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Effect of Temperature, Soil Compaction and Soil Sterilization on Root Development of Wheat and Canola Seedlings

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コムギ及びナタネ実生の根形成に及ぼす生育温度，土壌硬度及び土壌殺菌処理の影響

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Wheat and canola are important rotational crops in south-western Australia. The precipitation is typically low, and crop root development is inhibited by the hard soil pan at even shallow soil depth. In this region, the crop productivity is evenly affected by water stress. Even if rainfall is enough for the germination, root development is affected by temperature, soil compaction and biological effect in soil. Accurate assessment of interactions among these factors may allow the determination of optimum condition for root development in the seedling stage to maximize the crop growth. We used the monolith method (Morita et al., 1995) to study the effect of temperature, soil compaction and soil sterilization by the fumigation with methyl bromide gas on the root development of wheat and canola in the seedling stage.

Materials and methods: In June 2003, intact soil cores were drawn randomly from a rotational field in pasture using PVC rings (diameter 10 cm, height 11 cm) at Ginninderra Experimental Station of CSIRO (149°06′E, 35°12′S), Canberra. These were placed on an iron tray, transferred to two temperature conditions i.e. a fully-covered glasshouse (WARM: daily av. 16 ˚C) and a wire-net house (COLD: daily av. 10 ˚C). Two levels of soil compaction were made from intact soil cores (HARD: av. 0.67 MPa) and cores that were mixed with small shovel (SOFT: av. 0.37 MPa). The assessment of the biological effects to the root development was also carried out by fumigating the soil with methyl bromide gas. Half of the cores were fumigated for 4 days (FUM.), so that they were fully sterilized. Non-fumigated cores (non-FUM.) were used as control of that. Seven days after the fumigation, seeds of wheat (*Triticumu aestivum* L. cv. Diamondbird) and canola (*Brassica napus* L. cv. Hyola 60) were sown in the cores (1 seed / core). Then cores were irrigated to maintain the soil water content between 16 to 18 % (w/w) through out the experimental duration. No nutrients were supplied to the cores. Two months after sowing, the dry weight of leaf and stem, and the number of roots were recorded. The soil cores were taken out from PVC rings carefully, and the core was cut at the center by saw-like knife for the observation of core profile. The number of roots observed in each 5 mm^2 mesh on the profile was defined as root frequency. Number of roots in control cores (without any sowing) if any, were subtracted from the number of roots in the cores sown with seed, to get an unbiased estimate of the root frequency. Using image analysis with WinRhizo (Regent Instruments Inc., Canada), data were also recorded for roots length, roots thickness, surface area, volume and number of branches. Root dry weight was measured by drying the roots to a constant weight at 80 ˚C for 72 hrs. The layout of the experiment was a completely randomized block design in each level of temperature, with three replications (1 core / replication). All calculations were made using combined analysis with SPSS Base 7.5.1 J for Windows (SPSS Inc., USA).

Results and discussions: Both in wheat and canola, leaf and stem biomass was significantly higher in warmer condition and in fumigated condition (Table 1). The root dry weights in both crops were also significantly higher in warmer condition, and in wheat it was higher than that of canola. The ratio of root biomass to total biomass was significantly higher in warmer condition. These were also a trend that the root ratio in wheat was higher than in canola. This may be due to higher root dry weight in wheat.

Roots were significantly longer under warmer condition (Table 2). Other characteristics of roots i.e. surface area, volume and the number of root branches also showed the same tendency (data not shown). The results thus showed that warmer condition promoted the seedling's growth in both the crops, however, the thickness of roots did not change with the temperature in both wheat and canola. The roots were significantly thicker in fumigated condition, and the roots of wheat were thicker than that of canola. The root frequency on the core profile was significantly lower in harder condition, indicating that the root development was inhibited by the soil compaction in both the crops. In soft soil condition, the root frequency in fumigated condition was significantly lower than that of non-fumigated soil. It is concluded that in both wheat and canola, warmer and softer soil condition will promote plant as well as root development. Though the effect of soil sterilization with fumigation was not clear, thicker roots in fumigated soil indicated that in non-sterilized soil presences of micro-organisms adversely affected the root thickness.

Reference: Morita S., Yamada S. and Abe J. 1995 Analysis on Root System Morphology in Rice with Reference to Varietal Differences at Ripening Stage. Jpn. J. Crop Sci., 64(1): 58-65.

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Table 1. Effect of temperature, soil compaction and fumigation on dry matters into above and below ground parts of wheat and canola seedlings.

Temperature (T)	Crop (C)	Hardness (H)	Fumigation (F)	Leaf,stem DW (g)	Root DW (g)	rootDW/total DW ratio
WARM	Wheat	HARD	FUM.	0.79 ± 0.05[1)]	0.38 ± 0.03	0.33 ± 0.02
			non-FUM.	0.52 ± 0.01	0.42 ± 0.08	0.44 ± 0.05
		SOFT	FUM.	0.80 ± 0.01	0.35 ± 0.04	0.30 ± 0.02
			non-FUM.	0.42 ± 0.10	0.32 ± 0.14	0.39 ± 0.05
	Canola	HARD	FUM.	0.82 ± 0.21	0.15 ± 0.04	0.16 ± 0.03
			non-FUM.	0.45 ± 0.06	0.12 ± 0.04	0.20 ± 0.04
		SOFT	FUM.	0.81 ± 0.08	0.21 ± 0.09	0.19 ± 0.05
			non-FUM.	0.75 ± 0.06	0.35 ± 0.03	0.32 ± 0.01
COLD	Wheat	HARD	FUM.	0.11 ± 0.03	0.04 ± 0.01	0.29 ± 0.03
			non-FUM.	0.08 ± 0.02	0.04 ± 0.01	0.36 ± 0.07
		SOFT	FUM.	0.11 ± 0.01	0.08 ± 0.02	0.42 ± 0.02
			non-FUM.	0.05 ± 0.01	0.04 ± 0.00	0.45 ± 0.03
	Canola	HARD	FUM.	0.17 ± 0.04	0.03 ± 0.01	0.13 ± 0.02
			non-FUM.	0.15 ± 0.04	0.02 ± 0.00	0.10 ± 0.01
		SOFT	FUM.	0.12 ± 0.04	0.02 ± 0.00	0.15 ± 0.04
			non-FUM.	0.07 ± 0.02	0.01 ± 0.00	0.16 ± 0.01
		ANOVA[2)]	T	**	**	**
			C	n.s.	*	n.s.
			H	n.s.	n.s.	n.s.
			F	*	n.s.	n.s.

[1)] Average ± S.E. of 3 replications.
[2)] n.s.: not significant ($P \geq 0.05$), * and **: significant at $P < 0.05$ and 0.01, respectively.
T: temperature, C: crop, H: hardness, F: fumigation. Interaction was not detected.

Table 2. Effect of temperature, soil compaction and fumigation on various root parameters of wheat and canola seedlings.

Temperature (T)	Crop (C)	Hardness (H)	Fumigation (F)	Length (cm)	Thickness (mm)	Frequency[1)] (count/cm^2)
WARM	Wheat	HARD	FUM.	1185 ± 87[2)]	0.44 ± 0.02	4.6 ± 0.2
			non-FUM.	1656 ± 189	0.39 ± 0.01	4.0 ± 0.5
		SOFT	FUM.	1177 ± 256	0.44 ± 0.02	3.0 ± 0.2
			non-FUM.	1478 ± 479	0.37 ± 0.01	5.3 ± 1.1
	Canola	HARD	FUM.	692 ± 195	0.40 ± 0.00	3.9 ± 0.4
			non-FUM.	577 ± 245	0.41 ± 0.00	2.7 ± 1.0
		SOFT	FUM.	1264 ± 483	0.41 ± 0.01	4.1 ± 0.7
			non-FUM.	2423 ± 60	0.40 ± 0.01	6.4 ± 0.4
COLD	Wheat	HARD	FUM.	162 ± 53	0.45 ± 0.00	(0.4) ± 0.3
			non-FUM.	168 ± 22	0.41 ± 0.03	(0.1) ± 0.4
		SOFT	FUM.	404 ± 69	0.44 ± 0.01	0.6 ± 0.3
			non-FUM.	267 ± 28	0.37 ± 0.02	1.5 ± 0.3
	Canola	HARD	FUM.	117 ± 43	0.41 ± 0.02	(0.5) ± 0.1
			non-FUM.	113 ± 6	0.36 ± 0.03	(0.1) ± 0.2
		SOFT	FUM.	167 ± 20	0.35 ± 0.01	0.8 ± 0.3
			non-FUM.	167 ± 73	0.32 ± 0.02	1.4 ± 0.4
		ANOVA[3)]	T	**	n.s.	**
			C	n.s.	*	n.s.
			H	n.s.	n.s.	*
			F	n.s.	*	n.s.
			C*H	n.s.	n.s.	n.s.
			C*F	n.s.	n.s.	n.s.
			H*F	n.s.	n.s.	*
			C*H*F	n.s.	n.s.	n.s.

[1)] The root frequency in the non-seeded cores (background noise) were subtracted from that of seeded cores. Values in parentheses represent minus values.
[2)] Average ± S.E. of 3 replications.
[3)] n.s.: not significant ($P \geq 0.05$), * and **: significant at $P < 0.05$ and 0.01, respectively.
T: temperature, C: crop, H: hardness, F: fumigation.
Interaction with temperature (T) was included into error term.