1 and 2, the harvest occurred at the end of the 28th and 8th twelve-hourly period, respectively.

Harvesting was performed by washing the seedlings from the trays followed by recording the number of seedlings emerged, the length of the longest seminal root and shoot length. The plants were then divided into roots and shoots, dried at 80°C for 48 hours and weighed.

Results

Seedling emergence

Soil type had a major effect on the rate of seedling emergence irrespective of residue treatment in experiment 1 (Table 2). The lateritic podzolic soil gave slower rates of emergence at both high and low temperatures. The residues also had a significant effect on the number of seedlings emerged (Table 3). In experiment 1, seedling emergence compared to control was depressed by 71% under a wheat residue, by 57% under a sorghum residue and by less than 50% under pea and rape residues. At low temperature (experiment 1), although no significant interactions occurred between soil type and residue species, each residue appeared to reduce germination to a greater extent on the lateritic podzolic soil; in particular, compared to control, sorghum depressed emergence by 78% on the lateritic podzolic compared to 64% on the chocolate soil (Fig. 1).

Table 2. Main effect of soil type on the number of emerged wheat seedlings

	Experiment 1 (Low temperature)		Experiment 2 (High temperature)	
	Chocolate	Lateritic podzolic	Chocolate	Lateritic podzolic
Mean germination (Maximum of 20)	11.0	7.0	8.4	4.9
LSD 1%	3.14		2.24	

Table 3. Main effect of residue species on the number of emerged wheat seedlings. (Maximum germination of 20)

Experiment	Control	Rape	Sorghum	Pea	Wheat	LSD 5%
1 – Low temperature	15.9	9.5	6.8	8.4	4.6	3.68
2 – High temperature	13.1	5.5	4.9	5.5	4.4	2.62

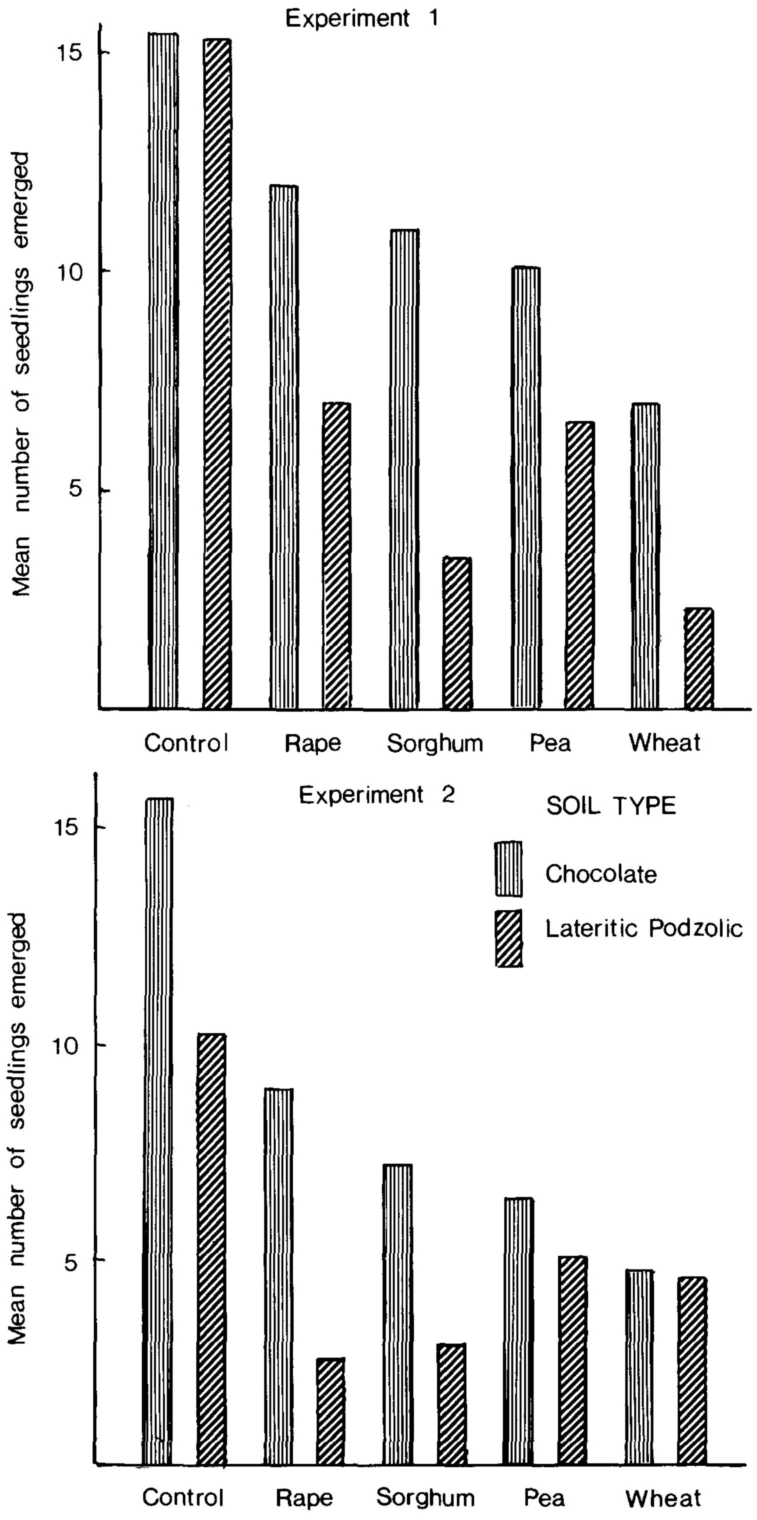

Fig. 1. Effects of soil type and crop residues on emergence levels of wheat seedlings. (Experiment 1 – Low temperature; Experiment 2 – High temperature).

Similar results were produced at high temperatures in experiment 2, with major main effects of both soil type and residues (Tables 2, 3). The chocolate soil again produced a significantly faster emergence of wheat seedlings, although absolute levels were below those for the low temperature experiment (Table 3). The residues depressed seedling emergence with the effect being greater and more uniform across the species than in experiment 1.

Although no interactions between soil type and residue were recorded, there was a strong suggestion in both experiments of a progressively increasing residue effect through rape, sorghum, pea and wheat on the chocolate soil compared to a more random residue-type effect on the lateritic podzolic soil (Fig. 1).

Shoot length

In experiment 1 the mean shoot length for wheat grown in lateritic podzolic soil was shorter than for wheat grown in chocolate soil (Table 4). Shoot length from seeds grown under wheat residues were found to be shorter than the controls (Table 5). Results from experiment 2 again showed a significant effect on shoot length. Shoots from the chocolate soil were longer than those from the lateritic podzolic soil by 33% compared with a 42% increase in experiment 1. Residues again reduced shoot length (Table 5) with rape in particular producing

Table 4. Main effect of soil type on shoot length of wheat seedlings

	Experiment 1		Experiment 2	
	Chocolate	Lateritic podzolic	Chocolate	Lateritic podzolic
Mean shoot length (mm)	41.9	29.6	26.7	20.1
LSD 1%	8.18		3.36	

Table 5. Effect of residue species on shoot length of wheat seedling (mm)

Experiment	Control	Rape	Sorghum	Pea	Wheat	LSD 5%
1 – Low temperature	41.9	34.8	36.0	34.0	32.0	9.58
2 – High temperature	27.9	20.0	21.5	22.8	24.8	3.94

the greatest suppression in growth. Wheat residue failed to significantly depress shoot length at the higher temperature of experiment 2. There was no significant interaction between soil type and residue species present for shoot length in either experiments 1 or 2.

Root length

Residue treatments had no effect on root length in either experiment (Table 6). The chocolate soil produced roots 18% longer in experiment 1 and 20% longer in experiment 2 compared to the lateritic podzolic soil. Mean root lengths were similar in both experiments.

Table 6. Effect of residue species on root length (mm)

Experiment	Control	Rape	Sorghum	Pea	Wheat	LSD 5%
1 – Low temperature	61.4	62.6	63.5	57.5	62.4	NS*
2 – High temperature	59.4	55.4	60.8	60.4	68.7	NS

* NS – Differences not significant at 5% level.

Root and shoot dry weights

No effects of residue treatments on root or shoot dry weights were recorded in either experiment.

Root to shoot length ratios

In both experiments the ratio of root to shoot lengths was greatest in plants from the podzolic soil (Table 7). Similarly, in both experiments, crop residues induced greater root/shoot length ratios compared to the non-residue controls (Table 8). The soil type effect was associated mainly with a greater reduction in shoot length on the podzolic soil compared to chocolate soil.

Table 7. Effect of soil type on root to shoot length ratio for wheat seedlings

	Experiment 1		Experiment 2	
	Chocolate	Lateritic podzolic	Chocolate	Lateritic podzolic
Mean root/shoot ratio	1.67	2.02	2.53	2.97
LSD 5%	0.315		0.76	
1%	0.182		0.57	

Table 8. Effect of residue species on root to shoot length ratio of wheat seedlings

Experiment	Control	Rape	Sorghum	Pea	Wheat	LSD 5%
1 – Low temperature	1.51	1.90	1.97	1.78	2.08	0.214
2 – High temperature	2.18	3.00	2.83	2.93	2.82	0.594

Discussion

The rates of seedling emergence and early growth of wheat were severely depressed by crop residues. Data from these experiments showed significant depressions in wheat seedling emergence, particularly under wheat and sorghum residues at low temperatures. These results support work by Kimber[9] who reported a marked depression in wheat germination under a wheat straw residue. A depression in seedling emergence was also reported for the pea residues, but at levels less than for wheat residues; this was in contrast to American data which showed that grain legume residues were most toxic to wheat seedlings (Cochran, Elliot and Papendick[4]). Horricks[8] has also reported adverse effects of rape residue and data in this paper support those findings.

The chocolate soil throughout the experiments produced larger plants and more rapid germination. This major soil type effect in a short-term experiment was not expected although the soils do differ greatly in both chemical and physical properties (Table 1). The clay soil had a much greater water-holding capacity as indicated by the field capacity water content (v/v) of 39 and 11 per cent, respectively, for the clay and podzolic soils. These major soil differences, however, failed to induce any significant residue/soil type interactions in emergence rate or plant growth. Soil type interactions with crop/weed residue effects have been found in other studies[1]; our seedling emergence data (Fig. 1) do suggest greater residue effects on the lateritic (sand) podzolic soil than on the heavy clay soil.

Although plant growth was naturally much slower in the low temperature experiment, in general the residues induced similar negative effects on the rate of emergence and shoot length at both high and low temperatures. No residue effects were induced in plant dry weights; in short-term experiments, this is likely since the plant is still mainly reliant on seed reserves for growth. Recent work (Jessop and Purvis, unpublished) has, however, shown major dry weight and grain yield effects of a range of crop residues on wheat.

The higher temperature regime produced major increases in root to shoot length ratios (Table 7); this resulted from shorter shoots in experiment 2 with no corresponding change in root length. Earlier work[12] has also shown shorter shoot lengths following the incorporation of a range of crop residues.

The data in this paper show major negative effects of residues on the early growth of wheat. Under the prevailing experimental conditions, it seems unlikely that modified water storage[3] or nitrogen immobilisation[6] caused these effects since the soils were maintained close to field capacity and the early growth of the wheat seedlings would be reliant on seed reserves of plant nutrients. The results suggest that the effects were due to phytotoxin production during the decay of the residue material, although the exact cause and effect relationship will require further study.

Whilst major effects of residues in slowing germination and reduced shoot growth were recorded in these experiments, root growth was not affected. Previous work[12] has shown that residues may either increase or decrease root growth depending on the method of application. The close proximity of the decaying crop residues to the growing coleoptile appeared to cause the depressions in shoot growth.

From the data in this paper, it is suggested that the adoption of stubble retention farming systems may have some inherent problems which will require further study. Residues from wheat and sorghum, two of the four most popular Australian crops, have produced adverse effects on the emergence and early growth of wheat. Continuous cropping rotations in particular, especially in areas where crop residues are heavy, may experience these adverse effects if stubble retention is practised.

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