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Effect of crop residues on soil fertility and yield of wheat (Triticum aestivum) - guar (Cymopsis tetragonoloba) crops in dry tropics

Nazar Omer Hassan Salih 1, A. R. Mubarak1*, A.A. Hassabo2

Abstract-The effect of crop residue on soil fertility and yield of wheat - guar crops wear conducted in this experment for six seasons in a guar-wheat crop rotation. Across all seasons, average plant yield was higher in crop residue plots treatments than that found in residue removal plots (227.78%). Also, fertility of soil was consistently higher with crop residue plots compared to crop residue removal. These results indicate that continuous application of crop residues along was improved soil fertility and efficiency in yield of wheat and guar.

Key words: field crops/ N loss/ dry tropics / straw/crop residue/ Cymopsis tetragonoloba/ Triticum aestivum/ soil fertility/ wheat / guar

1. Introduction

Intensive cultivation, inadequate replacement of nutrients, deforestation and clearance of vegetation lead to a decline in soil fertility. Most soils of the arid zone (including Sudan) are characterized by both low organic matter and N content (Blokhuis, 1993) and slow accumulation of organic matter (Ali and Adam, 2003). It is beyond doubt that more mineral fertilizers are needed to sustain food production. In the developing countries (Africa, Asia and Latin America) and by the year 2020, 70% of plant nutrients need to come from fertilizers (Ayoub, 1999). For example, fertilizer consumption increased from 14% in 1965-66 to 53% by 1995 and to sustain food security, the land-scarce Asian countries would need to increase fertilizer application to over 250 kg of NPK ha–1 by the year 2020 from the present rate of less than 100 kg ha–1 (Hossain and Singh, 2000). However, large amounts of these mineral fertilizers are subjected to losses particularly through leaching or diffusing into the air (Kinzig and Socolow 1994; .Lehmann et al., 1999). This might add to environmental pollution and threaten surface and ground water quality as more than 50% of applied fertilizers may not be taken up by the crop (Bockman et al., 1990; Janzen, et al. 2003). Management practices that concentrate on application of fertilizers in combination with recycling and use of nutrients from crop residues has received greater consideration for ensuring sustainable land use and agricultural production in the humid tropics (Mubarak, et al. 2001a; 2001b; 2003a; 2003b), dry tropics (Powel and Unger, 1997; Mandal, et al. 2004; Paul and Mannan, 2006; Mubarak, et al. 2009) or temperate (Sukhdev, et al. 2011; Avalos, et al. 2012). Accordingly, N use efficiency in such systems would be influenced by the specific crop/soil and environmental conditions. The use of 15N as a tracer in soil–plant research helps to determine N balances for the applied 15N-labelled fertilizer and to infer any losses that might occur under different ecological or management conditions (Wolf and Legg, 1984). Worries about global pollution have cast further attention on the N cycle in farmlands because farms are a main source of N2O, and management practices that incorporate N in a slow release component would be encouraged. Our objective was to estimatethe Effect of crop residues on soil fertility and yield of wheat (Triticum aestivum) - guar (Cymopsis tetragonoloba L.) rotation system in dry tropics

1Faculty of Agricultural Technology and Fish Sciences, El Neelain University, Khartoum, Sudan
1Department of Soil and Environment Sciences, Faculty of Agriculture, University of Khartoum, Shambat, Sudan
2Faculty of Agricultural Technology and Fish Sciences, El Neelain University, Khartoum, Sudan
**Present address: Desertification and Desert Cultivation Studies Institute, University of Khartoum, Shambat 13314, Khartoum North, Sudan (mubarakaba@yahoo.com)*

2. Materials and methods:

3. Site, soil and climate:

This study was conducted in the research farm of the Faculty of Agriculture, University of Khartoum, Shambat, Khartoum North, Sudan (latitude 15o 36'N and longitude 32o 32'E) and extended for six growing seasons (wheat – guar - wheat-guar - wheat-guar). The soil is classified as smectitic, fine montmorillonitic, clay, isohyperthermic, typic chromustert (Gaafar 1983). The annual rainfall is 160 mm year-1, average temperature in summer is 40oC while in winter drops down to 20oC, the solar radiation varies from 400 to 500 Cal/cm/day (El Nadi, 1980).

4. Experimental design and treatments:

Recommended rates of inorganic fertilizer (N and P) with crop residue (F Cr+).
2. Recommended rates of inorganic fertilizer (N and P) without crop residue (F Cr-).
3. Crop residues (Cr+).
4. Control, no crop residue, no inorganic fertilizer (C).

Recommended inorganic fertilizer for wheat included application of 88 Kg N ha^{-1} (as urea 46% N applied in two equal doses, at sowing and at tillering) and 95 Kg P_2O_5 ha^{-1} (as Triple superphosphate). However, for guar, an application of a starter dose (96 Kg N ha^{-1}) was added at sowing. Treatments were assigned to main plots (4 m × 4 m), replicated four times (24 experimental plots) and arranged in a Randomized Complete Block Design (RCBD).

5. Sowing of guar and wheat:

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Seeds of guar (genotype HFG 75) were supplied by the Sudanese Guar Company whereas (var condor) seeds of wheat were obtained from the ministry of Agriculture and Forest, Sudan. For both crops, the experimental site was prepared by disc ploughing (0-30 cm), disc harrowing and leveling. For every wheat in the rotation, 96 kg seeds ha-1 was sown in lines (70 cm between lines) whereas guar (treated with inoculant ENRI 16) was sown at a seed rate of 3 kg ha^{-1} (70 cm between lines,2-3 seeds in a holes of 30 cm apart and thinned to one stand two weeks later). Irrigation water was added through irrigation canals (1000 m^3 ha^{-1}, i.e. 10 cm head of water) at an interval of two weeks. Table 2 shows time of sowing, harvesting and crop residue application of crops in the rotation.

6. Application of crop residue:

At harvest, 8 plants from the microplots were harvested and separated into pods/or seeds and straw (leaves and stem). For the 1st guar, samples were separated into stems, leaves and seeds whereas sampling of subsequent guar crops were divided into seeds and straw (leaves and stem). Fresh weight of the 8 plants was determined and the moisture content was calculated after oven drying at 75^0C until constant weight and values were used for calculation of total plot dry matter, crushed, sieved (0.5 mm) and kept for analysis. Microplots with ^{15}N were harvested separately, weighted in the field and kept a side. The remainder of main plots was harvested and fresh weight of straw was determined in the field. Before sowing the crop, residues were chopped (10-15 cm) and manually incorporated in the top 0-30 cm of FCr^+ treatment using hoes. Consequently, for treatments without crop residues (i.e control and fertilizer without crop residues (FCr^-), residues were removed and plots were left clean. However, crop residues from the ^{15}N micro plots, were consistently replaced by equivalent amount of non-labelled crop residues. Soil samples were taken with an auger (diameter 5 cm) to a depth of 80 cm in three layers: 0–20 cm, 20–40 cm and 40–60 cm. The soil from each layer was spread separately on a plastic sheet, air dried and crushed after removal of roots, sieved (2 mm). Total N and the ^{15}N at% excess N was determined by the Egyptian Atomic Energy Agency using Emission Spectrometry (Fischer NOI-6 PC, FAN, Germany).

Results:

3.1 Nitrogen derived from fertilizer NDFF:

After harvest of the first season (guar), NDFF in the leaves (2.71-2.87) was higher than that of the stem (1.35-1.52) by about 94% whereas, the seeds have similar values to the leaves (Table 1). After incorporation of the 1st guar crop residues, NDFF values of the wheat straw recorded in plots where residues were incorporated were similar to that in plots with residue removal. However, after incorporation of the 2nd crop (wheat) residue, a slight increase in NDFF was determined in straw and pods of guar in the FCr+ plots compared to FCr^- which continued to the end of the cropping system. Increase in NDFF in wheat crop preceded with guar residue was only 1-2% compared to that found in guar preceded with wheat residue (12-20%). After harvest of the 1st crop, 53, 32 and 14% of total NDDF was found in the 0-20, 20-40 and 40-60 cm depths, respectively (Table 2).The study observed that only after application of the wheat residue, NDFF from crop residue treated plots had higher values. For example, NDFF values in the top 0-20 cm determined after harvest of the 3rd and 5th crops (guar) of crop residue plots were 33.9 and 20.6% compared to 29.8 and 18.4% of plots with residue removal, respectively. Also, total NDFF values after harvest of subsequent guar crops of FCr+ were 59.8 and 38.8% compared to 53.9 and 35.5% in FCr- plots, respectively.

3.2 Recovery in the soil:

After harvest of the first crop (guar), of the applied ^{15}N (12.72 kg ha^{-1}), 33.95% was recovered in the aboveground plant parts (Table 3). Of which, 41.9% was recovered in the straw (leaves 33.52% and stem 8.38%). After harvest of the 2nd crop (i.e. after incorporation of the 1st guar residue), N recovery in the straw of plots with crop residues was slightly higher than that in residue removal plots. Accordingly, N15recovereies in straw, seeds and total recovery in crop residue and residue removal plots were 22.46, 15.55, 38.01 and 21.16, 15.55, 36.71%, respectively. However, after harvest of the 3rd crop (guar), there was an increase (by 14.9%) of total plant recovery in plots treated with crop residue (29.73%) as compared with complete removal of crop residues (25.88%). Additionally, N recovery in the straw and pods of crop residue plots was greater than that recovered in residue removal by 17 and 11.61%, respectively. Similar to the 3rd crop, after harvest of the 4th crop (wheat), total N recoveries in FCr+ and FCr- plots were 29.36% and 26.67%, respectively (i.e. 10% increase). The increase in total N recovery due to crop residue application was more pronounced after harvest of the 5th crop (guar) where it was found to be 26%. Of this increase, 32% was contributed by the straw compared to 68% by the pods. At the end of the experiment, N recoveries in both plots were close, though a slight increase with crop residue treatment was found. Across all seasons, average total N recovery in crop residue plots (25.19%) was 11% higher than that found in residue removal plots (227.78%).

3.3 Total N recovery:

One season after 15N application, most of the total N recovered in the soil/crop system was retained in the soil profile (Figure 1). It was observed that total recovery decreased from 82.9-89.9% (after the 1st season) to 36.9-38.2% (at the end of the cropping system). It was also found that incorporation of guar and crop residues had increased N recovery in the crop/soil system from 36.9-73.3% to 38.2-77.2% in residue removal plots. Increase in total recovery after harvest of guar crops (preceded by wheat residue incorporation) was 12.6 to 16.1% compared to that found after harvest of the wheat crop (preceded by guar residue) which was only 3.4 to 7.7%. From these results it could be calculated that one season after fertilizer application showed N unaccounted for to range between 10 and 17%. However, across all seasons, N unaccounted for in crop residue plots (22.8-61.8%) were lower than those found in residue removal plots (26.7-63.1%).

Discussion:

Recovery of fertilizer-N by agricultural crops is normally within the range of 30-78% (Broadbent and Carlton, 1978). However, the fertilizer N recovery (33.95%) observed after harvest of the 1st crop (guar) reported in this study is within the 8.0 - 36.2% range of other reported values in the tropics (Akinnifesi, et al. 1997; Kamukondiwa and Bergstörm, 1994; Lehmann, et al.

1999). In the present study, low plant recovery of ^{15}N could be explained in terms of readily immobilization of NH_4 (Recous, et al. 1988), the form in which ^{15}N was applied. The recovery of fertilizer N in the tropics is low compared to average recovery values ranging between 47 and 63% in west Europe (Pilbeam, 1996). Additionally, low recoveries may perhaps be caused by an inherent physiological inefficiency of the crops grown in these places. Caution is therefore necessary when making comparisons of fertilizer N recovery between locations, especially between those that differ widely in their climatic characteristics, particularly the precipitation: evaporation ratio. Moreover, Baligar and Bennett (1986) reported that efficiency of fertilizer N in tropical soils is low compared to temperate regions and estimated this efficiency to be less than 50% of the applied N. Higher plant N recovery found in the 2nd crop (36.71 - 38.01%) as compared to the 1st crop (31.0-33.95%) may be explained by late mineralization of N immobilized in the roots. Fertilizer N recovered in the top 50 cm soil depth after harvest of the 1st crop (guar) indicates that, most of the fertilizer N was recovered in the soil (55.96%) than in the crop (33.95%). Similar results were observed by Kamukondiwa and Bergström (1994) and Pilbeam et al. (1997). Because of the amount of microbial biomass C per unit organic C in the soil is greater in the topsoil (Insam et al. 1989), higher recoveries in the topsoil are expected. The present study showed that N losses after harvest of the 1st crop were close to those reported in the Vertisols of the semi-arid Moroco of about 10 % (Corbeels, et al. 1999).

Our study indicated that incorporation of crop residues (FCr^+ plots) had increased total N efficiency over the inorganic fertilizer N without crop residue FCr- which was found in all seasons. This could possibly be due to the fact that application of crop residues provide C source for microorganisms, thereby, inducing further

Conclusions:

In the Vertisols, fertilizer N recovered in the top 50 cm soil depth after harvest of the 1st crop (guar) indicates that, most of the fertilizer N was recovered in the soil (55.96%) than in the crop (33.95%). One season after fertilizer application, N unaccounted for was found to range between 10 and 17% whereas values in the

immobilization of the ^{15}N remained after harvest of the 1st crop followed by slow released later in the following seasons. Therefore, the overall effect of straw incorporation was to decrease the loss of N, both labelled and unlabelled, from the crop-soil system. This would be accompanied by improvement of N uptake by subsequent crops. Previous results concentrating on N retention in the crop/soil system for better use efficiency showed similar findings which are commonly known as best management practices. For example, the use of cover crops during the inter-growing season has led to lower residual soil NO3 and reduced leaching in corn and other field crops (Strock, et al. 2004). Shirazi et al. (2002) reported that nitrogen recovery studies, using ^{15}N isotopes tracer technique showed that the application of Acacia residues along with inorganic N fertilizers have increased the availability of soil nitrogen to sorghum plants. In humid tropics, Mubarak et al. (2003c) reported higher proportion of fertilizer N retained in the soil (0–50 cm) of the subsequent maize-groundnut crops of 30% in crop residue treated plots and 22% in plots where crop residues were removed. They suggested that, in tropical regions with high rainfall, conserving and decreasing soil N losses from mineral fertilizers could be achieved (in the long term) by the combined application of crop residues with mineral fertilizer. In the temperate regions, Powlson et al. (1985) also reported an increase, but not significant, of labelled N by winter wheat in the presence of wheat straw. Contrary to this, Kumar and Goh (2002) reported no effect of crop residue management practices on the recovery of residual fertilizer by the subsequent crops and attributed this to the relatively large amount of N present in the soil shown by the small residual fertilizer N in proportion to that present in the soil and concluded that effects of different residue management practices become less apparent.

subsequent crops determined in crop residue plots were lower than those found in residue removal plots. Our study indicated that NUE could be improved through combined application of inorganic N with crop residues.

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