Poor growth of canola in retained wheat straw – causes and consequences

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Abstract

A field trial was conducted to investigate factors associated with poor growth of canola sown into wheat stubble. Wheat (cv Snipe and Diamond Bird) was grown in 2000 and wheat stubble decomposition treatments were established on the site in early 2001 using rainout shelters to exclude rainfall for different periods (0,3,6 months). Six treatments were superimposed on the cultivar and decomposition treatments in May 2001. The six treatments were: a) a fallow (root and shoot residue removed at harvest), b) a bare treatment c) a bare treatment plus additional nitrogen, d) 4 t/ha of residue retained e) 4 t/ha of residue retained plus additional nitrogen, f) simulated plastic residue. Canola (cv. Oscar) was direct-drilled across the site. Stubble type and decomposition period had no impact on canola growth but seedling emergence, biomass and yield were reduced in the presence of stubble and plastic residue. Nitrogen immobilisation or leaching of allelochemicals could not explain the early impact on crop growth. The major impact appears to be slower rate of leaf emergence and investment of assimilate in elongated hypocotyls for penetration of the straw layer, and increased likelihood of disease due to increased sites for infection on the hypocotyl. Colder temperatures at the surface of the wheat stubble exposing the canola meristem to colder temperatures may also play a role.

Key Words

Stubble retention, hypocotyl, allelopathy, phytotoxicity, direct-drilling

Introduction

Stubble retention was adopted in cropping systems to reduce the risk of erosion, to maintain organic matter, increase infiltration and to reduce evaporation (1). However, several studies in the United States and Australia have shown yield reductions associated with retained stubble (2, 3). More recently, retention of wheat stubble has been found to reduce the emergence, growth and yield of canola (4). A number of factors may contribute to the poor growth of canola in wheat stubble including: (a) nitrogen immobilisation (b) lowered temperatures on the surface of the stubble; (c) increased incidence of root disease, and (d) allelochemicals liberated from the stubble. This study investigated the factors that may contribute to the poor growth of canola in retained wheat stubble. In particular we sought to establish the role of allelochemicals liberated from wheat residue and nitrogen immobilisation in the poor growth of canola through wheat stubble.

Methods

Wheat (cv. Snipe and Diamond Bird) was grown in 2000 to provide wheat stubble for the experiment. The two varieties were selected based on the results of a previous laboratory experiment showing that the straw leachates had either a small (Diamond Bird) or large (Snipe) impact on germination and radicle growth of canola cv. Oscar. The experiments involved shaking undecomposed stubble of these and other varieties in distilled water for 4 hours, centrifuging, and filtering through a milli-pore filter. The leachates were then tested for toxicity to canola germination and radicle elongation in petri-dishes at 15^{o}C.

In the field experiment, three wheat stubble decomposition treatments were established on the site in early summer 2001 using rainout shelters to exclude rainfall (and thus reduce decomposition) for different periods (0,3 and 6 months) in the summer fallow. Six treatments were superimposed on the cultivar and decomposition treatments in May 2001. The six treatments were: a) a fallow (FALLOW), b) a bare treatment (BARE) c) a bare treatment plus 80kg/ha nitrogen (BARE + N), d) 4 t/ha of residue retained (STUBBLE) e) 4 t/ha of residue retained plus 80kg/ha nitrogen (STUBBLE + N), f) simulated plastic residue (PLASTIC). Canola (cv. Oscar) was direct-drilled across the site and was watered immediately and regularly after sowing to promote leaching of straw. Seedling emergence was measured regularly from 10 days after sowing. A vegetative harvest ($0.2m^2$) was taken 52 days after sowing. Shoot biomass, leaf number and hypocotyl length were measured. Four cores, 2 cm in diameter and 10cm deep were taken from each plot and soil mineral nitrogen determined. Four representative plants were taken 60 days after sowing and specific root length (SRL), root mass ratio (RMR) and the proportion of seedling disease complex were determined. At flowering, plants were removed from a $0.16m^2$ quadrat and shoot biomass and leaf area index determined. On the 30th November and 3rd December plants were harvested ($0.32m^2$) from BARE and FALLOW; and STUBBLE and PLASTIC treatments respectively and seed yield and harvest index determined.

Immediately prior to sowing, one soil core 2 cm deep and 10 cm wide, with surface residue intact, was randomly selected and removed from all treatments and replicates except the '+N' treatments. The cores were placed in a manifold under a drip infiltrometer and water dripped onto the cores at a rate of 10mm/hr. Forty mL of leachate were collected from the base of the cores, centrifuged and passed through a millipore filter (Millipore 0.45 μm) and tested on (a) the germination; (b) the radicle elongation of pre-germinated canola seedlings in petri-dishes. A further 200 mL of leachate was collected and applied to pots of canola to determine the impact on emergence and growth (to the 6 leaf stage).

Plant growth data were analysed using ANOVA in Genstat version 5. The emergence data was analysed by fitting exponential growth curves to the data and analysing the regression coefficients. Linear growth curves were fitted to the pot-trial emergence data.

Results

In the field experiment, seedlings in the BARE and the BARE + N emerged faster than seedlings in the FALLOW, STUBBLE, STUBBLE + N and the PLASTIC treatments (Table 1, Figure 1). PLASTIC had final seedling density 50% lower than BARE + N, although the number of plants in the PLASTIC did reach those of the STUBBLE treatments by the 2nd vegetative harvest (data not shown). There were no differences in emergence between the two wheat stubble varieties or the decomposition treatments.

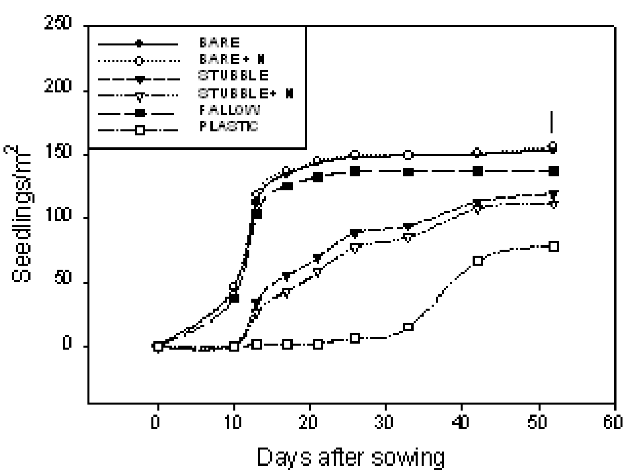

Figure 1. Effect of surface residue treatments on the emergence of canola. Data presented is the mean of both wheat stubble varieties and decomposition treatments. LSD =15.11 (p=0.05) is shown for Day 52.

Fifty-two days after sowing, shoot biomass in the BARE was twice that of the STUBBLE and PLASTIC treatments (Table 1). FALLOW was intermediate between these extremes. Hypocotyls were longer in the STUBBLE, STUBBLE + N and PLASTIC treatments. Soil min-N in the top 10cm of soil was reduced in the presence of stubble (Table 1). Shoot N concentration was highest in the '+ N' treatments and FALLOW and lowest in the STUBBLE and PLASTIC, however, total shoot N was highest in BARE, BARE + N and FALLOW and lowest in the stubble and PLASTIC due to high biomass. Sixty days after sowing RMR was reduced in the presence of STUBBLE and PLASTIC. SRL had the opposite response. The incidence of seedling disease was highest in the STUBBLE and PLASTIC treatments. There were no differences between the varieties or the decomposition treatments.

At flowering there was evidence for more advanced development (2-3 days earlier flowering) in the BARE treatments (data not shown). FALLOW and BARE treatments had most biomass and STUBBLE and PLASTIC treatments the least (Table 1). LAI followed the same trend. At final harvest, yield was lower in STUBBLE, STUBBLE + N and PLASTIC compared to the BARE treatments.

Table 1. Characteristics of plants and soil nitrogen in the six treatments. Data is the mean of both wheat varieties and decomposition treatments. (LSD at p = 0.05). The value for the rate of emergence e^{-k} is negatively related to the rate of emergence, so high values indicate slower emergence rates.

	Variable	BARE	BARE+N	FALLOW	STUBBLE	STUBBLE+N	PLASTIC	LSD
Emergence	Rate of emergence (e^{-k})	0.925	0.920	0.922	0.981	0.958	1.053	0.009
52 days after sowing	Shoot biomass (g/m^2)	10.2	11.0	8.7	4.6	4.2	4.7	2.3
	Hypocotyl length (mm)	0	0	0	23	24	25	2
	Soil N (ppm)	36.6	61.3	54.9	21.1	39.2	21.2	6.5
	Shoot N (%)	5.64	5.87	5.79	5.52	5.80	5.18	0.13
	Shoot N (g/m^2)	0.579	0.645	0.505	0.251	0.243	0.247	0.131
60 days after sowing	Root mass ratio	0.144	-	-	0.118	-	0.109	0.020
	Specific root length x 10^3(mm/g)	9.523	-	-	12.36	-	12.90	2.21
	Seedling disease	7.0	-	-	58	-	65	20

	complex (%)							
Flowering	Shoot biomass (g/m^2)	6.87	7.71	7.91	3.70	4.66	3.44	1.00
	LAI	7.20	7.93	8.11	4.44	5.28	4.22	0.87
Yield	Yield (t/ha)	5.14	5.53	5.46	4.07	3.88	3.82	0.60

Leachates obtained from intact field cores using the rainfall simulator had no effect on germination, radicle elongation, the emergence of plants in the pots nor on the plant biomass at the 6 leaf stage (Table 2). The lack of impact was consistent across all variety, decomposition and stubble treatments.

Table 2. Characteristics of seedlings in four treatments after addition of leachates from field cores obtained using the rainfall simulator. (L.S.D at p= 0.05).

	Variable	BARE	FALLOW	STUBBLE	PLASTIC	LSD
Petri-dish	Rate of germination (e^{-k})	0.8980	0.8935	0.9253	0.8955	ns
	Final germination (number out of 20)	19.4	19.2	19.3	19.4	ns
	Radicle length (mm)	6.0	6.8	6.2	6.6	ns
Pot-trial	Pot-trial rate of emergence	0.2499	0.2277	0.2372	0.2272	ns
	Pot-trial final emergence (number out of 9)	7.83	7.08	7.50	7.21	ns
	Pot-trial biomass (g)	0.40	0.38	0.44	0.43	ns

Conclusion

The presence of wheat stubble led to a slower rate of emergence, elongation of the hypocotyl, and a reduction in root growth, shoot biomass and yield of canola. Immobilisation of N and/or leaching of allelochemicals from the residue cannot explain the impact of wheat stubble on canola growth for a number of reasons: (a) additional N to the STUBBLE treatment did not improve emergence or biomass indicating that while N may be leached or immobilised in the presence of stubble it cannot explain the poor emergence or growth of canola through wheat stubble in this instance; (b) the leachates obtained using the rainfall simulator on field residues at realistic rainfall intensity had no effect on the germination or growth of the canola; (c) there was no difference in canola growth between the stubble varieties or level of decomposition and (d) the PLASTIC treatment had a similar effect to the STUBBLE treatment on canola growth suggesting that the presence of a physical layer of straw may play a more important role in reducing canola growth. The production of elongated hypocotyls in the stubble and plastic treatments supports this hypothesis. The lack of consistency between the lab experiments in 1999, where Snipe was found to be more toxic to canola than Diamond Bird, and the experiments discussed here, indicates that caution must be exercised when drawing conclusions on the role of allelochemicals in field-based phenomena from results of lab experiments which do not simulate natural conditions found in the field.

Laboratory experiments, such as those conducted in 1999, generally use leachates derived by shaking chopped straw in water for long periods, producing concentrations of allelochemicals which would be likely to exceed those generated by natural rainfall events in the field. In instances where stubble is incorporated into the soil or pinned into the seeding row, allelochemicals may play a role when the straw decomposes in close proximity to the seed (Patrick *et al*. 1963).

Other factors that may be responsible for the poor growth observed in this experiment include: the delay in leaf emergence caused by the production of long hypocotyls to penetrate the straw layer; increased likelihood of disease due to increased sites for infection on the hypocotyl; and colder temperatures at the surface of the wheat stubble exposing the canola meristem to colder temperatures. Recent research by Bruce and Ryan (2001) has found that poor emergence and growth of canola through wheat stubble could be reduced by using sowing techniques that push stubble off the seeding row.

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