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EFFECTS OF TILLAGE METHODS ON WHEAT YIELD AND YIELD COMPONENTS IN CONTINUOUS WHEAT CROPPING

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SUMMARY

A three-year field experiment was undertaken to evaluate the effects of tillage methods on grain yield and yield components of wheat (*Triticum aestivum*) in continuous cropping. The experiment was conducted on a Ramjerd, fine, mixed, mesic, typic Calcixerepts soil. Wheat was sown: (1) after burning residues followed by conventional tillage, (2) after complete residue removal followed by conventional tillage, (3) after soil incorporation of residues followed by conventional tillage, (4) into untilled residues, (5) using chisel seeder after field irrigation, (6) using chisel seeder plus herbicide application, and (7) after disking. Residue burning and removal increased spikes per square metre, grain per spike, 1000–grain weight, grain yield and harvest index compared with other treatments. This was due primarily to weed interference and lack of uniform crop establishment in the presence of residues. Reduced tillage methods retained more residues on the soil surface, which provided unsuitable conditions for crop emergence and growth. The incorporation of residues led to a build up of carbon in the soil, with lower grain yields compared with residue burning and removal, but these yields were higher than those of chisel-seeded plots.

INTRODUCTION

Residue management is critical to soil and water conservation. Maintaining residues on the soil surface protects the soil from wind and water erosion, provides a source of plant nutrients, improves organic matter levels in the soil and increases soil water content (Chastain *et al*., 1995). Winter wheat (*Triticum aestivum*) usually provides sufficient residues for these purposes (Crutchfield *et al*., 1985; Young *et al*., 1994). Wheat residues provide more shade to suppress weed growth when lying flat. When incorporated in the soil they decompose faster and improve the soil physical and microbiological conditions (Biederbeck *et al*., 1980; Vyn and Raimbault, 1993). However, it has been shown that, often, wheat yields are reduced when seeds are sown in heavy surface residues as compared with conventionally tilled seedbeds (Cochran *et al*., 1982; Jessop and Stewart, 1983). Reduced grain yield was more often associated with cool wet weather, especially during crop establishment in higher rainfall areas (Cook and Haguland, 1991). Factors contributing to yield depression include poor seed-soil contact (Cochran *et al.*, 1982), suboptimal temperatures, inconsistent seedbed quality, soil pathogens (Cook and Haguland, 1991), high crown set, low fertility, immobilization of N (Jessop and Stewart, 1983) and phytotoxicity from decomposing surface residues. Seedling growth is retarded most severely in the field spots where residues are concentrated and it approaches normal where residues have been either burned or removed (Cochran *et al.*, 1982). Moreover, wheat seedlings growing in heavy residues often set a high crown node that exposes the crown roots to applied herbicides or to phytotoxins produced during residue decomposition (Ferguson and Boatwaght, 1968). Continuous wheat cropping, especially under conventional tillage, favours root diseases (Cook and Haguland, 1991) and promotes establishment of annual grass weeds (Dao, 1987). Crop rotation is an important practice for weed management because different herbicides and tillages can be used to control weeds that otherwise are not controlled in monoculture crops (Wilson and Cussans, 1975).

Burning crop residues for summer or autumn plantings is a common practice in most southern provinces of Iran. It reduces heavy crop residues, makes land preparation easier for the next crop, releases minerals from the residues and helps to control pests, especially weeds (Biederbeck *et al.*, 1980). It may, however, hasten soil organic matter decline and cause deterioration in the physical and microbiological conditions of the soil in the long term (Jenkyn, *et al.*, 1995). Burning releases calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K) from residues, but increases their potential for loss due to leaching and erosion (Biederbeck *et al.*, 1980). Burning can also cause the loss of nitrogen (N), carbon (C), sulphur (S) and other nutrients due to volatilization. Tillage that incorporates residues assists productivity maintenance by recycling nutrients and retarding organic matter decline (Unger, 1988). Wheat stubble distributed flat on the soil surface also undergoes significant mass loss compared with standing stubble (Steiner *et al.*, 1994). Standing stubble persists until either it is decomposed at or below the soil surface or it is flattened in response to physical forces. Thus, the success of no-till wheat planting into wheat stubble depends, to a large extent, on the residue management to enhance vigorous crop growth (Cochran *et al.*, 1982).

There is not enough information on the long-term effects of residue management in Iran to show the influence of residues on continuous wheat cropping. The objective of the experiment presented here was to determine the effects on yield and yield components of irrigated winter wheat, of residue management using different tillage methods. The experiment was carried out in the Doroodzan region of Fars province, one of the main wheat-growing areas with more than 50 000 ha wheat grown as nearly continuous cropping.

MATERIALS AND METHODS

A three-year (1994–96) field experiment was conducted on a uniform six-ha cropland site at Kushkak Agricultural Experiment Station of Shiraz University (52°46′E, 29°50′N, altitude 1650 m asl), 75 km northwest of Shiraz on a Ramjerd, fine, mixed, mesic, typic Calcixerepts soil with pH 7.3 and EC = 0.28 dSm^{-1}. The experiment site had been sown previously with winter wheat (cv. Falat) and the amount of wheat residue was determined by random throwing of a 0.25-m^2 frame. It was estimated to be 5 t ha^{-1}. There were seven treatments in which wheat was sown: (1) after burning residues followed by conventional tillage (CT), (2) after complete residue removal including straw stubble and chaff followed by CT, (3) after soil incorporation of residues followed by CT, (4) into untilled residues, (5) using a chisel seeder (CS) after field irrigation, (6) using CS plus herbicide application, and (7) after disking. CT included mouldboard ploughing and disking twice. A chisel seeder was used to till the soil and plant the seed simultaneously. It was expected that this implement could work better than other seeders in land covered with the residues of the previous crop.

Treatments were arranged in a randomized complete block design with four replications. Plots were permanent with dimensions of 20 × 60 m. Total soil organic matter was 2–2.3%. In CT methods, seeds were planted with a chisel seeder at 15 cm row width along the long axis of each plot at a rate of 180 kg ha^{-1}, in mid-November of each year. The fertilizers broadcast at sowing consisted of 200 kg ha^{-1} ammonium phosphate (AP) and 250 kg ha^{-1} urea (U) (first year); 250 kg ha^{-1} AP and 150 kg ha^{-1} U (second year); and 200 kg ha^{-1} AP and 200 kg ha^{-1} U (third year). Annual topdressings of U, at a rate of 60, 60 and 80 kg ha^{-1} in the three years respectively, were applied at the early booting stage of crop growth. The plots were irrigated uniformly by siphon as practised by the farmers in the region. Five irrigations were applied during each growing season and the soil was close to field capacity each time. Weeds in the herbicide treatment were controlled by 2,4-D (2,4-dichlorophenoxy acetic acid) plus dichlofop-methyl (methyl 2-[4-(2,4-dichlorophenoxy) phenoxy] propanoate) at respective active ingredient rates of 0.9 and 0.79 kg ha^{-1} at the late tillering stage of the wheat crop. Weeds were counted per m^2 in all plots at the mid-tillering stage before spraying and at the heading stage six weeks after spraying.

The plots were harvested in early July of each year to determine the grain yield (13% moisture). Spike numbers m^{-2}, grain numbers per spike, and 1000-grain weights were determined from 120 plants harvested from pre-designated central areas of each plot. Soil carbon content was also measured at three random locations at a depth of 0–300 mm before planting in each plot every year (Walkley and Black, 1934). Data were statistically analysed and the standard errors were calculated.

RESULTS AND DISCUSSION

Experimental treatment had a significant effect on grain yield and its components (except for grains per spike) (Table 1). Both residue burning and removal, which generally tended to increase spikes m^{-2}, grains per spike, 1000-grain weight, grain yield and harvest index, compared well with other cultivation methods averaged over three years.

Table 1. Effects of different planting treatments on yield and yield components of wheat for three years.

Planting treatment	Grain yield ($t\ ha^{-1}$)	1000-grain weight (g)	Grains per spike	Spikes (m^{-2})	Harvest index (%)
Residue burning	6.19	41.20	44.80	504.60	48.10
Residue removal	6.04	40.50	46.20	476.30	41.20
Residue incorporation	4.94	41.10	43.60	458.90	42.10
Untilled residues	3.40	38.60	42.40	386.20	40.20
CS* after irrigation	2.90	39.20	39.50	295.80	40.20
CS+herbicides	2.40	39.10	40.30	269.50	35.60
Disking	3.99	41.60	41.20	454.80	36.40
s.e.	0.26	0.73	1.79	29.55	2.15

* CS = chisel seeder

Table 2. Year comparison of yield and yield components during 1993–96.

Year	Grain yield ($t\ ha^{-1}$)	1000-grain weight (g)	Grains per spike	Spikes (m^{-2})	Harvest index (%)
1993–94	5.84	42.90	42.40	501.30	51.00
1994–95	4.40	40.00	44.70	517.80	27.30
1995–96	2.63	37.70	40.70	200.70	44.60

The mean of grain yield was significantly higher where wheat was planted in burnt residues (6.19 $t\ ha^{-1}$) or residues were removed (6.04 $t\ ha^{-1}$) than where it was planted in soil-incorporated residues (4.94 $t\ ha^{-1}$), untilled residues (3.4 $t\ ha^{-1}$), or where a chisel seeder (2.90 $t\ ha^{-1}$) was used after irrigation. Wheat growth and yields were better in burnt and removed residue plots than other plots in all three crop years (Table 1). This could primarily be due to the destruction of weed seeds and soil pathogens and lack of interference by residues. Similar results have also been reported by others (Cook and Haguland, 1991). There was a decrease in grain yield over all treatments as the experiment continued to the third year, which can be attributed to the adverse effects of continuous cropping and weeds (Table 2).

Grass and broadleaf weed populations at the mid-tillering growth stage of winter wheat were highest in burnt and incorporated-residue plots (Table 3). Burning altered the situation in favour of the previously suppressed weeds. In incorporated-residue plots, no special weed control measure was taken, compared with other treatments. Thus more weeds were able to express themselves. Lowest weed populations at the mid-tillering and heading growth stages of winter wheat were obtained in chisel-seeder plots where herbicides were used. Results showed that wheat yield was not highest in these plots where the lowest weed population existed. Weeds in these plots did not reduce grain yield because they emerged late in the growing season and developed little top growth. This is because winter wheat is an excellent competitor against some spring-germinating weeds. Weeds remained below the winter wheat canopy and competed very little. Generally, the

Table 3. Grass- and broadleaved weed populations m^{-2} at wheat mid-tillering and heading stages in 1994–95.

Treatment	Grass weeds		Broadleaved weeds	
	Mid-tillering stage	Heading stage	Mid-tillering stage	Heading stage
Residue burning	292	206	129	4
Residue removal	26	22	29	9
Residue incorporation	225	159	167	37
Untilled residues	19	24	78	13
CS* after irrigation	30	27	25	14
CS + herbicides	19	13	7	9
Disking	77	56	72	25

*CS = chisel seeder; *s.e.* for grass weeds at wheat growth stages = 8.5; *s.e.* for broadleaf weeds at wheat growth stages = 6.43; *s.e.* for grass weeds in each treatment = 28.85; *s.e.* for broadleaf weeds in each treatment = 45.45.

only weeds that survived were the more competitive grasses, such as wild oat (*Avena fatua*) and wild rye (*Secale montaneum*), and deep-rooted broadleaf weeds such as field bindweed (*Convolvulus arvensis*).

The number of grass weeds at the heading stage of winter wheat was significantly less than at the mid-tillering stage only in burnt and incorporated-residue plots. However, broadleaved weeds at the heading stage were significantly lower than at the mid-tillering stage in all treatments except for chisel-seeder plots where herbicides were used. In these plots, lowest weed populations existed throughout the season.

Burning and removal of residues could have given relief from yield depression due to planting into previous residues, whereas residue incorporation left greater amounts of weed seeds and, probably, plant pathogens in the soil. Some weed seeds germinated to increase their population and add substantial numbers to the soil bank for years ahead. By the end of the last year, the weed infestations in chisel-plough plots were so high that continuous cropping was nearly impossible. This reflected the presence of high weed seed populations in the soil from previous years.

Chisel-plough plots retained more residues on their surface than did those where a mouldboard plough was used. High surface coverage in the former provided unsuitable conditions for crop emergence and growth. These results are in agreement with those of Jenkyn *et al.* (1995) and Prew *et al.* (1995) who reported respectively that repeated residue accumulation resulted in severe disease and weed problems. Stott *et al.* (1990) reported that chisel ploughs left more residues compared with conventional ploughs, and Opoku *et al.* (1997) showed that no-till yield potential of corn (*Zea mays*) was affected by wheat residues. Heavy residues probably provided poor seed-soil contact as shown by low spike number m^{-2} and seed yield (Table 1). Herbicide application in chisel-plough plots also could not provide complete weed control, probably due to the inadequate rate of herbicide application and the spectrum of weeds present.

Table 4. Effects of wheat planting methods on soil carbon (%) from crop years 1993–96.

Planting treatment	1993–94	1994–95	1995–96	Mean
Residue burning	1.29	1.08	1.27	1.21
Residue removal	1.19	1.06	1.22	1.16
Residue incorporation	1.27	1.33	1.44	1.35
Untilled residues	1.26	1.33	1.33	1.31
CS* after irrigation	1.20	1.23	1.46	1.30
CS + herbicides	1.20	1.33	1.16	1.24
Disking	1.14	1.10	1.73	1.31
s.e.	1.22	1.21	1.38	

*CS = chisel seeder

The rate of loss of residues from the plots by decomposition and wind removal was slow during the experiment probably due to lack of moisture and low temperatures. Over-winter residue losses might be primarily due to microbial action (Swanson and Wilhelm, 1996). Higher losses during the spring and the following summer could have been due to increased soil fauna and microbial action as well as physical breakdown and, probably, wind removal. The rate of residue loss reported here was not as noticeable as those reported by Steiner *et al.* (1994). Therefore, there was a cumulative build-up of residues on the soil surface in unburnt and unremoved-residue plots. By early in the second year after residue retention, the residues had decomposed or may have been transported to the extent that they did not interfere dramatically with crop growth. Wheat growth, though, was heavily retarded. Weed infestations were so severe by the end of the third year that the experiment could not proceed any further.

Phytotoxins produced during the early stages of residue decomposition might have prevented seed germination, emergence or regular growth of wheat as indicated by Prew *et al.* (1995). Thus, wheat cultivation methods that left residues on or near the soil surface resulted in the least number of spikes m^{-2} (except in disking) and lowest grain yield (Table 1).

Although residue burning or removal has deleterious effects on soil characteristics in the long term as mentioned earlier, this was not obvious from soil carbon measurements in this experiment (Table 4). It appeared that residue incorporation in the soil might have had beneficial effects through a build-up of carbon in the soil, but it produced a smaller grain yield compared with residue burning or removal.

Reduced-tillage cultivation methods (shallow depth of 150 mm with chisel plough) also could not provide appropriate conditions for suitable crop establishment and yields. It seems that if a planter with a rotary cutter that could work in heavy residue conditions had been available the residue probably could have decomposed earlier. In the longer term, this would have provided for more even crop establishment and the experiment could have continued to accumulate soil carbon in the residue-incorporation plots.

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