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PRIMING MECHANISM: SOIL AMENDED WITH CROP RESIDUE

S. MUHAMMAD[1], R.G. JOERGENSEN[2], T. MUELLER[2] AND T.S. MUHAMMAD[3]

[1]*Department of Soil and Environmental Sciences, University College of Agriculture, University of Sargodha, Sargodha, Pakistan,*
E-mail: shermuhammad10@hotmail.com (Tel. 0304-9507108)
[2]*Department of Soil Biology and Plant Nutrition, Witzenhausen, University of Kassel, Germany*
[3]*Department of Chemistry, Islamabad Model College for Girls F-6/2, Islamabad, Pakistan*

Abstract

Priming effect is an extra decomposition of organic C after addition of easily-decomposable organic substance to the soil. Moreover, priming effects are strong short term changes in the turnover of soil organic matter caused by comparatively moderate treatments of the soil. The priming effect arises either immediately or very shortly after the addition of a specific substance to the soil. Priming affects in soils rich in C and N are larger than those in poor soils. The size of priming effects increases with the amount of the added organic substances or mineral fertilizers. An opinion expressed in literature says that not only microorganisms alone contribute to priming effects. Interactions between soil microorganisms, soil fauna and plants are regarded as one of the keys for understanding priming effects. Substances released by soil fauna can cause priming effects by stimulating microbial activity. However, more prevalent in the literature are descriptions of the faunal grazing on soil microflora (predation). The effects induced by predation as fallow: increased CO_2 release, increase N and P mineralization and release of nutrients immobilized in microorganisms, increased N up take of plant, and intensified plant growth ultimately. Similar trend was observed in our study regarding the nutrients mobilization which can be termed as priming effects. In this study extra mineralization of 400 µg g^{-1} soil CO_2–C production resulted in priming effect of the added alfalfa residue.

Introduction

Incorporation of plant residues in agricultural systems is an important factor in the control of soil fertility and maintenance of soil organic matter. If such measures are not taken into account at the right time, then ultimately soil is depleted with deterioration of fertility and productivity side by side. Plant residues are known to affect soil physical properties (Hulugalle *et al*., 1986), availability of nutrients (Wade & Sanchez, 1983; Asghar *et al*., 2006) and soil biological activity (Tian *et al*., 1993). However, effects of plant residues on soil and crop differ and depend on their decomposition and nutrient release-rates. Ground or finely chopped residues material, for example, is likely more susceptible to microbial attack than intact plant parts due to a better soil-residue contact (Angers & Recous, 1997) and lack of intact lignified barrier tissues (Summerell & Burgess, 1989). In contrast to this, however, fine particles are also more likely to be protected against decomposition through physical protection by clay and other particles (Stickler & Frederick, 1959). The rate of CO_2 efflux, under conditions where moisture and temperature are not limiting, can provide an indication of organic matter quality and whether the soil environment is conducive to the decomposition process (Sparling, 1997). Plant residues with high C:N ratio and high lignin and polyphenol contents decompose and release nutrients slowly (Fox *et al*., 1990; Tian *et al*., 1992; Achakzai & Bangulzai, 2006). Such residues have a low direct nutrient effect and a high indirect mulching effect on crop. In turn, residues with low C:N ratio, and lignin and polyphenol contents decompose rapidly, and have a high direct nutrient effect and a low indirect mulching effect. Therefore, the decompositions of plant residue is related to their C:N ratio and lignin and phenol contents. To better predict the effect of plant residues on the soil and crop, a plant residue quality (PRQI) was proposed by Tian *et al.* (1995). Our attempt in this study was also to evaluate the impact of decomposed alfalfa litter on enhancement of different soil properties i.e. chemical, physical and especially biological properties. The main aim of this study was to see the priming of the added residues in the soil and their mobilization trend in the soil.

Materials and Methods

Soil sampling and preparation: A pot experiment with 7 replications was conducted in the greenhouse including the following four treatments: 1. Control without maize plants and without alfalfa residues, 2. With maize plants but without alfalfa litter, 3. Without maize plants but with alfalfa residues, 4. With maize plants and with alfalfa litter. This Soil was sieved through 2 mm sieve and 3 cm alfalfa fresh particles were incorporated and homogenised as green manure (200 g per pot on fresh weight basis). Approximately 2 mg C/g soil (2000 µg/g soil) was initially added to the soil in the form of alfalfa residue with the C:N ratio of 12.5. Then the soil mixed with alfalfa material was filled in pots and 1.3 cm^{-3} densities were maintained by pressing the soil with wooden hammer. After filling the soil in pots water was added to these pots and left for two weeks without any cultivation so that the process of decomposition of alfalfa litter in treatments 3 and 4 must not be coincided with the germination of plants. After two weeks of mixing of alfalfa in the pots four maize seed /pot were cultivated in treatments 2 and 4 which were screen out to two healthy plants up to maturity. This experiment was conducted for 3 months and evolved CO_2 was measured three times a week with infrared detector (CIRAS) and to maintain the moisture in the pots water was provided regularly with measured quantity. For this purpose the pots were weighed twice a week. In the beginning moisture was maintained at 60% of soil water holding capacity which was reduced to 40 and then ultimately up to 30% after observing the soil and roots optimum conditions and aeration.

Soil respiration during experiment was measured once in a week with infrared detector (CIRAS) Instrument (Blanke, 1996) and evolved CO_2-C was calculated at the end of experiment.

Results

Cumulative CO_2 production was double in the treatments where only alfalfa litter was incorporated or maize was grown alone over the control but the rate of CO_2 even increased three fold in the alfalfa and maize incorporated treatment table (Table 1-2). This increase in CO_2 production showed strong relationship between the microbial activities and decomposition rate.

The content of organic C increased significantly in the soil after 90 days of pot experiment where alfalfa litter was incorporated in growing maize crop as compared to control. Increase in other treatments with alfalfa and growing maize alone have slight difference but visible over control. This trend in response to organic N contents was different and maximum increase was observed in treatment of only alfalfa litter incorporated in the soil followed by the maize plus alfalfa litter, growing maize crop

Table 1. CO_2-C-Production rate, Cumulative CO_2-C-Production and sum of substrate derived CO_2-C- (substrates–control) after 90 days

	CO_2-C [µg g^{-1} soil d^{-1}]	$\sum CO_2$-C	substratderived $\sum CO_2$-C
		[µg g^{-1} soil]	
Control	4.7 a	420 a	
Alfalfa litter	9.1 b	820 b	400
Maize	8.7 b	780 b	360
Maize + Alfalfa litter	14.0 c	1260 c	840

Different letters within a column indicate a significant difference ($p<0.05$, Tukey/Kramer, n = 7)

Table 2. Organic C in shoot and root material > 2 mm, ratios shoot organic C-to-total N and shoot C-to-root C at the end of the experiment

	Shoot C (g pot^{-1})	Shoot C/N	Root C (g pot^{-1})	Shoot C/ Root C
Maize	18.8 a	94 a	3.8 a	5.4 a
Maize + alfalfa residues	49.5 b	86 a	7.5 b	5.2 a

Different letters within a column indicate a significant difference ($P < 0.05$, Tukey/Kramer, n = 7)

alone and control respectively. Similarly, if we observed mean difference between $\delta^{13}C$, it depicted clear significant difference among the various treatments but the effect was more apparent in only growing maize crop as compared to other three treatments including control. Growing maize enriched more $\delta^{13}C$ as compared to the other three treatments although the difference is not so big but clearly visible and significant and support the hypothesis which we set before study that maize being C_4 plant enriched ^{13}C in the soil (Figs. 1 & 2).

If we look into the residues C add up ratio in the soil from maize roots and alfalfa litter, it has very clear message that 85% C was added up by maize roots only while 15% was contributed by alfalfa litter. This ratio of C was double where alfalfa litter was put together with growing maize over the treatment where maize crop was grown alone. Moreover, this results showed that maize crop reduced alfalfa turnover by some physiological processes and add up more C as compared to alfalfa litter in the soil.

Discussion

Evolution of CO_2 rate after substrate addition there must be mineralisation or mobilization of some nutrients i.e., C in the rhizosphere which is called priming effects. Priming affect can be negative if retardation is occurred in decomposition of added organic substrates and positive when decomposition rate of added substrate is accelerated. Priming effect elaboration differs from study point of view and depends on whether the studies were made with special attention to C or N. In studies of C turnover the definition is supported that priming affect is an extra decomposition of organic C after addition of easily-decomposable organic substance to the soil (Dalenberg & Jager, 1989). Moreover, priming effects are strong short term changes in the turnover of soil organic matter caused by comparatively moderate treatments of the soil. The priming effect arises either immediately or very shortly after the addition of a specific substance to the soil (Dalenberg & Jager, 1981, 1989; Kudeyarov, 1988, Pascual *et al*., 1998); priming affects in soils rich in C and N are larger than those in poor soils (Hart *et al*., 1986); the size of priming effects increases with the amount of the added organic substances (Dumontet *et al*., 1985; Kawaguchi *et al*., 1986; Asmar *et al*., 1994) or mineral fertilizers (Jenkinson *et al*., 1985; Kudeyarov, 1988; Laura & Parshad, 1992). An opinion expressed in literature

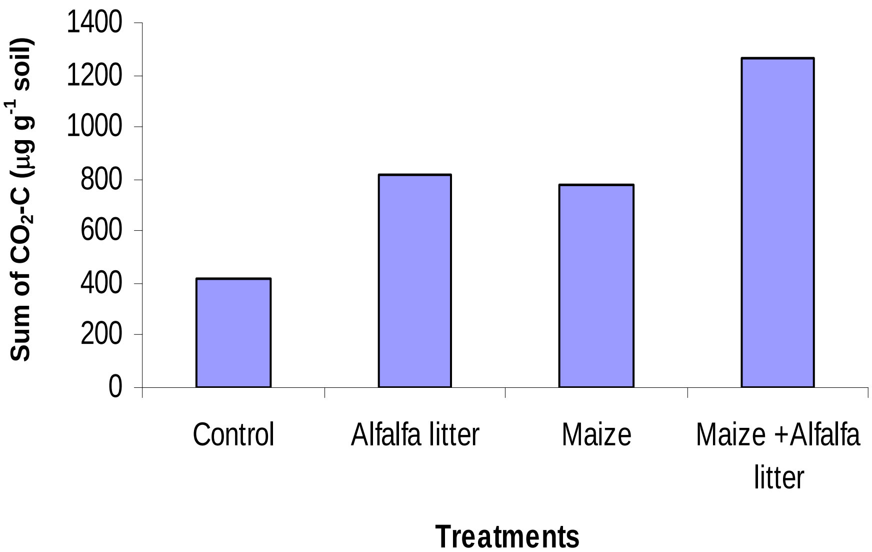

Fig. 1. Cumulative CO2-C evolution during the decomposition of alfalfa and maize growth.

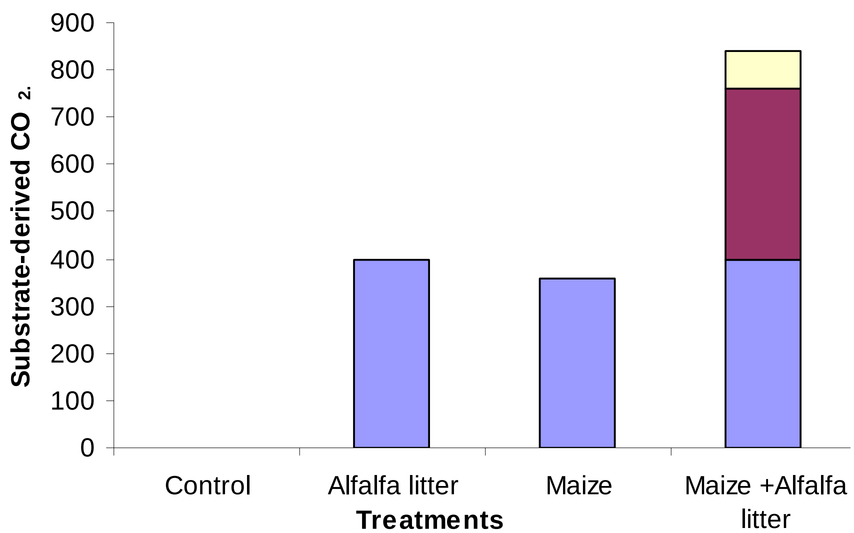

Fig. 2. Positive priming affect after addition of alfalfa residue in growing maize.

says that not only microorganisms alone contribute to priming effects (Griffiths, 1994). Interactions between soil microorganisms, soil fauna and plants are regarded as one of the keys for understanding priming effects. Substances released by soil fauna can cause priming effects by stimulating microbial activity. However, more prevalent in the literature are descriptions of the faunal grazing on soil microflora (predation) (Alphei *et al*., 1996). The effects induced by predation was summarized by Ingham *et al*., (1985) as follows: increased CO_2 release, increase N and P mineralization and release of nutrients immobilized in microorganisms, increased N up take of plant, and intensified plant growth ultimately. Similar trend was observed in our study regarding the nutrients mobilization which can be termed as priming effects, while incorporation of alfalfa residue increased maize growth and also lavish nutrients supply.

Conclusions

The addition of Alfalfa litter led to increase in cumulative surface CO_2-evolution. As a consequence, additional soil C must have been mobilised. Organic C and C: N ratio of particulate organic matter (POM) has shown very clear increase in coarse fraction but tiny effect has been observed on fine fractions. It can be said that maize roots and alfalfa litter decomposition mainly contributed to coarse fraction of the POM apart from showing very little impact on finer fractions. It would suggest that addition of alfalfa residue as green manure revealed very positive impact on biological soil characteristics and mobilised at least nutrients for growing maize crop.

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