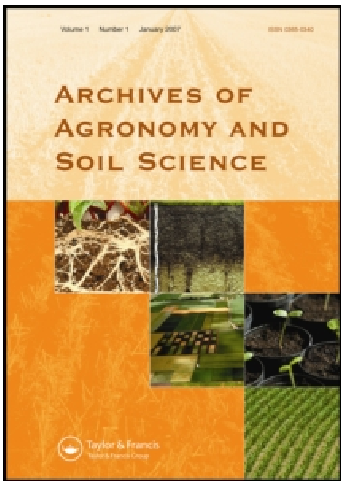

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Effects of soil tillage, canola (Brassica napus L.) cultivars and planting date on canola yield, and oil and some biological and physical properties of soil

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Effects of soil tillage, canola (*Brassica napus* L.) cultivars and planting date on canola yield, and oil and some biological and physical properties of soil

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Determination of different agronomical properties including soil-related parameters for enhanced canola (*Brassica napus* L.) production can be of great significance. Hence, the objectives were to determine the effects of different tillage systems, canola cultivars and different planting dates on: (i) canola yield and oil, and (ii) soil moisture and microbial carbon (C) and nitrogen (N). Two field experiments were planned as split-plot experiments in three replicates. The main plots were different tillage systems including no-tillage (NT), minimum tillage (MT) and conventional tillage (CT), and the subplots were the combination of different canola cultivars (PF and Hyola 401) and different planting dates (PD): 8 and 23 September and 7 October. Soil moisture under CT and PF was significantly less than that of MT and NT, and Hyola 401, respectively. Carbon and N microbial biomass was the highest at NT and on the first PD. The tillage method and planting date also significantly affected canola yield, oil content and the amount, and the number of earthworms. We may conclude that although the amount of yield was the highest at CT, it may be more agronomically sustainable to plant canola under NT or MT earlier during the autumn growing season.

Keywords: canola (*Brassica napus* L.) yield and oil; planting date; microbial activities; soil biological and physical properties; tillage systems

Introduction

Effects on soil moisture and crop yield

Sowing directly in the crop residue from the previous season has turned into a very common tillage practice in many countries in the world, because it is agronomically, ecologically, economically, and environmentally very beneficial. As a result of maintaining crop residue on the soil surface (Sidiras et al. 1982; Franchini et al. 2007), no-tillage (NT) and minimum tillage (MT) can have very improving effects on soil properties. These effects include increased soil moisture retention, decreased soil temperature fluctuations and soil erosion by water and wind, improved soil structure, and increased soil organic matter with time, resulting often in increased crop yield (Malhi et al. 2006; Franchini et al. 2007).

No-tillage and MT may also reduce global warming, as a result of turning soil into a carbon (C) sink, and save time and energy, up to 40% due to lower use of labor and energy in the field (Food and Agriculture Organization [FAO] 2004; Franchini et al. 2007). Plant

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residue mineralization may decrease by up to 20% under NT, and is a function of crop chemical combination, especially for legumes, and rate of mineralization (Franchini et al. 2007).

Because oil seeds have high amounts of unsaturated biochemical bonds and high economical value, they are very important for human health. Hence, finding an optimum method of planting for oil plants is of great importance (Fioretto et al. 2001; Zaman et al. 2002). Among the environmental parameters affecting oil seed, temperature (planting date) is the most important one, decreasing the amount of oil if it increases. In addition, various plant cultivars may perform differently under differential environmental conditions.

Soil biological properties including microbial biomass carbon and nitrogen, and earthworms

Carbon (C) fluctuations under different tillage systems are attributed to C allocation to different soil organic carbon fractions, differing in their biochemical and microbial degradation (Stevenson 1994), accessibility and interactions (Sollins et al. 1996). Light fraction includes plant like materials that are very much subjected to mineralization under different management practices (Bremer et al. 1994), and hence are of less stability and of high C concentration (Golchin et al. 1994).

However, the heavy fraction is more stable and resistant to mineralization and has less C (Golchin et al. 1995a, 1995b). Carbon of light fraction can also significantly affect microbial respiration (Alvarez and Alvarez 2000). In addition, the significance of light fraction is through affecting the formation and stability of soil structure, especially macroaggregates (>250 μm).

In addition to enhancing soil microbial biomass and activity (Hungria 2000; Franchini et al. 2007), NT may also increase the soil beneficial microorganisms, such as N_2-fixing rhizobia (Hungria and Stacey 1997; Ferreira et al. 2000; Franchini et al. 2007) and mycorrhizal fungi (Franchini et al. 2007). For example, Miransari et al. (2007) found that soil compaction (i.e. high use of agricultural machinery in the field) may adversely affect mycorrhizal fungi symbiosis with corn (*Zea mays* L.).

Increased microbial biomass may protect C and nitrogen (N) reduction, by microbial immobilization, reducing the release of C and N according to plant growth requirements. Measuring the soil microbial population and activity, which are under the influence of crop and tillage practices, is also a good indicator of soil quality (Franchini et al. 2007). N_2O emission may also be affected by soil tillage practices and be increased at NT (Fan et al. 1997; Mackenzie et al. 1997; Malhi et al. 2006); however, it may reduce at NT under dry climates (Malhi et al. 2006).

The other important biological parameter that is affected by soil tillage is the number of earthworms. Earthworms, for example *Lumbericus terestiristis* L., are ecologically of great importance because they can significantly affect soil structure and nutrient cycling (Chan and Barchia 2007). They inhabit the soil, and feed completely on soil resources for their nutrition. Hence, the parameters affecting soil properties can greatly explain the variation in the number of soil earthworms, and may be very important for the selection of appropriate management practices to build up a good population of earthworms in the soil (Chan 2001).

The abundance of earthworms in the soil may also be a good indicator of soil quality as different tillage systems may differently affect soil biological properties including the population of earthworms.

Since there is not any information on the performance of different cultivars of canola (*Brassica napus* L.) as very important oil seed plants at different planting dates, and under different tillage practices in dry zones with respect to the physical and biological properties of the soil, we conducted this research work. Hence, the objective was to evaluate the effects of different tillage systems, canola cultivars, and planting dates on crop yield, oil and some physical and biological properties of soil.

Materials and methods

Experimental design

The experiments were conducted in 2002 and 2003 in the Agricultural Research Station of Sari, Iran (latitude 33°36′, longitude 53°, located 23 m above sea level). The experiments were arranged as split-plot on the basis of completely randomized block design. The main plots were tillage systems, including no-tillage (NT) at cereal residues (wheat or rice), minimum tillage (MT) using chisel plow and conventional tillage (CT) using moldboard plow. The combination of different canola cultivars, including Hyola 401 and PF (Sarigol), and different planting dates (PD): 8 and 23 September and 7 October, were assigned to the subplots. The cultivars were selected based on their good adaptation with the weather conditions at the province of Golestan, where the experiments were conducted. Cultivar PF is the common genotype in the region and Hyola 401 is a Canadian cultivar, usually planted in the spring. However, it was planted to compare with cultivar PF.

Experimental procedure

Each subplot, measuring 14 m^2, included ten 7-m rows, planted at every 5 cm, with 20 cm inter row spacing and 3 m inter plot spacing. Each replication had 18 plots covering a total area of 2000 m^2. The amount of N, P (P_2O_5) and K (K_2O) fertilizers, at 150, 59 and 100 kg/ha, respectively, were determined according to soil testing, and one third of N fertilizer and the complete phosphorus (P) and potassium (K) fertilizers were applied at seeding according to canola fertilization requirements under different climates. The remaining amount of N was applied at 1/3 at stemming and 1/3 at flowering. If required, plants were thinned at the 4–5 leaf stage or before stemming (Harper and Berkenkamp 1975).

In September the field was cultivated, fertilized, and using herbicides the weeds were controlled before planting. The field was irrigated twice at seeding with a 7–9 day interval, to ensure the good germination of seeds and also at stemming and flowering along with fertilization, at podding and at grain filling stages. Pests were controlled, chemically during the growing season.

Soil, yield and yield components measurements

Climate data, including temperature, humidity, precipitation, wind and degree-days (Swan et al. 1987), for the complete year are presented in Table 2. The soil physical and chemical properties were determined (Table 1). Soil moisture was determined using 100 g soil samples, dried for 24 h at oven at 105°C. Soil texture was determined by the hydrometric method (Gee and Bauder 1986). Acidity of a saturated paste and electrical conductivity of a saturated extract were also measured (Rhoades 1982). Organic C and total N (%) were measured using wet oxidation (Nelson and Sommers 1982), and Kjeldahl method (Nelson

Table 1. Soil physical and chemical properties.

Soil texture	Organic C (%)	pH	EC (dS/m)	Total N (%)	P (ppm)	K (ppm)
Silty clay loam	0.63	7.7	0.6	0.055	31	400

and Sommers 1973), respectively. P and K were determined by sodium bicarbonate extraction (Olsen 1954), and flame photometer (emission spectrophotometry) (Knudsen et al. 1982), respectively.

Seeds were harvested when 40–50% of the main pods and stems turned bright brown. For plant morphological determinations the middle rows were selected for random sampling of 12 plant samples from each plot. For economical yield determination at physiological maturity, the 30 and 50 cm spaces from each side of the plots were ignored and the plants were harvested from the middle part and after three days of air-drying, the seed yield was determined. At physiological maturity all the yield components were measured and using the following equation the final yield was calculated:

$$Y = K * P * G * W \tag{1}$$

where Y is seed yield (kg/ha), K, number of plants per hectare, P, the number of pods per plant, G, seeds per pod, and W, the weight of one seed per kg. At harvest, in addition to the amount of yield, oil content and amount, soil moisture, N and C microbial biomass, and the number of earthworms were also determined.

Soil microbial C and N measurements

To measure the microbial activity of soil, 100 to 120 g soil was taken from the 5–15 cm depth and was kept at 4°C before laboratory analyzing (Lee et al. 2007). For each soil sample, soil moisture content was determined at 105°C for a 24-h period. Soil C of microbial biomass was determined using the chloroform method (Aoyama and Naguma 1997). Soil samples were kept at 25°C using incubator for one week at 60% moisture. The samples were sterilized using ethanol without chloroform for 24 h at 25°C and C was extracted using potassium sulfate 0.5 M for 30 min. Soil C of microbial biomass was determined using the following equation:

$$C\ (\mu g/g) = 2.04 * Ec \tag{2}$$

where Ec is the extracted carbon in sterilized soil minus extracted C in unsterilized soil (Inubushi 1992). In addition, soil C of microbial biomass was also estimated using organic carbon analyzer (Shimadzu, Toc-500). Soil N of microbial biomass was also determined (Howarth and Paul 1994).

Determination of earthworm abundance

Earthworms were collected from a 0.123 m^2 to a 15-cm depth. Collection of three samples was conducted in the spring of the first year and in the autumn of the second year for each experimental plot. To keep the soil structure intact, using the collected soil the holes were filled. To avoid the interacting effects between the plots, the earthworm samples were taken from the middle rows.

Table 2. Climate data.

Parameter	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Temperature (°C)	7	7.3	9.5	14.9	19.5	23.5	25.5	25.7	22.8	18.1	13	8.6	16.3
Humidity (%)	84	83	84	81	78	79	81	82	83	84	85	86	82
Precipitation (mm)	66.2	62.6	63.6	36.4	31.2	31.1	31.4	48.2	80.4	103.6	99.9	77	731.6
Wind (m/s)	2.9	3	3.3	3.4	3.1	2.7	2.4	2.4	2.3	2.4	2.4	2.5	2.8
Degree-days	135.2	120.7	125.1	161	205.7	215.8	210.8	171.5	157.7	170.3	145.4	130.4	1949.6

Statistical analysis

Using Sas (Sas Institute, 1988) data were analyzed for the analysis of variance, comparison of means, using Dunkan's multivariate test, and coefficients of correlation. Bartlett's test was also performed on all measured parameters and since the variance of soil moisture content in both years was not homogenous, the average of soil moisture was calculated on a yearly basis.

Results

Soil moisture

The effects of soil tillage in both years ($p = 0.01$), cultivar in the first year ($p = 0.01$), and the interaction effects of soil tillage and planting date, and soil tillage and cultivar ($p = 0.05$) in the second year on soil moisture were significant (see Tables 3 and 4). The combined effects of NT and MT with canola cultivars and PD resulted in significantly higher soil moisture, compared with CT.

The highest soil moisture is related to NT at PD3, which is almost 19% higher than the lowest soil moisture at CT and PD3 (Table 5). Different cultivars did not significantly affect soil moisture at different tillage systems (Table 5). The amount of soil moisture under MT was significantly higher at PD3, compared with PD2. Under MT soil moistures at different PDs were not significantly different. However, under CT soil moisture was significantly higher at PD1, compared with PD3 (Table 5).

Table 3. Analysis of variance for different tillage, planting dates and cultivars and their interaction effects, affecting soil moisture.

	Year	
Parameter	2002	2003
Soil tillage (ST)	**	**
Planting date (PD)	ns	ns
Cultivar (C)	**	ns
ST*PD	ns	*
ST*C	ns	*
PD*C	ns	ns

ns, *, **, not significant, significant at 5 and 1% of probability, respectively.

Table 4. Soil moisture means (%), for different canola cultivars and soil tillage systems.

	Year	
Cultivar	2002	2003
Hyola 401	17.49a	–
PF	16.91b	21.91a
Tillage		
No tillage	18.03a	23.09a
Minimum tillage	17.58a	22.43a
Conventional tillage	15.98b	20.53b

Means, followed by different letters are statistically significant at 5% of probability, using Duncan's multivariate test.

Table 5. The interaction effects of soil tillage, and canola cultivar, and soil tillage and planting date on soil moisture.

Tillage	Cultivar	Soil moisture
No tillage	Hyola 401	18.41a
	PF	17.64ab
Minimum tillage	Hyola 401	18.04ab
	PF	17.12b
Conventional tillage	Hyola 401	16c
	PF	15.96c
	Planting date	
No tillage	PD1	23.23ab
	PD2	23.38bc
	PD3	23.65a
Minimum tillage	PD1	22.23bc
	PD2	22.03cd
	PD3	23.03abc
Conventional tillage	PD1	21.08de
	PD2	20.63ef
	PD3	19.88f

Means, followed by different letters are statistically significant at 5% of probability, using Duncan's multivariate test. PD1, 8 Sept; PD2, 23 Sept; PD3, 7 Oct.

Canola yield and oil

The amount of yield and oil under CT was significantly ($p = 0.05$) higher than those of NT and MT. The highest yield was related to PD1, significantly ($p = 0.05$) different from PD3. The first planting date (PD1) resulted in the highest and significantly different ($p = 0.05$) oil content and amount, compared with PD2 and PD3 (Table 4).

The highest yield and oil amount was related to the combination of CT, PD1 and cultivar PF (Figure 1), which was significantly different ($p = 0.05$) from other combinations. The lowest yield and oil amount were related to treatments MT, PD2 and cultivar PF and Hyola 401, respectively, significantly different ($p = 0.05$) from other treatments (Tables 6 and 7). Under NT at PD1 and PD2, the yield of cultivar Hyola 401 was higher than cultivar PF, and at PD2 the difference was significant.

Soil microbial biomass C and N

The highest and lowest microbial biomass C and N were related to NT and PD1, and CT and PD3, respectively, significantly different from other treatments (Tables 6 and 7). The combination of NT, PD1 and PF, and MT, PD3 and Hyola 401 resulted in the highest and lowest, microbial biomass C, respectively (Table 8). PD3 resulted in the lowest microbial biomass C and N (Table 7).

Earthworm abundance

The effects of tillage, planting date, and the interaction effects of tillage and year, and also planting date and cultivar were significant on the number of earthworms. No-tillage and MT resulted in higher number of earthworms, compared with CT. The highest number of earthworms was related from PD3 significantly different to PD1 (Table 6).

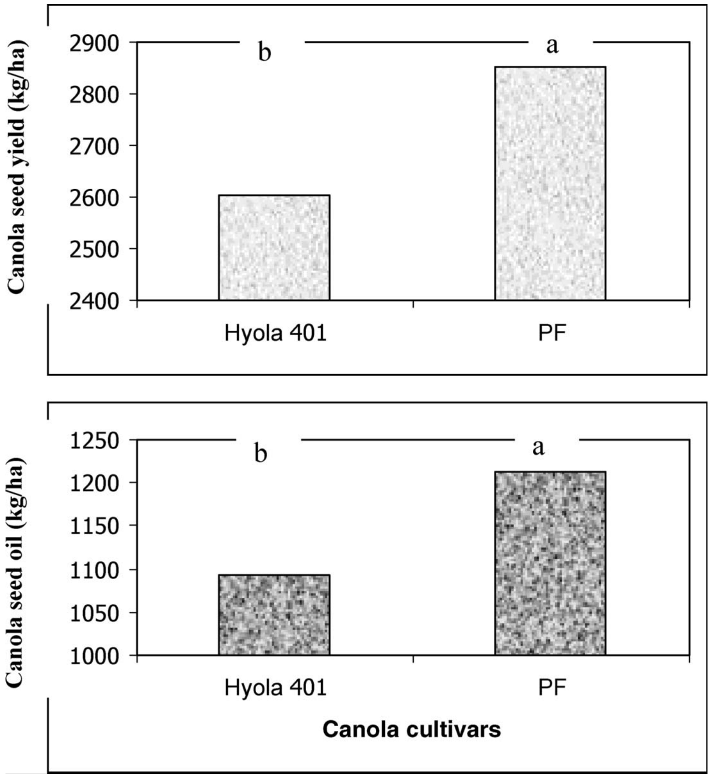

Figure 1. Effects of different canola cultivars, Hyola 401 and PF, on the amount of seed yield (kg/ha) and seed oil (kg/ha).

Table 6. Effects of different tillage systems and planting dates on canola yield, seed oil percentage and amount, microbial biomass C and N, and number of earthworms.

Tillage	Yield (kg/ha)	Oil content (%)	Oil amount (kg/ha)	Microbial biomass C (mg/kg)	Microbial biomass N (mg/kg)	Number of earthworms (m^{-2})
NT	2612.2b	42.54a	1112.7b	317.07a	26.94a	8a
MT	2661.9b	41.63b	1105.5b	273.16b	24.45b	6.72a
CT	2906.8a	42.68a	1240.8a	263.24c	23.96b	5.25a
Planting date						
PD1	2887.41a	42.86a	1239.21a	297.17a	25.56a	6.25b
PD2	2835.16a	41.89b	1188.94b	282.84b	25.09b	6.78ab
PD3	2458.38b	42.09b	1030.92c	273.48b	24.72c	6.94a

Means, followed by different letters are statistically significant at 5% of probability, using Duncan's multivariate test. NT, no tillage; MT, minimum tillage; CT, conventional tillage; PD1, 8 Sept; PD2, 23 Sept; PD3, 7 Oct.

Discussion

Soil moisture fluctuations

Soil tillage significantly affected soil moisture. This is because, according to Sarkar and Singh (2007), tillage methods affect soil porosity and organic matter, influencing soil

Table 7. The interaction effects of different tillage systems and planting dates on microbial biomass C and N.

Tillage	Planting date	Microbial biomass C (mg/kg)	Microbial biomass N (mg/kg)
NT	PD1	341.20a	28.03a
MT		316.70b	26.33b
CT		293.32c	26.47b
NT	PD2	282.47d	24.38cd
MT		270.79e	24.86c
CT		267.83ef	24.13cd
NT	PD3	266.22f	24.27cd
MT		261.02g	24.08cd
CT		260.89g	23.54d

Means, followed by different letters are statistically significant at 5% of probability, using Duncan's multivariate test. NT, no tillage; MT, minimum tillage; CT, conventional tillage; PD1, 8 Sept; PD2, 23 Sept; PD3, 7 Oct.

Table 8. The interaction effects of different tillage systems, planting dates and cultivars on canola yield, seed oil amount and microbial biomass C.

Tillage	Planting date	Cultivar	Yield (kg/ha)	Oil amount (kg/ha)	Microbial biomass C (mg/kg)
NT	PD1	Hyola 401	3164.7b	1374.56bc	340.22a
		PF	2912.9bcd	1300.19cd	342.18a
	PD2	Hyola 401	2754.8cde	1183.74ef	317.47b
		PF	2463.3fg	1107.25f	315.93b
	PD3	Hyola 401	2697.7def	1168.88ef	295.57c
		PF	2986.8bc	1363.04bc	291.08c
MT	PD1	Hyola 401	2675def	1127.59ef	280.85d
		PF	3012.3b	1294.62cd	284.08d
	PD2	Hyola 401	2693.6def	809.95h	273.18e
		PF	1958.9i	1152.90ef	268.40e
	PD3	Hyola 401	3148.4b	967.02g	259.97f
		PF	2197.4h	1412.67b	272.48e
CT	PD1	Hyola 401	3162.1b	1421.56b	268.28e
		PF	3689.2a	1694.36a	267.38e
	PD2	Hyola 401	2306gh	971.54g	260.75f
		PF	2523.7efg	1085.18f	261.28f
	PD3	Hyola 401	2554.7efg	1100.76f	261.30f
		PF	2709def	1234.09de	260.46f

Means, followed by different letters are statistically significant at 5% of probability, using Duncan's multivariate test. NT, no tillage; MT, minimum tillage; CT, conventional tillage; PD1, 8 Sept; PD2, 23 Sept; PD3, 7 Oct.

moisture and thermal properties of soil and, hence the productivity potential of soil. The effect of tillage on soil porosity is through affecting the size, shape and continuity of soil pores. These may all collectively determine the selection of an appropriate tillage and also mulching method, and hence, result in enhanced soil moisture retention. Although tillage can increase evaporation from soil, removing weeds results in the reduction of soil transpiration (Sarkar and Singh 2007).

As a result of plowing, smaller soil aggregates and voids are created and water capillary movement, and hence evaporation from the soil surface, is inhibited. This is because the created loose soil on the surface can act as a mulch (Agele et al. 2000). According to Moitra et al. (1996) different tillage methods may influence water use efficiency.

In addition, soil tillage may also affect the thermal properties of the soil, influencing the soil microclimate (Sarkar and Singh 2007). By influencing the pore properties of the soil, and hence soil water content, the thermal conductivity reduces. High use of agricultural machinery in the field results in the compaction of soil and increased bulk density (Miransari et al. 2007), which increases soil thermal conductivity (Sarkar and Singh 2007).

The differences in soil moisture related to different cultivars may be attributed to the amount of rain and temperatures in different months. For example the high amount of rain in the month of October had definitely affected the growth of cultivars with different stages, although at different intensity. Increased temperature enhances evapotranspiration. The interaction between soil tillage and canola cultivar may also indicate the differences between the two cultivars in responding and utilizing soil moisture. These may all explain the variation in soil moisture when different canola cultivars are planted.

Regarding the effect of different planting dates in addition to the tillage method, employed, and also different cultivars planted, the climate data may greatly account for variation in soil moisture. According to Table 2, in addition to a decreased air temperature, the amount of rain in the month of October also considerably increased, compared with that of September.

It is worth mentioning that although NT may be agronomically, ecologically, economically, and environmentally advantageous compared with CT, many farmers are reluctant to use such a method because of the unpredictability in the amount of yield producing under NT. Both reduction and increase in the amount of yield has been reported as a result of using NT in the field. For example, Lal et al. (1978) reported enhancing effects of NT on crop yield, but Wilhelm et al. (1987) found adverse effects. Soil type, climate and cropping history may also explain such differences. Under NT soil bulk density, and hence soil resistance increases, resulting in reduced soil porosity, compared with chisel plow and moldboard plow (Cassel et al. 1995).

There are many other factors behind the variation in crop quality such as soil, climate, cultivar, cropping methods and grain storage conditions (Borghi et al. 1997). Under NT, the rate of water stable aggregates and also the size of aggregates increase, resulting in the improvement of soil structure (Beare et al. 1994). Under NT, aggregates formation persist, but under MT and more CT this process is disrupted, regularly (Green et al. 2007).

Canola yield and oil

The effects of tillage, canola cultivar and planting date on the amount of yield and oil, and oil content were significant. Although the rate of soil moisture under NT is higher, the lower amount of yield under NT, compared with CT may be attributed to the higher rate of N immobilization and also the higher amount of soluble C and N, making less C and N available to the microorganisms and plant (Franchini et al. 2007).

The optimum temperature (Table 2) for seed germination and microbial activity may explain the higher yield of canola, planted at PD1. The differences, related to soil moisture, stated above regarding the architecture of different cultivars, may also account for the variation in the yield of different canola cultivars. Different significant interactions also indicate that the performance of canola is under the influence of different combination of tillage, cultivar and planting dates.

Changes in microbial biomass C and N

Compared with recalcitrant pools, the fractions of C that are easily affected under tillage practices are the labile pools of organic C including the light fraction, mineralizable C and the water-extractable fraction (Ghani et al. 2003).

Tillage practices can affect microbial respiration (CO_2 emission). Plowing under CT increases CO_2 emission and hence results in soil organic C reduction of the light fraction, which is easily exposed to mineralization. As it is evident from our results, NT, compared with other tillage practices increased soil microbial biomass C and N, which is in agreement with Franchini et al. (2007).

The lower microbial biomass under CT is attributed to higher microbial respiration and hence, CO_2 emission, and also indicates that under such conditions, little amount of plant residue is turned into microbial biomass. It has also been known that the difference between soil organic matter in temperate areas is between 10 and 20% in NT and CT, which is also clear from the microbial biomass. Microorganisms are more efficient under NT as lower amount of CO_2 is emitted (Franchini et al. 2007).

Under undisturbed conditions, soil organic matter is protected from microbial degradation. However, if the soil is disturbed, in addition to enhanced soil O_2, soil organic matter becomes more exposed to the microbial population, hence the mineralization rate increases (Balesdent et al. 2000). It is also worth mentioning that in addition to affecting soil physical and chemical properties, plant residues on the soil surface may influence many soil biological properties including microbial habitat and activity and soil organic matter alterations (Franchini et al. 2007).

Soil biological properties are very important for the sustainability of agriculture, and are very good indicators of soil quality. The main functions of soil microorganisms are nutrient cycling, stability of soil and also organic matter mineralization. Hence, the role of biological parameters is of great significance for soil management (Green et al. 2007). In addition to affecting the amount of soil organic matter, different tillage practices also influence the distribution of soil organic matter. With increased depth, the differences in soil organic matter, related to different tillage practices, decreases and at the first 5 cm they are very obvious. Change in soil organic matter, due to different tillage practices, is a long time process, while soil microbial biomass and mineralizable N seem to be more susceptible (Green et al. 2007).

The high and significant correlation between soil moisture content and microbial biomass C indicates the significance of soil moisture for the growth of microbial population, which is also indirectly reflected in the high and significant correlation between soil microbial biomass C and soil microbial biomass N. This high and significant correlation may be used as very good predictors for the physical, chemical and biological properties of soils and hence for the selection of an appropriate tillage method (Table 9).

Table 9. Coefficients of correlation among different parameters.

	SMC	SMBC	SMBN	EW
SMC	1			
SMBC	0.679**	1		
SMBN	0.811**	0.798**	1	
EW	0.517**	0.528**	0.405**	1

SMC, Soil moisture content; SMBC, Soil microbial biomass C; SMBN: Soil microbial biomass N; EW, Earthworm.

Earthworm abundance

Tillage significantly affected earthworm abundance. The highest number of earthworm was resulted under NT. This is mainly due to the disturbance of soil and also the lower rate of soil organic matter at CT. Soil disturbance, in addition, to directly disturb the earthworm population, can indirectly influence the population and activity of earthworms through affecting soil physical, chemical and biological properties. For example, it is certain that in a soil with a good structure, and hence better air circulation (Chan and Barchia 2007), optimum chemical processes and active and high population of microorganisms, the earthworm population would rise.

It is also clear that the number of earthworms was the highest at PD3, which can be attributed to the higher rate of rain, and hence, soil moisture (Table 2) (Kladivo et al. 1997) as they are very sensitive to moisture deficiency and the existence of light. Soil moisture is also a determining factor in earthworm tunneling rather than soil strength as with increased soil moisture, the tunneling activity of earthworms also increases (Dexter 1978).

Conclusion

We may conclude that the results of this research work on this very important oil seed crop can be very helpful for designing appropriate canola-cropping strategies under different tillage practices, planting date and canola cultivars. These parameters may also explain a large part of variation in the amount of canola yield and oil, oil content, soil physical properties, including soil moisture, and soil biological properties including microbial biomass C and N and also earthworm abundance. Although the amount of seed and oil yield is higher under CT, it is agronomically more sustainable to plant canola using NT or MT. Hence, determination of parameters that makes these tillage methods more productive in addition to their soil physical and biological superiority make future research work even more interesting.

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