Agricultural Water Management 97 (2010) 738–748

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Synthetic and organic mulching and nitrogen effect on winter wheat (*Triticum aestivum* L.) in a semi-arid environment

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ARTICLE INFO

Article history:
Received 19 March 2009
Accepted 12 January 2010
Available online 1 February 2010

Keywords:
Organic and synthetic mulch
Crop growth
N uptake
Water use
Wheat

ABSTRACT

Field experiments were conducted in 2002–2003 and 2003–2004 to evaluate the relative performance of synthetic (black polyethylene) and organic (paddy husk and straw) mulches on soil and plant water status *vis-a-vis* N uptake in wheat in a semi-arid environment of India. Scope of better utilization of soil moisture was documented through all the mulches, especially during initial crop growth stages, when the moisture content was 1–3% higher in mulches. Soil temperature was more moderate under organic mulches. Paddy husk recorded significantly higher plant biomass, while the effect of mulching in enhancing root growth was clearly documented. Organic mulches produced more roots (25 and 40% higher root weight and root length densities compared to no-mulch) in sub-surface (>0.15 m) layers, probably due to greater retention of soil moisture in deeper layers and relatively narrow range of soil temperature changes under these systems. Incremental N dose significantly improved all the plant parameters in both mulch and no-mulch treatments. Grain yield was 13–21% higher under mulch and so with increasing N levels. Nitrogen uptake was higher in organic mulches and also with higher N doses, while polyethylene mulch showed mixed trend. Mulches were effective in reducing 3–11% crop water use and improved its efficiency by 25%. Grain yield and biomass were well-correlated with leaf area index (r = 0.87 and 0.91, respectively) and water use was better correlated with root length than its weight. Results indicated substantial improvement in water and N use efficiency and crop growth in wheat under surface mulching, and the organic mulches, especially rice husk performed better than synthetic mulches.

1. Introduction

Wheat (*Triticum aestivum* L.), the second most important *rabi* cereal crop in India, has been witnessing significant yield stagnation and decline since 1999 and is presently showing an average yield of 4–5 Mg ha^{-1} with recommended (120 kg N ha^{-1}) dose of fertilizer (Duxbury et al., 2000; Yadav et al., 2000; Nagarajan, 2005). With no chance of expansion in area and little scope for further intensification of wheat based cropping systems, increase in yield through better crop management might be the only option. Being highly sensitive to water stress, the yield of wheat with restricted water supply is substantially low and improving the water use efficiency may significantly increase the yield in such situations (Kalra et al., 2007; Chakraborty et al., 2008). The availability of water for irrigated wheat (water requirement of high yielding variety normally varies between 400 and 500 mm) is also progressively becoming limited, even in high yielding areas of Punjab, Haryana and western Uttar Pradesh. In coming years, the growth in agricultural productivity *vis-a-vis* food security in India will increasingly depend on improved utilisation of rainfed regions, which might cater for the country's 2nd Green Revolution. As water is limited, these regions must adopt suitable water conserving techniques in order to improve the water use efficiency and thereby increasing the productivity. Mulching has been proved to be beneficial in conserving moisture and increasing productivity in wheat (Verma and Acharya, 2004a,b; Li et al., 2005; Huang et al., 2005; Rahman et al., 2005; Chakraborty et al., 2008). The recommended N application rate under mulch situation is 120 kg ha^{-1}, which is likely to be different under the modified moisture regime induced by mulching. So far, little information is available on comparative effects of various types of mulches and

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doi:10.1016/j.agwat.2010.01.006

Table 1
Physical properties of the experimental field.

Soil depth (m)	Particle size distribution (%)			Bulk density ($Mg\,m^{-3}$)	Vol. moisture content ($m^3\,m^{-3}$)	
	Sand	Silt	Clay		Field capacity (0.03 MPa)	Wilting point (1.5 MPa)
0–0.15	74.4	9.6	15.7	1.51	0.243	0.008
0.15–0.30	73.8	10.2	15.5	1.49	0.239	0.081
0.30–0.45	72.5	11.0	16.2	1.50	0.242	0.086
0.45–0.60	69.3	12.8	17.4	1.48	0.233	0.089
0.60–0.90	70.8	11.9	16.3	1.50	0.250	0.101
0.90–1.20	68.4	12.2	18.6	1.43	0.237	0.108
1.20–1.50	69.7	14.0	15.1	1.49	0.252	0.101

nitrogen response in wheat under the semi-arid environment of India. Keeping these in background, field experiments were carried out in a sandy loam soil in semi-arid environment of Delhi, India, to study the effect of different types of mulches along with nitrogen application rates on growth and yield of winter wheat and its water and nitrogen use efficiencies.

2. Materials and methods

2.1. Study area

Field experiments involving mulching during 2002–2003 and 2003–2004 were conducted at the Indian Agricultural Research Institute Research Farm, New Delhi, India (28°37′N, 77°9′E, 228.7 m amsl). The soil type was sandy loam (Typic Haplustept), non-calcareous and neutral in reaction (pH 7.5) and low in soil organic matter content (0.2–0.5 g kg^{-1}). Brief information on the soil physical properties of the experimental field is presented in Table 1. The climate is semi-arid. Average day-time temperature during the sowing and seedling establishment of wheat was mild (15–20 °C) and during grain filling stage moderate (20–25 °C). Light rains usually occurred during January to March, followed by slow and gradual increase in temperature from 2nd fortnight of March. Mean monthly maximum and minimum temperature, precipitation and pan evaporation during periods of study recorded at the agromet-observatory close to the experimental site are presented in Table 2.

2.2. Experimental design

The experiments comprised of 16 factorial combinations of 4 mulch treatments: black polyethylene (BP), paddy straw (PS), paddy husk (PH) and no-mulch (NM), and 4 levels of nitrogen application: 0 (N0), 60 (N60), 120 (N120) and 150 (N150) kg N ha^{-1}. The thickness of black polyethylene was 400 μm. Paddy straw and paddy husk were applied @6 and 9 Mg ha^{-1}, respectively.

The field was prepared well before sowing through two harrowings, three ploughings (using a field cultivator), followed by one field levelling (wooden planking). Wheat (cv. HD 2329) was sown on 27th and 20th November in 2002 (1st year) and 2003 (2nd year), respectively by the seed-cum-fertilizer drill (at a depth of ~0.05 m) with a seed rate of 100 kg ha^{-1}, following a pre-sowing irrigation (30 mm). In both the years, mulches were applied soon after sowing between the rows, so as to ensure normal plant growth and entry of rain and irrigation water into the soil. Nitrogen was applied as urea in three equal splits: at sowing as basal dose, 20 and 40 days after sowing (DAS), while P_2O_5 and K_2O were applied as single super phosphate and muriate of potash @60 and 40 kg ha^{-1}, respectively at sowing. Measured quantity of irrigation water (each 60 mm) was applied by surface irrigation method at crown root initiation, tillering, flowering and grain filling stages by installing parshall flumes ensuring free flow of water. Regular weeding was done either manually or by using herbicides and care was taken to keep the crop free from pests and diseases.

2.3. Sampling and data collection

Soil moisture was monitored gravimetrically (g/g) at 0–0.15, 0.15–0.30, 0.30–0.45, 0.45–0.60, 0.60–0.90, 0.90–1.20 and 1.20–1.50 m depths at 10–15 days interval, and was converted into volumetric moisture by multiplying with the corresponding bulk densities. Soil moisture depletion was calculated by the difference in moisture content between two successive observations. Soil temperatures at 0.05 and 0.10 m depths were monitored using digital thermal probe (Decibel, New Delhi) twice a day at 10:00 and 14:30 h.

Three plants at flower initiation stage were randomly chosen from each plot, their green leaves were separated and total green leaf area was measured using leaf area meter (LI-COR 3100). Thereafter, the leaves were dried at 65 ± 5 °C till constant weight and the specific leaf weight (SLW) was determined (leaf weight per unit of leaf area). The aboveground dry biomass was determined by

Table 2
Monthly mean maximum and minimum temperature, rainfall and pan evaporation during the periods of study (values in parentheses indicate 30 years normal).

Year	Months	Temperature		Precipitation (mm)	Pan evaporation (mm day^{-1})
		Maximum	Minimum		
2002–2003	November	27.7 (27.9)	12.1 (11.4)	0.0 (5.7)	1.4 (2.8)
	December	23.4 (22.7)	7.6 (7.1)	4.0 (7.5)	1.6 (2.1)
	January	16.3 (19.9)	5.7 (6.5)	18.8 (19.8)	1.6 (2.0)
	February	21.7 (23.0)	9.7 (8.8)	12.0 (16.7)	2.7 (3.1)
	March	28.1 (28.7)	13.8 (13.3)	3.0 (16.6)	4.8 (5.1)
	April	37.3 (35.9)	20.2 (18.9)	0.0 (9.9)	7.8 (8.0)
2003–2004	November	27.4 (27.9)	10.6 (11.4)	0.0 (5.7)	2.6 (2.8)
	December	19.9 (22.7)	9.3 (7.1)	0.0 (7.5)	1.8 (2.1)
	January	17.4 (19.9)	7.3 (6.5)	5.6 (19.8)	1.7 (2.0)
	February	24.0 (23.0)	9.3 (8.8)	14.2 (16.7)	3.2 (3.1)
	March	32.5 (28.7)	15.6 (13.3)	0.0 (16.6)	5.9 (5.1)
	April	37.5 (35.9)	21.4 (18.9)	0.0 (9.9)	9.1 (8.0)