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Short communication

# Soil microbiological and chemical changes in rice-wheat cropping system at Palampur (Himachal Pradesh) after twelve years of *Lantana camara* L. residue incorporation

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**Abstract**

Long term effects of lantana (*Lantana camera* L.) residue incorporation on major soil microbes and on certain soil chemical properties in the rice-wheat cropping system were studied at Palampur (Himachal Pradesh) in an experiment that started in 1988 with four levels of lantana incorporation (0, 10, 20, 30 $Mg{\cdot}ha^{-1}$ on fresh weight basis) and three tillage practices (no puddling, puddling, and soil campaction). The tillage practices, however, were replaced with three levels of N and K (33, 66, and 100% of the recommended 90 and 40 $kg{\cdot}ha^{-1}$ N and K respectively) to rice from 1997 onwards. N, P and K application to wheat was at 66% of the recommended dose (120, 90, and 30 $kg{\cdot}ha^{-1}$). After 12 crop cycles (2001–'02), lantana residue application at 10, 20, and 30 $Mg{\cdot}ha^{-1}$ increased soil organic carbon (7, 13, and 19% over 1.29 g C $kg^{-1}$ under no residue treatment) and pH (5.23 to 5.29 as against 5.12 in the control). Lantana incorporation at 10 to 30 $kg{\cdot}ha^{-1}$ also recorded a significant increase in the bacterial (249 to 369 $10^4$ CFU), fungal (148 to 220 $10^4$ CFU), actinomycetes (79 to 144 $10^4$ CFU), and phosphorus solublizing microorganism (53 to 100 $10^4$ CFU) counts (0 to 0.15 m soil depth) compared to control. The most important variable contributing to rice and wheat yield was soil organic carbon ($R^2$= 86 to 95%), followed by bacteria and fungi.

**Keywords:** Soil organic carbon, Soil microorganisms, Phosphorus solublizing microbes.

Integrated nutrient management involving biomass residue incorporation improves soil quality (Vineela et al., 2008). However, limited availability of organic manures and the economic value of crop straw as fodder necessitate search for alternate soil organic amendments. Lantana (*Lantana camara* L.), an obnoxious weed growing extensively in many parts of India, has the potential to be incorporated into the soil to improve soil organic matter status and to economize the use of chemical fertilizers. Therefore, a long-term field experiment on rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system was initiated to evaluate its potential as an alternate organic source of nutrients and to evaluate its effect on soil microbial populations, organic carbon, and pH.

The field experiment was intiated during *kharif* (mid-June to mid-September) 1988 in the silty clay loam soil (Typic Hapludalf) of Palampur, India (32°6'N, 76°3'E, 1300 m altitude) in the mid-hill wet temperate zone of northwest Himalayas. The experimental variables included four levels of lantana incorporation (0, 10, 20, and 30 $Mg{\cdot}ha^{-1}$ on fresh weight basis) and three tillage practices (no puddling, puddling, and soil campaction)

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for rice. It was laid out in a completely randomized block design with 12 treatments, replicated thrice (plot size 10 $m^2$). The residual effect of lantana incorporation and tillage practices were evaluated on the succeeding wheat crop every year till *rabi* (November-April) of 1992–'93. During *kharif* 1993, however, the experiment was modified and the tillage practices were replaced with three levels of N (50, 75, and 100% of the recommended 90 $kg{\cdot}N{\cdot}ha^{-1}$) for rice. Nitrogen levels for wheat were 100, 75, and 50% of the recommended 120 $kg{\cdot}N{\cdot}ha^{-1}$. These treatments were maintained till *rabi* 1996–'97. From *kharif* 1997, the fertilizer levels were further modified to 33, 66, and 100% of the recommended N and K (40 $kg{\cdot}ha^{-1}$) to rice. Phosphorus application was skipped. N, P, and K application to wheat was also modified as 66% of the recommended levels (120, 90, and 30 kg N, P, and K $ha^{-1}$, respectively). Regarding method of application, for rice entire K was applied at transplanting, 50% N 10 days after transplanting, and the remaining 50% N in two splits (20 and 40 days after transplanting). For wheat, all P and K and 50% N were applied at sowing, and the remaining 50% N top dressed in two equal splits at crown root initiation and flowering stages.

Lantana biomass from wastelands was collected and incorporated 10 to 15 days before transplanting rice. Lantana twigs were chopped into small pieces (4 to 5 cm), spread uniformly over the entire plot, and incorporated in the surface soil (0 to 15 cm) using spades. Each plot was then irrigated and left as such for 10 to 15 days, dug again, and mixed up manually.

Soil samples were collected from the 0 to 15 cm layer (treatment-wise) after 12 cycles of rice-wheat cropping (i.e., after the wheat harvest in 2001–'02). The soil samples were mixed thoroughly, air dried in shade, crushed to pass through 2 mm sieve, and stored in sealed plastic jars for analysis. Processed soil samples were analyzed for pH, organic carbon, and microbial population. Viable microbial populations were determined by plate count technique (Wollum, 1982) through serial dilution using respective media for each microbial group. Rice and wheat yields were recorded and correlated with organic carbon, pH, and the different groups of microbes. The data were subjected to ANOVA for completely randomized block design and the means were compared using least significant differences at 5% probability, using the IRRISTAT data analysis package.

Lantana incorporation for 12 years at 10, 20, and 30 $Mg{\cdot}ha^{-1}$ increased the soil organic carbon content significantly over no lantana treatment by 7.0, 13.2, and 19.4%, respectively (Table 1). Biomass C addition through lantana residues, better crop root growth, and some aboveground plant residue addition after harvest of crops may explain this increase (Verma and Mathur, 2009). Continuous application of lantana since *kharif* 1988 also improved soil pH significantly over no

*Table 1.* Effect of *Lantana camara* residue and fertilizer application on soil organic carbon, pH, and microbial population in the surface (0 to 15 cm) soil in a rice-wheat cropping system at Palampur (Himachal Pradesh).

| Lantana addition ($Mg{\cdot}ha^{-1}$) | Organic carbon ($g{\cdot}kg^{-1}$) | pH | Bacteria ($10^4$ CFU) | Fungi ($10^4$ CFU) | Actinomycetes ($10^4$ CFU) | PSM ($10^4$ CFU) |
|---|---|---|---|---|---|---|
| 0 | $1.29^a$ | $5.12^a$ | $106^a$ | $90^a$ | $59^a$ | $45^a$ |
| 10 | $1.38^b$ | $5.23^b$ | $249^b$ | $148^b$ | $79^a$ | $53^a$ |
| 20 | $1.46^b$ | $5.29^b$ | $260^b$ | $188^b$ | $133^b$ | $92^b$ |
| 30 | $1.54^b$ | $5.29^b$ | $369^b$ | $220^b$ | $144^b$ | $100^b$ |
| Fertilizers (% of recommended dose) | | | | | | |
| 33 | $1.37^a$ | 5.20 | $155^a$ | $120^a$ | $88^a$ | $56^a$ |
| 66 | $1.45^b$ | 5.24 | $228^b$ | $184^b$ | $98^a$ | $71^a$ |
| 100 | $1.47^b$ | 5.26 | $280^b$ | $180^b$ | $126^b$ | $90^b$ |

Means with the same superscripts within a column do not differ significantly at 5%. Recommended dose fertilizers for rice: 90 and 40 $kg{\cdot}ha^{-1}$ of N and K (P skipped). For wheat N, P, and K application was 66% of the recommended 120, 90, and 30 kg N, P, and K $ha^{-1}$.

lantana incorporation. The absolute values of pH under 10, 20, and 30 Mg·ha$^{-1}$ were 5.23, 5.29, and 5.29 respectively as compared to 5.12 under the treatment where lantana was not added. Organic matter addition for 12 years might have released bases into the soil solution to bring about the observed increase in soil pH. This is consistent with the observations of Ling et al. (2002) who noted increased pH following additions of lantana biomass. Like lantana incorporation, application of chemical fertilizers also increased the soil organic carbon content: 5.8 and 7.3% more in the 66 and 100% N and K treatments respectively, over the 33% treatment. Presumably, there were greater additions of root biomass as well as other organic materials into the soil in the high fertilizer treatments compared to the lower ones. Such organic matter fluxes may improve the mean weight diameter of soil aggregates, providing physical protection to soil organic carbon from decomposition (Banger et al., 2010).

Twelve years of lantana incorporation significantly increased the microbial populations of bacteria, fungi, actinomycetes, and P-solubilizers (PSB) in the 0 to 15 cm soil layer. Average increase over control was highest for bacteria (2.35 to 3.48 times) followed by fungi (1.64 to 2.44 times), actinomycetes (1.34 to 2.44 times), and minimum for P-solubilizers (1.18 to 2.22 times). Higher levels of fertilizers (66 and 100% of recommended doses) also stimulated soil microbial growth. This might be due to the continuous mineralization of nutrients from the organic to inorganic pools and in maintaining supply of food as well as energy supplies for microbial growth (Patil and Varade, 1998). Observations by Vineela et al. (2008) also indicate that bacterial populations are generally more under integrated use of organic and inorganic fertilizers.

The populations of bacteria, fungi, actinomycetes, and PSB correlated positively and significantly with soil pH, organic carbon, as well as yield of wheat and rice (Table 2). Organic carbon, in general, had the highest correlation coefficient with the populations of all microbes. Similarly, wheat and rice yield also correlated positively and significantly with microbial counts giving the highest correlation coefficient for fungi.

The continuous annual additions of lantana residues for 12 years significantly increased soil organic carbon and populations of all soil microbial groups with maximum increase for bacteria followed by fungi, actinomycetes, and the least for phosphorus solublizing microorganisms. The most important variable contributing to rice and wheat yield was soil organic carbon, which determined the bacterial and fungi populations. This study showed the potential of weed biomass in nutrient substitution for sustaining rice-wheat productivity. Such organic matter additions would improve soil resilience of the rice-wheat production system in the Typic Hapludalf of Palampur situated in the mid-hill wet temperate zone of northwest Himalayas and would contribute to sustainable crop production.

*Table 2.* Coefficient of correlation (r) between microbial population in the surface (0 to 15 cm) and pH, organic carbon (OC), and crop yields soil in a rice-wheat cropping system at Palampur (Himachal Pradesh).

| | Bacteria | Fungi | PSB | Actinomycetes |
|---|---|---|---|---|
| Wheat | | | | |
| pH | 0.818** | 0.874** | 0.783** | 0.866** |
| OC | 0.925** | 0.883** | 0.834** | 0.898** |
| Yield | 0.795** | 0.835** | 0.810** | 0.798** |
| Rice | | | | |
| pH | 0.818** | 0.874** | 0.783** | 0.866** |
| OC | 0.925** | 0.883** | 0.834** | 0.896** |
| Yield | 0.877** | 0.907** | 0.826** | 0.826** |

**Significant at 1%.

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