

Effects of Crop Residue and Nitrogen Rates on Yield and Yield Components of Two Dryland Wheat (*Triticum aestivum* L.) Cultivars

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Abstract : In most southern parts of Iran, wheat (*Triticum aestivum* L.) residues have been traditionally burned or removed; that is often criticized for soil organic and nutrient losses, reducing soil microbial activity and increasing CO₂ emission. A 2-years (2005–2007) field study was carried out at the College of Agriculture, Shiraz University, Shiraz, Iran, to evaluate the influence of crop residues management and nitrogen (N) rates on dryland wheat. The experiment was conducted as strip split plot with four replications. Horizontal plots were three crop residues rates (0, 500 and 1000 kg ha⁻¹), vertical plots consisted of two dryland current wheat cultivars (CVs) (Azar 2 and Nicknejad), and sub-plots were three N rates (0, 35, and 70 kg N ha⁻¹). Increasing crop residue rates increased soil organic carbon. Number of spike per plant, grains per spike, grains per plant and 1000-grain weight of both CVs significantly increased with increased N and residue rates in both years. The lowest grain yield was obtained from 1000 kg ha⁻¹ residue incorporation without N application showing the soil N imbalance. The optimum crop growth and the highest grain yield was achieved from the highest crop residues and N rates, indicating that the most reliable system for dryland wheat production in the region is complete residues incorporation into the soil following disking, seeding with chisel seeder and application of 70 kg N ha⁻¹.

Key words : Crop residue, Dryland wheat, Grain yield, Nitrogen rates.

In dryland farming system, it is now a standard practice to maintain an appreciable amount of crop residues on the soil surface for prevention of soil erosion and increase in moisture storage. Wheat residues shade portion of soil surface, and may increase or decrease the reflectance of solar radiation, and increases the resistance to heat and vapor transfer, compared with bare soil (Bruce et al., 2006). These effects in turn lead to compensating adjustments in the energy balance that tend to reduce evaporation, increase the amount of available soil moisture, and maintain cooler soil temperatures (Sauer et al., 1996; Mahli et al., 2006).

A possible and practical method for maintaining soil C/N Ratio is using different N rates appropriate with crop residues rates. Nitrogen content or C/N ratio is principal determinant of wheat residue effects on nutrient soil availability after residue incorporation into the soil. As plant tissue N increases or C/N ratio decreased, the initial N mineralization potential and rate increases and the over cross time for net N mineralization decreases (Kou and Jellum, 2002; Kou et al., 1997).

In most southern parts of Iran, wheat (*Triticum aestivum* L.) residues have been traditionally burned or removed; that is often criticized for soil organic and nutrient losses, reducing soil microbial activity and increasing CO₂ emission (Biederbeck et al., 1980;

Curtin et al., 1998; Halvorson et al., 2004; Halvorson et al., 1999; Reinertsen et al., 1984). Whereas, crop residues incorporation can improve soil quality and reduce air pollution on a long term basis. However, where residues have been soil incorporated, farmers often have concerns for reduced soil fertility from nutrient immobilization and problems for cultivation associated with slow rates of residues decomposition (Cookson et al., 1988). Effective mitigation of these effects depends on developing crop residue management strategies that enhance residues decomposition. Realizing the potential benefits of cereal residues incorporation depends on synchronizing the release of N with the crop demands, while minimizing the risks to nutrient losses (Powlson et al., 1985; Hooker et al., 1982). Where residue have been incorporated before planting the next crop, grain yield was lower than where residues were removed or burned, resulting in N immobilization (Bahrani et al., 2002; Singh et al., 2004). The most influencing factor on wheat yield is N fertilization, although the degree of influence is governed principally by weather conditions and residual soil N (Garrido-Iestache et al., 2005). There is not enough information on the effects of residue management and N rates on dryland wheat in southern part of Iran, where more than 130,000 ha of this crop is nearly grown as continuous cropping.

Table 1. Soil properties (0–30 cm) of Badjgah region before plant sowing for two cropping years.

Year	OC (%)	pH	Sand (%)	Silt (%)	Clay (%)	Soil texture	EC (dSm ⁻¹)	P (mg kg ⁻¹)	K (mg kg ⁻¹)	Total N (%)
2005–2006	0.83	7	7	66.7	26.3	Siltyloam	0.55	16.5	476	0.08
2006–2007	0.91	7	7	66.7	26.3	Siltyloam	0.44	17.4	470	0.09

Table 2. Monthly rainfall and mean temperature of Badjgah region during 2005–2006 and 2006–2007 growing seasons compared to 30 years means.

Month	Rainfall (mm)			Temperature (°C)		
	2005–2006	2006–2007	1975–2005*	2005–2006	2006–2007	1975–2005*
October	94.5	0.0	24.4	10.3	12.3	9.9
November	5.0	82.0	77.3	8.2	2.7	8.8
December	126.0	50.5	96.2	3.5	0.8	3.4
January	71.5	82.5	88.2	7.4	4.5	3.5
February	7.0	35.0	68.8	7.8	7.4	6.9
March	49.5	138.0	45.6	11.6	11.5	10.9
April	15.0	3.0	14.1	16.9	17.1	15.6
May	1.0	3.0	0.9	20.1	22.1	20.1

*Unpublished Data, Dept. of Irrigation Eng., College of Agric., Shiraz University, Shiraz, Iran

Materials and Methods

A field experiment was conducted in two cropping seasons (2005–2007) at the college of Agriculture, Shiraz University, Shiraz Iran (52°46'E, 29°50'N, altitude 1810 m asl), 12 km north of Shiraz on a fine mixed, mesic typic Calcixerpets soil. The experimental site had been previously sown with winter dryland wheat to determine the potential yield and to provide residue cover for the plot, and the experiment started in cropping year of 2005 and continued through 2007.

The experiment was conducted as strip split plot with four replications. Horizontal plots consisted of three crop residues rates (0, 500 and 1000 kg ha⁻¹), vertical plots were two dryland current wheat cultivars (CVs) (Azar 2 and Nicknejad), and sub-plots were three N rates (0, 35, and 70 kg N ha⁻¹ as urea). Half of the N was applied at planting time and the other half during the tillering stage and before the end of spring rainy season. Plots were 5 × 7 m. Wheat was sown about mid-October of each year before the rainy season. Seed-beds were prepared by disking, and wheat residues were spread over the plots before seeding. Seeds were sown in 20 cm row width with chisel seeder (120 kg ha⁻¹). Total Nitrogen content of crop residue used in this study was 0.345% and 0.347% (3.45 and 3.47 g kg⁻¹) at the years of 2005 and 2006, respectively, was determined by Dumas combustion on a LECO C/N/S analyzer (LECO Corp., St. Joseph, MI) at 1050°C (McGill and Figueirido, 1993).

Soil properties, monthly precipitation and mean monthly temperatures are shown in Tables 1., 2 respectively.

Plots were harvested in early June to determine the grain yield (14% moisture). Plant material was sampled from a 0.91 m² areas to determine biological yield and spike number per plant. The average number of grains per spike was determined from 20 randomly selected spikes. Thousand-grain weight was determined from 500 grains sample randomly taken from the grain produced on each plot (Wilhelm et al., 1989). Soil organic carbon was determined by Walkley and Black method (Nelson and Sommers, 1996). The data were statistically analyzed for each year and combined for two yr by SAS software (SAS Inst., 1985). Means were separated by Duncan's Multiple Range Tests at $p \leq 0.05$.

Results

Experimental treatment had significant effects on grain yield and yield components of both CVs in both years (Table 3). Residue and N rates, generally increased spikes per plant, grains per spikes, 1000-grain weight, grain yield, biological yield and harvest index. Grains per spike and harvest index significantly increased with increased crop a residue rate. There was no significant difference between residues rates of 500 and 1000 kg ha⁻¹ for grain yield, spikes per plant and biological yield. Azar 2 CVs had significantly higher spikes per plant, grains per spikes, 1000-grain weight, grain yield and harvest index, than Nicknejad. Increased crop residue rates increased soil organic carbon (Table 3).

Grain yield, grains per spike and biological yield significantly increased with increased N rates. The interaction between residue rate and nitrogen rate

Table 3. Effects of crop residue and N rates on grain yield and yield components of two dryland wheat cultivars for two cropping years.

Treatments	Grain yield (kg ha ⁻¹)	1000-grain weight (g)	Grains per spike	Spikes per plant	Biological yield (kg ha ⁻¹)	Harvest index (%)	Soil carbon (%)
Residue (kg ha ⁻¹)							
0	457 b	28.84 b	6.44 c	1.42 b	1303 b	23.54 c	0.477 b
500	940 a	26.05 b	7.28 b	1.94 a	2881 a	27.53 b	0.622 a
1000	1036 a	28.40 a	9.38 a	2.00 a	3134 a	30.58 a	0.731 a
N (kg ha ⁻¹)							
0	608 c	25.22 b	6.59 c	1.52 b	1719 c	25.65 b	0.676 a
35	794 b	26.24 b	7.94 b	1.89 a	2462 b	28.75 ab	0.662 a
70	1031 a	28.84 a	9.03 a	1.95 a	3395 a	30.83 a	0.624 a
Cultivar							
Azar 2	954 a	29.70 a	9.06 a	1.80 a	2514 a	31.40 a	0.610 a
Nicknejad	668 b	23.80 b	6.34 b	1.58 b	2498 a	23.00 b	0.612 a
Year							
2005–06	950 a	29.1 a	9.10 a	1.72 a	2510 a	31.10 a	0.600 a
2006–07	660 b	23.1 b	6.31 b	1.40 b	2490 a	23.01 b	0.604 a

Means at each column for ten treatments followed by similar letters are not significantly different (5%).

Table 4. Effect of different planting treatments on yield and yield components of wheat cultivars.

Residue rate (kg ha ⁻¹)	N (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)		1000-grain weight (g)		Grains per spike		Spikes per plant		Biological yield (kg ha ⁻¹)		Harvest index (%)	
		Azar 2	Nicknejad	Azar 2	Nicknejad	Azar 2	Nicknejad	Azar 2	Nicknejad	Azar 2	Nicknejad	Azar 2	Nicknejad
0	0	264 ef	135 f	24.26 e	19.11 f	5.45 ef	4.69 fg	0.91 ef	0.85 f	853 gh	543 h	26.48 def	19.89 e
	35	581 cde	169 f	28.24 de	20.30 ef	6.09 ef	5.16 f	1.53 d	1.25 e	1901 efg	871 gh	25.61 def	18.08 f
	70	678 cd	915 bc	28.72 de	21.80 ef	8.38 d	8.86 cd	1.95 bcd	1.69 cd	2162 ef	3342 cd	26.73 def	24.47 e
500	0	907 bc	447 def	26.45 de	21.84 ef	9.54 abcd	5.64 ef	1.87 bcd	1.95 bcd	2783 cde	1946 fg	32.33 cd	20.62 f
	35	1514 a	927 bc	33.92 ab	23.39 de	10.81 a	10.48 abc	2.09 abcd	2.01 abcd	3169 cde	3517 bcd	37.95 abc	23.90 e
	70	1134 b	711 cd	34.40 ab	25.19 de	9.13 bcd	8.69 d	1.83 d	1.70 d	3123 cde	2191 def	33.01 bcd	22.66 e
1000	0	851 bc	439 def	26.15 de	24.44 de	6.85 e	3.20 g	0.85 f	1.76 cd	1555 fgh	1891 efg	33.82 bcd	20.11 e
	35	1089 b	1093 b	33.80 abc	27.94 de	9.51 abcd	4.33 fg	2.28 ab	1.99 abcd	2465 def	3367 cd	38.08 ab	21.06 e
	70	1569 a	1177 b	35.48 a	35.02 a	11.03 a	10.67 ab	2.40 a	2.04 abcd	4666 ab	4861 a	41.68 a	27.02 d

Means at each column for ten treatments followed by similar letters are not significantly different (5%).

were investigated in (Table 4). The variation trend of different N rates at 0 kg N ha⁻¹ crop residue showed that yield and yield components significantly increased by increasing N rates in both CVs. (Table 4). The optimum crop growth and the highest grain yields (1569 and 1177 kg ha⁻¹ in Azar 2 and Niknejad, respectively) were obtained at 1000 kg ha⁻¹ crop residue rate and 70 kg N ha⁻¹.

Incorporation of 1000 kg ha⁻¹ residue into the soil without N application gave the lowest grain yield and

yield components in both CVs in both years. This may be attributed to the soil N imbalance due to the slower residue decomposition (Table 4).

Discussion

Residue and N rates, generally increased spikes per plant, grains per spikes, 1000-grain weight, grain yield, biological yield and harvest index. Grains per spike and harvest index significantly increased with increased crop a residue rate which is in agreement

with Asseng et al. (1998) who indicated increased grain yield of 1 t ha^{-1} by an additional 50 kg N ha^{-1} of wheat residues. There was no significant difference between residues of 500 and 1000 kg ha^{-1} for grain yield, spikes per plant and biological yield. Azar 2 CV had significantly higher spikes per plant, grains per spikes, 1000-grain weight, grain yield and harvest index, than Nicknejad (Tadayon, 2007).

Grain yield, grains per spike and biological yield significantly increased with increased N rates. Grain yield responses to N rates were reported by Garrido-Lestache et al. (2005) and Lopez-Bellido et al. (1996). Nakano and Morita (2009) showed that Grain yield of a bread wheat cultivar, 'Minaminokaori', was higher when 4 and 2 g N m^{-2} were applied at active tillering and jointing, respectively (4-2N), than when no N was applied at these stages (0-0N). The interaction between residue rate and nitrogen rate were evaluated in (Table 4). The variation trend of different N rates at 0 kg N ha^{-1} crop residue showed that yield and yield components significantly increased by increasing N rates in both CVs. When the highest crop residues rates were returned to the soil, but N rates were inappropriate with residue rates, yield components of both CVs significantly decreased in both years due to C/N ratio (Bronson et al., 2001) (Table 4). The optimum crop growth and the highest grain yields (1569 and 1177 kg ha^{-1} in Azar 2 and Niknejad, respectively) were obtained at 1000 kg ha^{-1} crop residue rate and 70 kg N ha^{-1} . This amount of crop residue probably improved soil infiltration, reduced soil water evaporation and increased soil moisture conservation (Melaj et al., 2003). Iijima et al. (2007) showed that the crops in the no-tillage field depend highly on the newly supplied easily accessible water (irrigation water and/or rainfall) as compared with those in the conventional tillage field under a limited water supply. Total soil mineralization was also greater under residue incorporation of 1000 kg ha^{-1} and 70 kg N ha^{-1} during the growth season and was significantly correlated with soil C/N ratio (Sadeghi, 2007). Doran et al. (1998) reported that increased residue accumulation, followed by higher level of organic carbon at the soil surface, can enhance N immobilization, thereby requiring higher rate of N fertilization to crop. Rochester et al. (2003) showed that crop residue incorporation slightly reduced the mineral N content in soil by encouraging biological immobilization. Realizing the potential benefits of wheat residue incorporation depends on synchronizing nutrient release with the crop demands, while minimizing the risks to nutrient losses (Beare et al., 2002). Li et al. (2008) showed that straw mulching significantly reduced the number of spikes in the crop. Both irrigation and straw mulching increased the number of kernels, but had no visible effects on the thousand kernel weight.

When a normal N rate was applied, the

1000-grain weight under the soil drying conditions reduced compared with the plant under the wet conditions, indicating the loss of photosynthesis may not compensate for the grain from increased remobilization of carbon reserves. While at higher N rate, kernel weight increased under water deficit (Table 3). The obvious explanation for such a result is that, when N was heavily used, delayed senescence led to a slow grain filling and a poor remobilization and partitioning of assimilates into the grain (Yang et al., 2000). While, Tanaka et al. (1990) reported that N application at the dryland conditions in late spring reduced 1000- grain weight and harvest index due to increase in stem elongation and vegetative growth. Melaj et al. (2003) also showed that applied N increased grain yield and the number of grains per square meter and decreased 1000-grain weight. López-Bellido et al. (2000) indicated that the inverse relation between kernel weight and N rate is probably due to increase in number of grains per spike and decline in 1000-grain weight prompted by increased N fertilizer rates. Sieling et al. (2005) showed that an increased N fertilization compensated for the lower number of ears m^{-2} and partly reduced the yield losses due to the unfavorable preceding crop combination.

Increased crop residue rates increased soil organic carbon (Table 3). Halvorson et al. (1999) showed that increased crop residue returned to soil in semiarid dryland region of Central Great Plains, USA, accompanied by increased N rate resulted in increased soil organic carbon levels which contribute to improved soil quality and productivity, and increased efficiency of carbon sequestration into the soil. However, Sainju et al. (2007) reported that increased crop residues rates did not influence soil organic carbon.

When a normal N rate was applied, the 1000-grain weight under the soil drying conditions reduced compared with the plant under the wet conditions, indicating the loss of photosynthesis may not compensate for the grain from increased remobilization of carbon reserves. While at higher N rate, kernel weight increased under water deficit (Table 3). The obvious explanation for such a result is that, when N was heavily used, delayed senescence led to a slow grain filling and a poor remobilization and partitioning of assimilates into the grain (Yang et al., 2000). While, Tanaka et al. (1990) reported that N application at the dryland conditions in late spring reduced 1000-grain weight and harvest index due to increase in stem elongation and vegetative growth. Melaj et al. (2003) also showed that applied N increased grain yield and the number of grains per square meter and decreased 1000- grain weight. López-Bellido et al. (2000) indicated that the inverse relation between kernel weight and N rate is probably due to increase in number of grains per spike and decline in

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Soil water content was higher under crop residue incorporation at all sampling times (Sadeghi, 2007). Soil under crop residue incorporation improves water storage due to lower evaporation losses (Melaj et al., 2003; Torbert et al., 1999). The effect of crop residue on grain yield could have been related to the soil water content and water use efficiency (Sadeghi, 2007). The differences in temperature and rainfall are reflected in soil water content. The response of yield and yield components to crop residue and N rates depending on the weather conditions during the growing season and is frequently limited by the high temperatures and drought characteristics at the dryland conditions. Boyer (1996) and Blum et al. (1990) also reported that the response patterns of wheat yield to crop residue and N rates may be prompted by the water shortages and high temperatures typical of the dryland region during grain-filling stage. Gooding and Davies (1997) suggested that moisture stress and high temperatures reduce grain yield due to decrease in carbohydrate accumulation. Li et al. (2008) showed that irrigation is required to obtain a high yield from winter wheat; these results in rapid aquifer depletion, there was a statistically significant difference in the evapotranspiration among the different growing seasons. Straw mulching reduced the evapotranspiration from the seeding stage to the regrowing stage, and the evapotranspiration with mulching was less than that non-mulching 47.4 mm. further. These results indicate that straw mulching may decrease the yield and water use efficiency (WUE) of winter wheat in North China (Li et al., 2008).

The proper rainfall distribution in the first year enhanced plant germination and emergence in October and the April rainfall prevented early plant senescence leading to higher yield (Table 2). However, in the second year, delaying in germination due to the lack of rainfall in October and high temperatures and water stress at the end of growing season (April and May) have prompted the lowest grain yield in both CVs due to accelerating senescence (Melaj et al., 2003) (Tables 2, 3.). Therefore, rainfall distribution and temperatures were only adequate and timely for good crop growth and development in the first year.

Conclusions

The increase in N and residue rate increased the numbers of fertile spikes per plant, grains per spike and grains per plant, and the 1000-grain weight significantly in both CVs in both years. When the crop residue was incorporated into the soil at the highest rate, but N rate was inappropriate, grain yield and

yield components significantly decreased in both years. The optimum crop growth and the highest grain yield were achieved at 1000 kg crop residue ha^{-1} and 70 kg N ha^{-1} , indicating that complete residue incorporation accompanied by application of 70 kg N ha^{-1} (half at planting and half at the tillering stage) is the most reliable system for dryland wheat production in the region

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