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Response of wheat (*Triticum aestivum* L.) to organic amendment and application of urea

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Abstract

Response of wheat to application of plant residues and urea was studied under field conditions. Plant residues with wide C/N ratio had negative effect on plant growth, while those with higher N content and narrow C/N ratio had a positive effect. Urea application did not affect the biomass yield of wheat probably because of the higher native content of mineral N in soil. Physiological attributes to biomass accumulation i.e., greenness and size of flag leaves and the photochemistry of photosystem II were not affected by different soil treatments. It was inferred that photosystem II was more relatively resilient to environmental perturbations including application of high C/N ratio plant residues that would have affected the availability of N to plants. The results also suggested that ample level of native soil N will mitigate the negative effect of plant residues that have the tendency of net immobilization of N.

Key words: C/N ratio, *Leptochloa fusca*, N immobilization, *Sesbania aculeata*, wheat, soil organic matter

Introduction

Organic matter content of the soil is an important determinant of soil productivity. Hence, low organic matter content of most of the agricultural soils of Pakistan (Azam, 1988) may be one of the reasons for a low productivity of these soils. The reasons for low organic matter content could be i) a rapid loss under the prevailing environmental conditions that are very conducive for oxidative processes, and ii) no or negligible organic matter returns to the soil. In order to sustain agricultural productivity, a desirable level of soil organic matter needs to be maintained through repeated applications and proper management. The improvement is, however, dependent upon the availability and chemical characteristics of the plant residues applied. Production of biomass on lands which are not suitable for normal agricultural crops could augment the supplies of organic matter, while residues having desirable chemical composition can be selected for use. For example, salt affected soils can be used to raise biomass of salt tolerant plants including both leguminous and non-leguminous. Kallar grass (*Leptochloa fusca* L. Kunth) and jantar or dhaincha (*Sesbania aculeata*) are tolerant to salinity; the former being much more tolerant than the latter. Both have good yield potential and can be used as a source of organic amendment. Sesbania can also be raised on normal agricultural soils and used as a source of organic matter and N. However, the two differ in chemical composition particularly the content of N and lignins. Kallar grass is relatively high in lignin content but low in N content, the reverse is true for Sesbania.

Residues high in lignin content contribute directly and substantially to the stable humus fractions (Haider and Martin, 1975; Kassim *et al*., 1981; Stott *et al*., 1983; Azam *et al*., 1985) that have proven beneficial effects on growth and nutrient acquisition of plants. However, wider C/N ratio of the residues may lead to temporary or long-term locking up of essential nutrients like N (Ahmad *et al*., 1969; Azam *et al*., 1985). Likewise, soil incorporation of residues rich in N result in the release and accumulation of N (Ladd *et al*., 1983; Fox *et al*., 1990; Palm and Sanchez, 1991; Azam *et al*., 1993; Soon and Arshad, 2002). Thus application of sesbania and kallar grass may affect soil fertility and productivity in different ways. Objective of the present study was to assess the role of the two types of plant residues in supporting wheat growth under filed conditions.

Materials and methods

Plant material

Chopped plant tops of sesbania and kallar grass were used for field application after drying. A portion of the chopped material was finely ground and analyzed for total carbon (C), total nitrogen (N), 2N H_2SO_4 hydrolysable C and hydrolysable N (Table 1). The two types of residues generally differed in most of the characteristics with kallar grass having a higher non-hydrolyzable (lignins and related substances) component and lower N as

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compared to sesbania. Thus the two materials will differ in contributing towards available N and humus fraction. For determination of C and N in the samples methods described by Azam and Sajjad (2005) and Bremner (1996), respectively, were used.

Table 1. Chemical characteristics of plant residues

Parameter	Plant material	
	Kallar grass	Sesbania
Total C, mg g^{-1}	344.69	354.66
% C	34.45	35.47
Total N, mg g^{-1}	6.89	25.56
% N	0.70	2.56
C/N ratio	49.96	13.88
Hydrolysable C, mg g^{-1}	77.83	149.43
Hydrolysable C, % of total C	22.57	42.13
Hydrolysable N, mg g^{-1}	2.73	19.20
Hydrolysable N, % of total N	39.68	75.13
C/N ratio of hydrolysate	32.16	7.78

Experimental site

The experiment was conducted at the fields of Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad. Physico-chemical characteristics of the soil were: organic C, 0.6%; total N, 0.09%; NH_4^+-N, 4.2 mg kg^{-1} soil; NO_3^-+NO_2^- -N, 67.9 mg kg^{-1} soil; pH (1:2.5, soil:water suspension), 7.4; EC, 0.8 d Sm^{-1} (1:2.5, soil:water suspension); water holding capacity, 31%; sand, 30%; silt, 36%; clay, 34%. Standard methods were followed for different analyses.

Field plots measuring 4 m^2 and brought to field capacity moisture were treated in triplicate as follows:

T1: Control (no soil treatment)

T2: Urea at 50 kg ha^{-1}

T3: Urea at 100 kg ha^{-1}

T4: Chopped or powdered Sesbania tops at 4.4 tons ha^{-1}

T5: Chopped or powdered Sesbania tops 8.8 tons ha^{-1}

T6: Chopped or powdered Kallar grass tops 4.4 tons ha^{-1}

T7: Chopped or powdered Kallar grass tops 8.8 kg ha^{-1}

The chopped plant material was worked well in the top 6-8 inches soil followed by application of N (T2 and T3), P and K at 25 and 31 ppm, respectively (all treatments). Nitrogen was added in two splits, half at sowing and the other half at tillering, while P and K were applied as basal dose. Seeds of wheat (*Triticum aestivum* L., line 41 that has been developed through wide hybridization and requires low inputs; Farooq and Azam 2001) were hand-drilled in rows (row to row distance, 25 cm; plant to plant distance, 15 cm). The plots were irrigated with canal water and weeding carried out as required. At grain filling stage, flag leaves were studied for green-ness using Minolta SPAD meter and photosynthetic efficiency using Hanstech Efficiency analyzer. For the later, leaves were dark adopted for 30 minutes before subjecting to measurement of photochemical parameters that involved exposure to high intensity actinic light (3000 µmol m^{-2} s^{-1}). At maturity crop was harvested and the data on yield and different yield components recorded.

Statistical analyses

Microsoft EXCEL software was used to determine standard deviation and coefficient of correlations as required.

Results and discussion

Flag leaves are considered to be an important determinant of ultimate yield in cereals particularly wheat. In the present study, however, the size of flag leaf did not show any significant effect of soil treatment; length ranged between 22 and 25 cm and width between 1.5 to 2.5 cm (Figure 1). Chlorophyll content of the flag leaves (Figure 2) as measured greenness using Minolta SPAD meter was also unaffected by different treatments. The values in Minolta units remained between 45 and 47 and are within the range reported by others (Zaharieva *et al*., 2001). Likewise, photosynthetic efficiency (Fv/Fm) remained above 0.80 in all the treatments with negligible differences due to soil treatment. In most of the studies reported, efficiency of photosynthesis is reported to be around 0.80 (Lu *et al*., 2003).

Apparently, soil amendments did not have an effect on photochemical parameters *per se* as was also the case for greenness of the leaves that also did not differ significantly (Figure 1). In general, however, F_m and F_v were higher for plants grown in treated than control soil; the exception being urea treatment where the values remained lower than control. In kallar grass treated soil, F_m and F_v were similar to control, while photosynthetic activity was

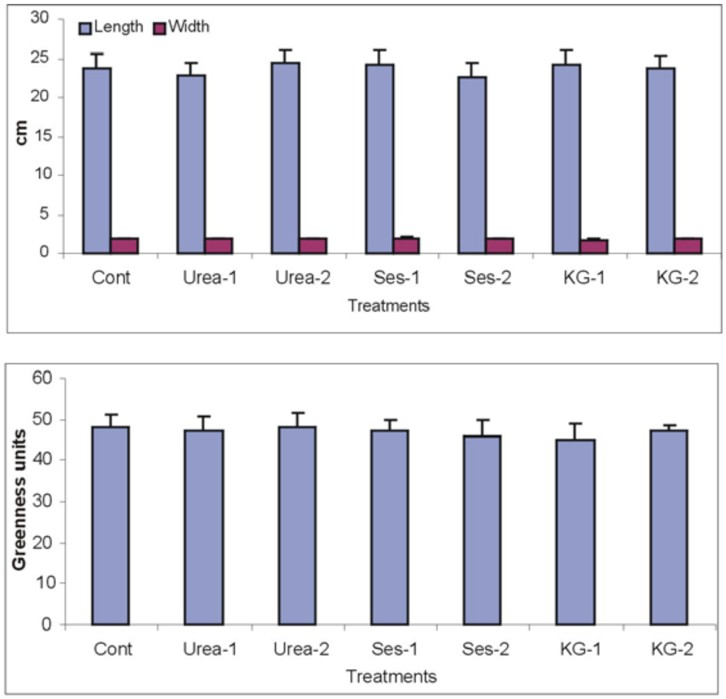

Figure 1. Characteristics of flag leaves of what plants grown under field conditions following different amendments.
Bars show ±SD.

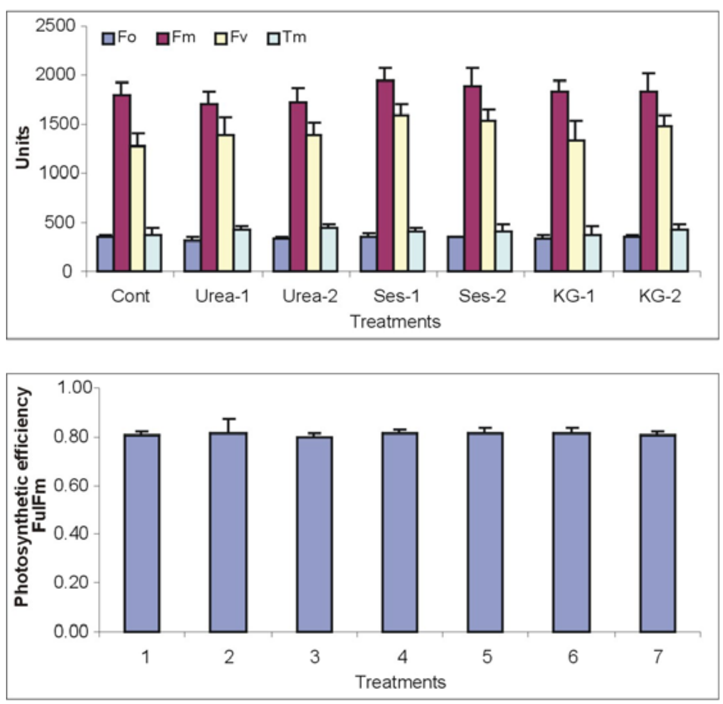

Figure 2. Photosynthesis parameters of flag leaves of what plants grownunder field conditions following different amendments.
Bars show ±SD.

not affected. Improved availability of N (urea and sesbania treatment) was expected to have a positive effect on photochemical activity, while nutrient stress particularly in kallar grass treated soil was supposed to retard the process. However, photochemistry was not affected. Stresses like salinity and temperature imposed alone or in combination are reported to have no effect on the photochemical activity of photosystem-II (Lu *et al*., 2003). Subramanyam *et al*. (2006) reported that the water stress in wheat had no significant effect on variable to maximum fluorescence ratio (F_v/F_m) indicating that water stress had no effect on primary photochemistry of photosystem-II. In some other studies, however, an inhibitory effect of stresses has been reported (Everard *et al*., 1994). It would appear therefore that the response of photosystem-II to environmental perturbations including availability of nutrients and organic amendment may not be consistent as believed (Baker, 1991).

In spite of the fact that soil treatment did not significantly affect the system components that are responsible for biomass accumulation (flag leaves, photochemistry etc.), differences were observed in grain and straw yields (Figure 3). In contrast to general observations of increase in crop yields following fertilizer application, in this study straw and grain yield decreased or showed no effect depending upon the amount of N added. However, harvest index was improved in urea treated soil. Such a response of wheat to N application could be attributed to relatively high native mineral N content of soil that was 60-70 ppm. This high N level in the soil was due to previous cropping history of the fields that were under green manuring crops before wheat planting. Similar observations were recorded for some greenhouse experiments using soil from the same field. It would appear therefore that good crop yields could be obtained following build-up of sufficient levels of available N in which case response to applied N may not be obvious.

Nitrogen may not be the only factor responsible for positive or negative plant performance under different conditions. Rather changes in biological activity through organic amendment or as a result of rhizodeposition may have a more significant role in determining plant performance. This contention is supported by a positive effect of sesbania on biomass yield. Although the increase was not significant statistically, both straw and grain yield of wheat was higher at both the levels of sesbania. With a high N content and significant proportion of carbon present in easily oxidizable forms (hydrolysable C, Table 1), sesbania was expected not only to enhance the microbial activity but the supply of N as well. Release and accumulation of N has been reported during decomposition of plant residues rich in total N (Ladd *et al*., 1983; Fox *et al*., 1990; Palm and Sanchez, 1991; Azam *et al*., 1993; Soon and Arshad, 2002). Similarly, incorporation of non-leguminous plant residues obtained at green stage and having a C/N ratio of *ca* 25 may also release substantial proportion of their N during decomposition (Azam *et al*., 1993; Ibewiro *et al*., 2000; Seneviratne, 2000).

Addition of kallar grass had a significantly negative effect on the total biomass as well as harvest index suggesting a net immobilization of N and thus its unavailability to wheat or due to the release of some inhibitory factors during the decomposition of kallar grass. In spite of the unexpected response of wheat biomass to soil treatments, the harvest index (HI) that determines the relative distribution of biomass into grain and straw fractions was not affected negatively by kallar grass. As a whole, the negative effect of kallar grass was not that high as could be expected in view of its wider C/N ratio that is reported conducive for a net immobilization of N (Azam *et al*., 1985; Gok and Otttow, 1988). Clearly negative effects of plant residues with wider C/N ratio on plant growth have often been reported (Azam *et al*., 1990; Sajjad *et al*., 2003), and attributed mainly to diversion of nutrient resources to microbial biomass that competes with the plants. In the present study, however, ample supply of mineral N (Table 1) substantially mitigated the negative effect of kallar grass on wheat.

Summing up the results of the organic matter amendment studies, it is inferred that i) the response of crop to applied fertilizer or other treatments will depend upon the availability of N in the soil at the time of cropping, ii) the chemical composition of the organic amendment that may cause a net immobilization or a net immobilization of N, and iii) soil nutrients particularly N could be mobilized during the decomposition of low C/N ratio organic matter leading to improved plant growth.

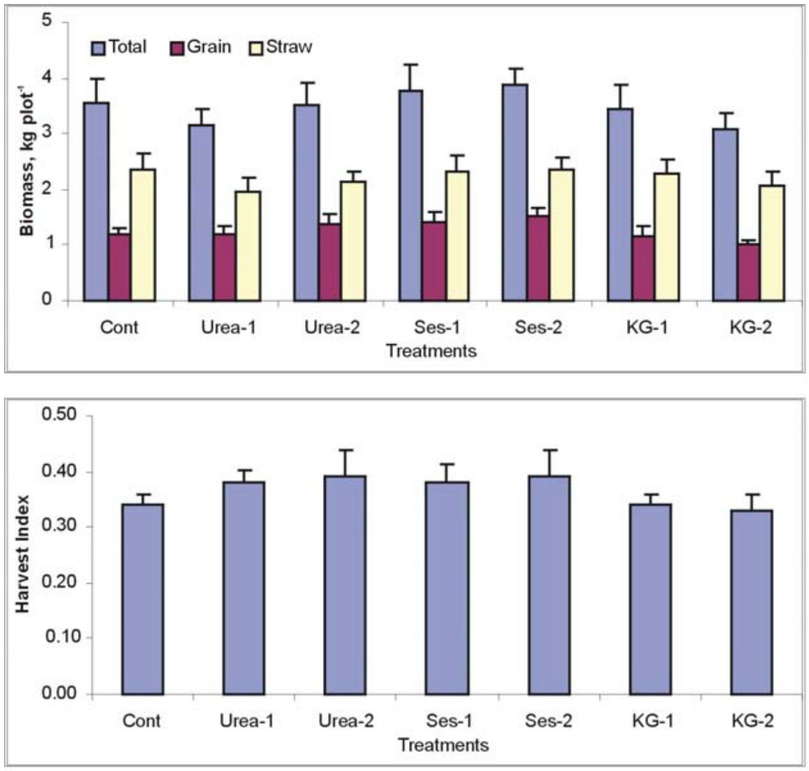

Figure 3. Dry matter partitioning and harvest index of what plants grown under field conditions following different amendments.
Bars show ±SD.

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