Soil and Water Management

Keynote Speech

Decomposition of Soil Organic Component under Organic Rice Cultivation in Bali, Indonesia

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Abstract
As mentioned in numerous sources of literature, soil organic carbon is the major component of the terrestrial carbon pool. Soil organic carbon in agricultural soil is a potential sink for the atmospheric carbon. The need for major changes in the global food system has been emphasized by numerous reports. Organic farming is considered to be one of the keys for the establishment of sustainable agriculture. In this study, our research team tried to compare the decomposition intensity of soil organic components under organic and conventional rice cultivations to find the effects of organic farming on the accumulation of soil organic carbon. From the examinations conducted in two organic and conventional paddy cultivation fields in Bali, we observed that the intensity of the decomposition of soil organic component was low in the organic paddy field, while high in the conventional. Not only the low input of fertilizers but also the input of plant residues can be considered to contribute for the stabilization of soil organic component in the organic farming systems.

Keywords: decomposition of soil organics, organic farming, paddy field, rice cultivation

Carbon Sequestration in Soil

Soil organic carbon is the major component of the terrestrial carbon pool. The awareness of greenhouse gas emissions and the concerns about the global warming issues has led to an increased interest in soil carbon sequestration (Banger *et al.*, 2009; Brar *et al.*, 2013; Follett, 2001). Soil organic carbon in agricultural soils is a potential sink for the atmospheric carbon. However, there are reports showing both negative and positive impacts of agricultural activities on carbon sequestration in soils (Brar*et al.* 2013). A 25-years examination of rice-wheat cropping system (Benbi and Brar, 2009) revealed a positive role of intensive agriculture in improving soil organic carbon status by 38%. On the contrary, Bhandari *et al.* (2002) and Regmi*et al.* (2002) reported negative effects of intensive agriculture on the organic carbon as well as the productivity of the soil.

Organic Farming and Carbon Accumulation

The need for major changes in the global food system has been emphasized during the past decades. Organic farming is a system aimed at producing food with minimal harm to the ecosystems, animals, or humans. Seufert *et al.* (2012) compared the yields of organic and conventional agriculture and found that the yields of organic farming systems are typically lower than those of conventional. However, those yield differences can be considered highly contextual because they are highly dependent on the system and the site characteristics. The declined yield with organic farming ranged from 5%, where the rain-fed legumes and perennials were grown in weak-acidic to weak-alkaline soils, to 34%, where the conventional and organic systems are most comparable, revealing complexities. Seufert*et al.* (2012) concluded that organic systems can nearly match conventional yields only under certain circumstances including good management practices, particular crop types, and favorable growing conditions.

Soil analysis on organic and conventional paddy fields in west Java, Indonesia, showed significantly higher soil organic carbon storage under organic farming (Komatsuzaki and Syuaib, 2010). Accordingly, it can be suggested that organic farming would help not only in mitigating global warming issues but also in establishing a sustainable food system. Furthermore, organic farming can be considered as one of the keys for the establishment of sustainable agriculture. Organic rice cultivation has also shown a high potential in improving the soil quality as well as in reducing the cost of chemicals that has recently being increasing with the increasing price of fossil fuels.

Rice Production in Indonesia

Rice production in Asia and other countries and regions has increased considerably by virtue of the Green Revolution, providing solutions to food shortages and poverty (Tilman *et al.*, 2002). In Indonesia, the rice yield per unit area showed an increment of approximately three-fold from 1760 kg ha^{-1} in 1961 to 5150 kg ha^{-1} in 2013. The country is currently the third largest producer of rice in the world. Concurrently, the domestic rice consumption has been increasing each year as a result of the dietary changes associated with population growth and economic development, making Indonesia a leading global rice consumer (USDA, 2015). As a result, the requirement for a stabilized and further improved rice production in the country is increasing during the recent years.

Cultivation of productive crops through the Green Revolution enhanced the use of large amounts of fossil energy resources for the agricultural machinery, chemical fertilizers, synthetic chemicals, etc. The increased use of chemicals led to various environmental problems such as reduced biodiversity, soil and water pollution, and eutrophication (Pimentel *et al.*, 1995).

Dissemination of Organic Farming in Bali

Organic farming has been attracting greater attention of Indonesia in the recent years because of the growing preferences of farmers and consumers for safety and health benefits of organic products and the governmental promotion for the use of organic products (Willer and Kilcher, 2011). This was triggered when the Asian financial crisis struck the country in 1998, leading to find the possible measures to return from a production system, which was becoming increasingly dependent on chemical fertilizers at the time, to a sustainable agricultural production system, which would be in balance with the environment (Syuaib, 2009). Farmers are interested in organic farming to obtain products with unit prices that are higher than those grown using chemical fertilizers, although it results in lower yields (Takada *et al.*, 2004). Some supermarkets in Indonesia have set up sections for organic rice, stimulating and encouraging the consumers to demand organic products.

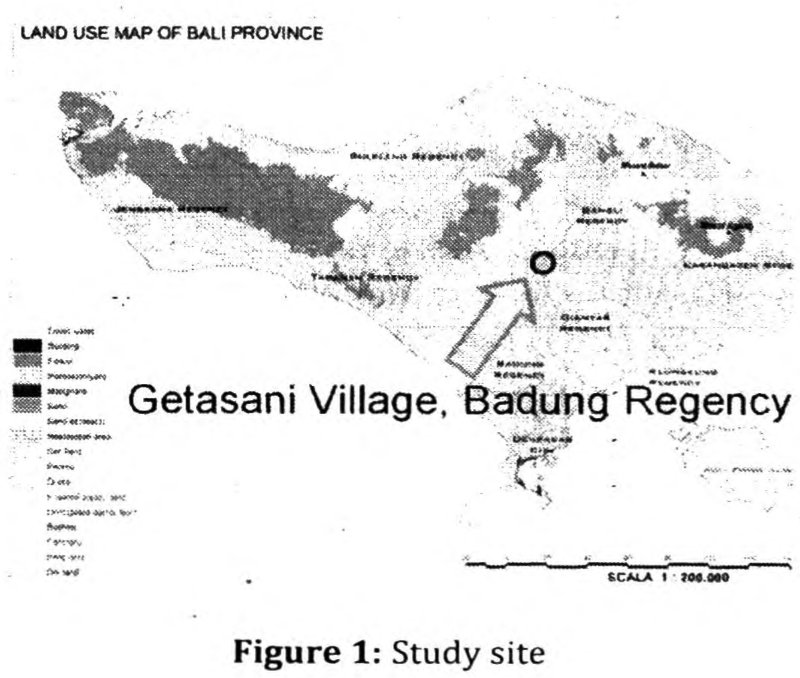

Figure 1: Study site

Based on the information provided by the Bali Agricultural Agency, Shiotsu *et al.* (2015) conducted a field research in the village of Getasani in the regency of Badung, where organic farming is practiced (Figure 1). Farmers in SubakBuangga were interviewed about their rice varieties, cultivation methods, cropping systems, and practicing of organic farming. Buangga comprises approximately of 200 farmers, managing a total paddy field area of 140 ha. Organic cultivation began in the Buangga in 2007 with an area of 10 ha. At the time of the survey (2014), an area of 40 ha was certified to be an organic farming system based on the national standards. Ciherang rice was grown in both the rainy and the dry seasons, whereas peanuts were grown as a secondary crop (Palawija). The farmers use only a form of cattle manure that is produced independently by a manure production group in Buangga consisting of 25 farmers who were supplying two cows each, totaling 50 cows.

The cattle manure production process consists of four steps. (1) Feed cattle with the weeds that have been collected from around the cattle sheds; (2) collect dung at the central square; (3) mix the dung with lime and ash, and ferment the mixture; and (4) spread out the manure mixture for drying. The annual production of cattle manure is 100–120 tons. In the distribution system, the manure produced by the farmers is purchased by the local government at a rate of Rp. 600 per kg, whereas the product is purchased by the farmers at a rate of Rp. 100 per kg. In other words, the farmers receive a governmental subsidy of Rp. 500 per kg for the cattle manure allocated to the system.

The paddy fields use 2000 kg ha^{-1} of cattle manure. The amount of cattle manure used for the paddy fields in Japan is 10,000 to 20,000 kg ha^{-1} (Japan Soil Association, 2015). Our interview with 10 farmers in Buangga revealed that the annual yield of organic rice is approximately 5.6 ton ha^{-1}, which is nearly equivalent to the mean yield in whole Bali.

According to Shiotsu *et al.* (2015), the Bali Agricultural Agency began to manage the certification of the organic agricultural products in 2009. Twenty-five farming groups were certified for the organic farming during the period of four years from 2009 to 2013. The crops certified as organic products included rice, onion, mangosteen, banana, dragon fruit, oranges, etc. Five farming groups were certified for organic rice farming, where the total cultivation area was 191 ha. One of these five groups was in Buangga (Shiotsu *et al.*, 2015).

Decomposition of Organic Component of Paddy Soils in Bali

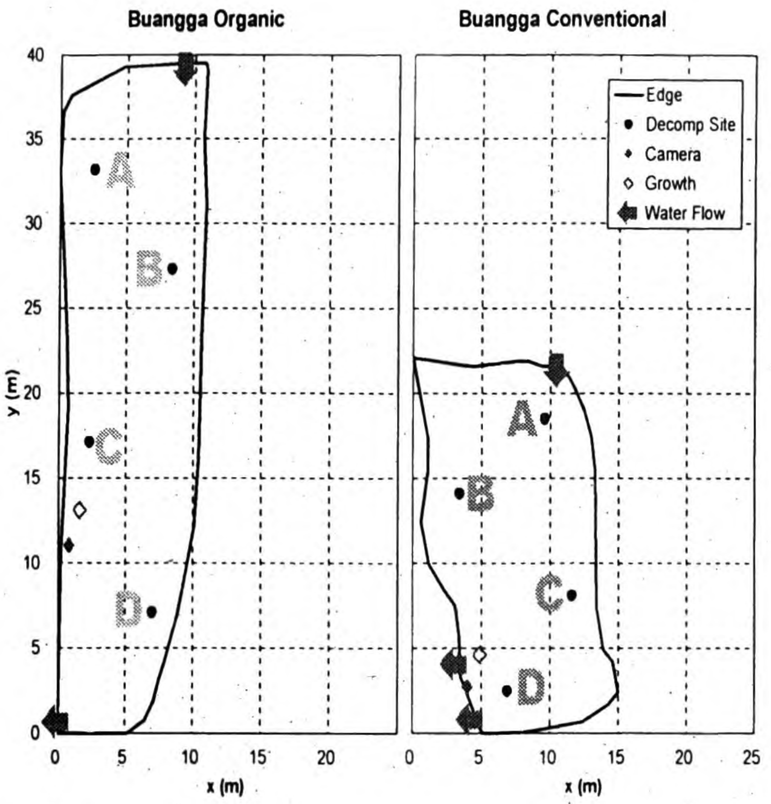

Figure 2: Organic and conventional paddy fields at SubakBuangga in the village of Getasani

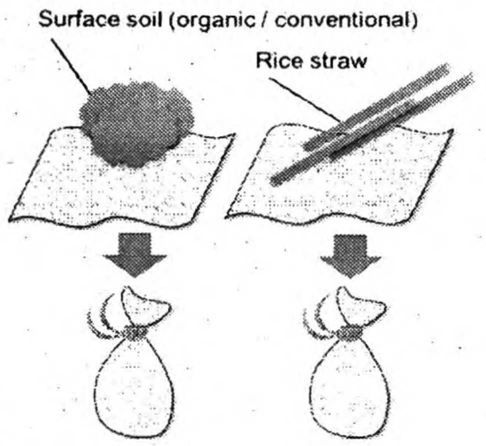

Figure 3: Surface soil and rice straw bound up by water-permeable and root-cutting sheet

In this study, our research team tried to compare the decomposition intensity of organic component under the organic and conventional cultivations of rice to determine how the organic farming affects the accumulation of organic carbon in soils. Our experiments were conducted at two paddy fields at SubakBuangga in the village of 1, 2).

Approximately 5-kg samples of surface soils (0-5 cm depth) were collected from both organic and conventional paddy fields (Figure 2). Soils passed through 2 mm sieve were air-dried for a period of two weeks at the room temperature. Rice straw from another paddy field was also air-dried for one week. Approximately 2.5 g of rice straw and 60 cm^3 of surface soil were wrapped up by root-cutting and water-permeable sheets (Figure 3, Toyobo STC, Osaka). As shown in Figure 4, 24 bags of surface soil and rice straw were installed in 2 fields (organic or conventional), 4 plots (A–D) in each field, and kept for 3 periods of time (40, 80, 120 days). To understand the circumstances when the cultivating system changed from conventional to organic, or organic to conventional, the organic surface soil bags were installed in the conventional paddy field, whereas the conventional soil bags were installed in the organic. In addition, the amount of root production was observed throughout the rice growth period by in-growth core method (Morita *et al.*, 2013).

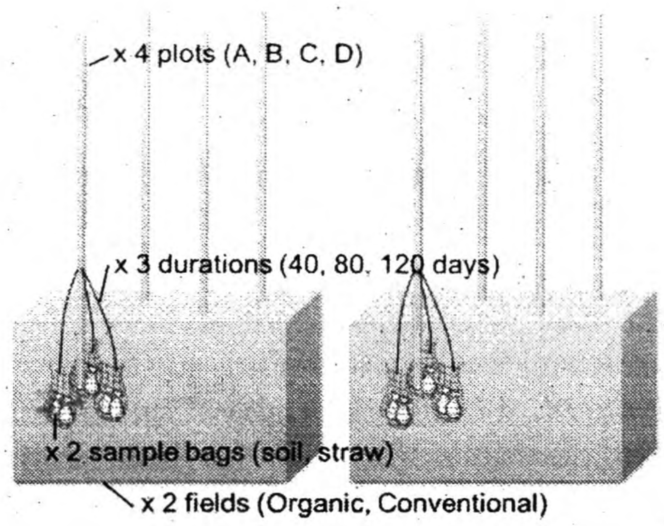

Figure 4: 24 bags of surface soil and rice straw were installed

Installed bags were collected from each plot at 40, 80, and 120 days after the transplanting of Ciherang seedlings (Figure 5). The oven-dried weight of rice straw was taken. Total carbon and total nitrogen contents of the soil samples were measured using CN analyzer(Sumigraph NC-22F, SCAS).

Figure 6 shows the decomposition of rice straw. The residue rate of rice straw at 40 days was slightly lower in the conventional paddy field. However, the rates at 120 days showed no significant difference between organic (52 ± 6 %) and for conventional (54 ± 6 %) fields.

The initial carbon contents of organic and conventional paddy fields were 1.91 ± 0.02 % and 2.62 ± 0.06 %, respectively. Figure 7 shows the total carbon and nitrogen contents, and the C/N ratio of surface soils after installation

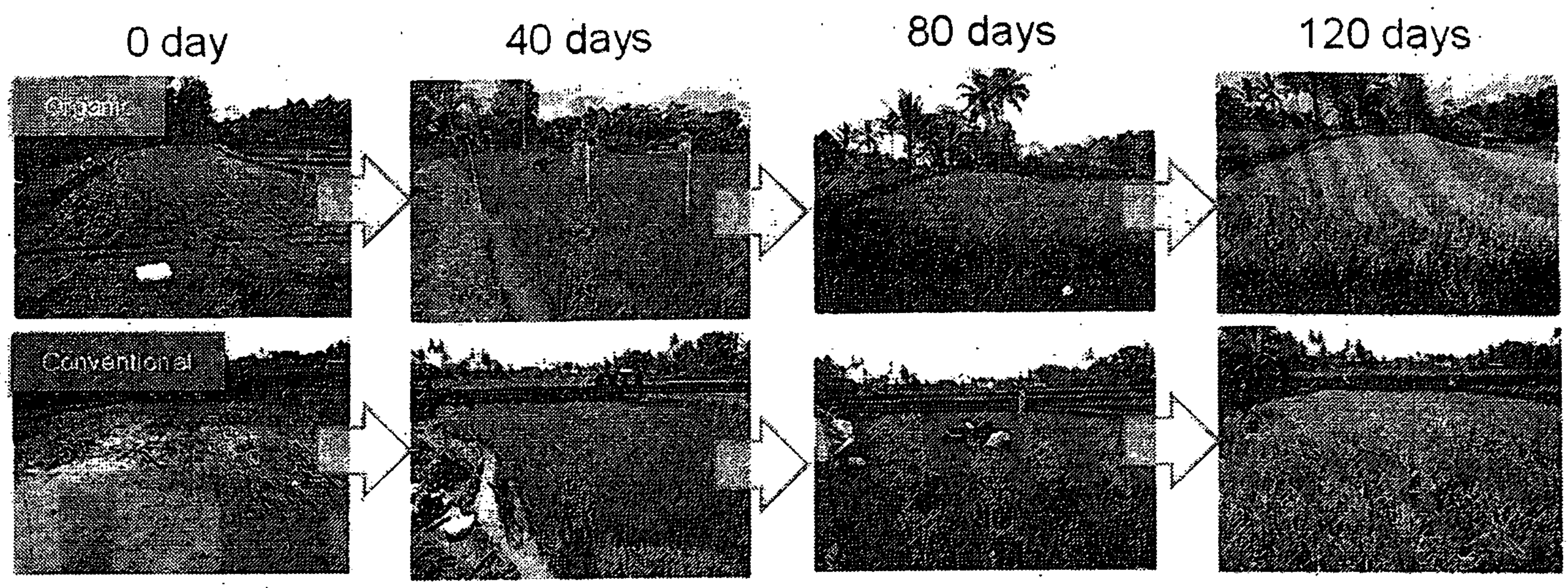

Figure 5: Paddy fields at 40 days, 80 days and 120 days after transplanting of Ciherang seedlings

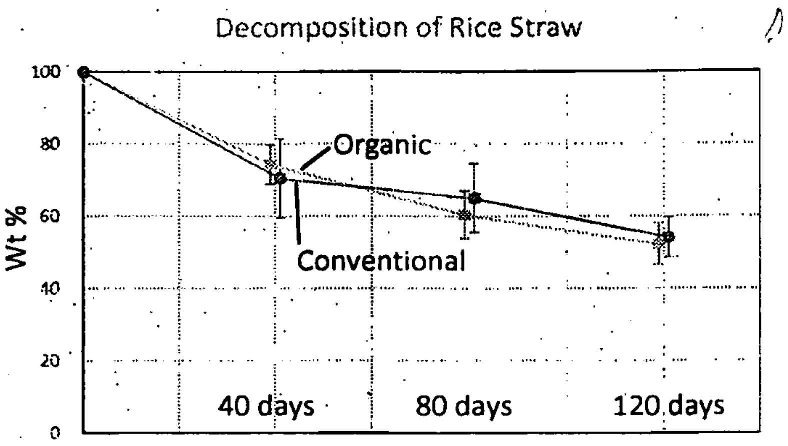

Figure 6: Residue ratio of Rice Straw

periods of 40, 80, 120 days under different farming systems. Under the organic cultivation, the carbon and nitrogen contents of the installed conventional soil showed a decrease at 40 days, and remained stable until the harvesting. The C/N ratio was also stable showing values between 10.1 and 10.2. On the contrary, under the conventional cultivation, the carbon and nitrogen in the installed organic soil did not show a rapid decomposition, but gradually decreased until the end of the experiment. The C/N ratio kept increasing from 9.2 to 9.4. These results suggest different intensities of decomposition for soil organic component, that is, low and stable in the organic, and high in the conventional paddy fields. The result of the in-growth core method showed that newly produced root length density from 80 to 120 days were 7.34 cm cm^{-3} and 10.13 cm cm^{-3} forthe organically and conventionally cultivated rice, respectively (Shiotsu *et al.*, unpublished). The high production of rice root in the conventional paddy fields supports our finding of higher decomposition intensity of soil organic component in the conventional fields.

The essential driver of the decomposition of soil organic component is soil microorganisms such as bacteria and fungi. By an examination in vegetable fields, Nagaoka *et al.* (2011) reported that fungal flora can easily be changed by implementing an organic farming system;

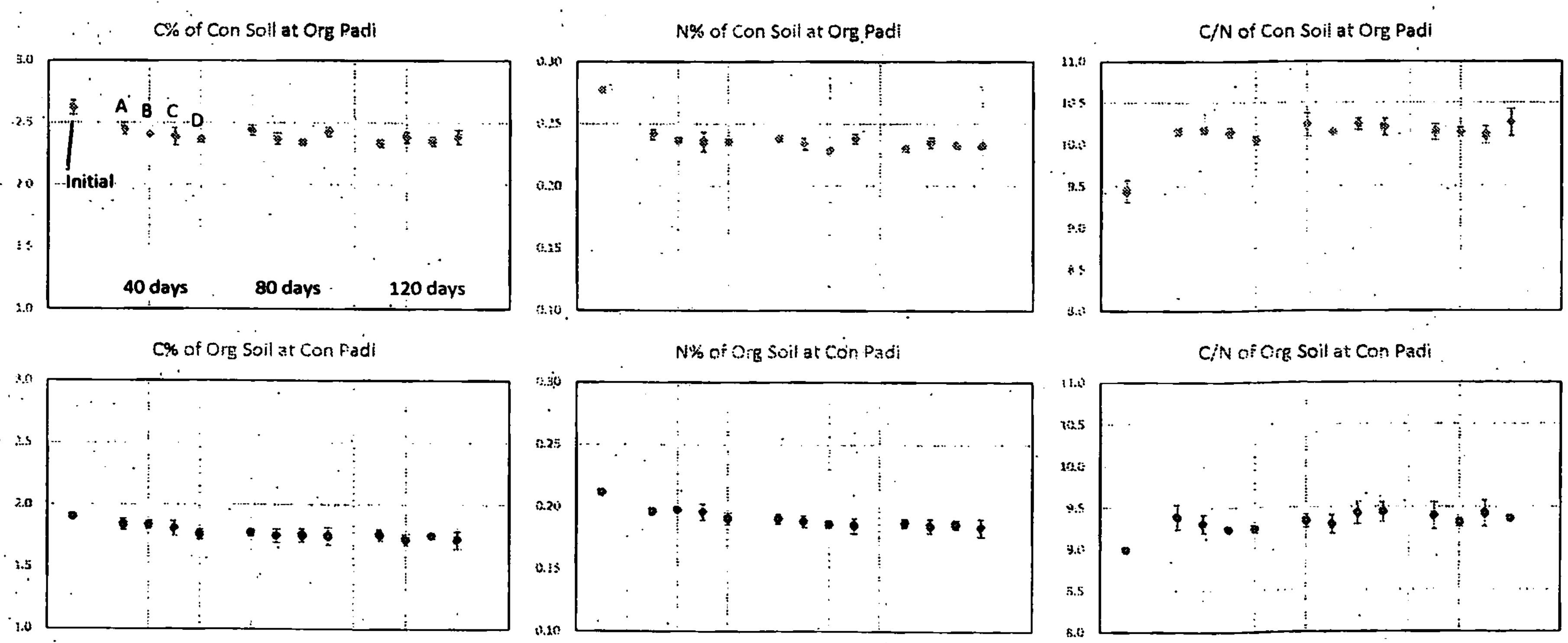

Figure 7: The total carbon content, the total nitrogen content, and the C/N ratio of surface soil after installation for 40, 80, and 120 days under different farming systems

however, bacterial flora tends to be stable for several years. Implementation of organic farming might drastically change the input of plant resides, including root, affecting soil microorganism, mainly the fungi. Not only the low input of fertilizers but also the input of plant residues can be considered to contribute for the stabilization of soil organic component in the organic farming systems.

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Effect of Sulphur Fertilization on Different Forms of Sulphur in the Soil under Mustard Cultivation in Terai Region of West Bengal, India

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Abstract
A field experiment was conducted in Indian mustard [*Brassica juncea* (L.) Czern & Coss.] growing soils with added doses of S (at 15, 20, 25, 30 kg ha^{-1}) each from two sources, namely bentonite-S and single super phosphate (SSP), to evaluate different forms of S in an acid soil (pH 5.2) of *Terai* region. It was observed that various forms of S present in initial soil followed the order: organic sulphur> non-sulphate sulphur> heat soluble sulphur> adsorbed sulphur> water soluble sulphur > sulphate sulphur. The analysis of initial and harvested soil showed that all the S forms decreased in the control plot until harvest. The total S content increased with the increased addition of S in both sources. The organic S content decreased in all treatments. However, this reduction was lowered with the addition of S. The status of the SO_4^{-2}-S in the soil at harvest did not vary across the treatments. Non-Sulphate S, adsorbed-S, heat soluble S were significantly increased with the sulphur addition. However, in case of water soluble S, large variations were observed among the treatments. Significant positive correlations of oil content were noted with total S (r=0.75*), organic S (r=0.69*) and sulphate S (r= 0.78*). The grain yield also exhibited positive correlations with all the forms of S. The Bentonite S showed better S use efficiency by the plants but SSP was found to be better in increasing the oil content of the crop, particularly at higher doses.

Keywords: Bentonite-S, Forms of sulphur, Mustard, oil content of mustard, SSP
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Introduction:
Sulphur (S) is one of the most important nutrients for all plants and animals and is considered as the fourth major nutrient for agricultural crops. S is known to involve in the metabolism of carbohydrates, proteins and oils, formation of cell wall and flavour imparting compounds. It is primarily involved in the formation of glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH-) linkages that are the source of pungency in onion, oils etc. Therefore, insufficient availability of sulphur to oil seed crops not only decline their growth and yield but can also deteriorate nutritional quality of the produce. Plants absorb S in the form of inorganic sulphate (SO_4^{-2}) ions through the roots. But sulphur is present in both inorganic and organic forms in soil and the proportion of inorganic to organic sulphur varies widely depending upon the nature of soil, its depth and management factors to which the soil is subjected. The common forms of inorganic sulphur in soils are sulphate sulphur, non-sulphate sulphur, adsorbed sulphur, heat soluble sulphur and water soluble sulphur. The abundance and the distribution of these inorganic S-forms widely depends on the characteristics of soil namely pH, organic matter content, nature of clay, presence of cations, competition with other anions etc. A large proportion of soil S exists in the form of organic compounds acting as reserve-S which must be mineralized to sulphate S to make available to plants. Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is an important *rabi* season oilseed crop in India. Mustard containing high amounts of glucosinolates has a high sulfur demand. Besides that, sulphur plays an important role in the chemical composition of mustard tissue. In general, oilseed plants have a high sulfur need. Sulfur fertilization has been shown to increase the oil content in seeds of various oil seed cops across the globe.

The present research was aimed to determine the effect of sulphur fertilization on different forms of S in soil under mustard cultivation and the contribution of these forms to the yield aspects of the crop.

Materials and Methods
The field experiment for the present investigation was carried out at the Instructional Farm, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India (26° 19'86"N, 89° 23'53"E, altitude of 43 m.a.s.l.). The soil was a Typic Fluvaaquent. The soil was characterized with respect to important physico-chemical properties (Jackson, 1967). The pH of the soil was recorded as 5.2. The soil samples collected from field before and after the harvest of the crop were used to analyze different forms of S (Williams and Steinbergs 1959). The field experiment was carried out with Indian mustard

(*Brassica juncea* (L.) Czern & Coss) cv. Binoy (B9) following the randomized block design. The treatments comprised of four doses of S, each from two sources namely bentonite-S (T_2 - 15 kg ha^{-1} S; T_3 – 20 kg ha^{-1} S; T_4 – 25 kg ha^{-1} S; T_5 - 30 kg ha^{-1} S) and single super phosphate (SSP) (T_6 - 15 kg ha^{-1} S; T_7 – 20 kg ha^{-1} S; T_8 –25 kg ha^{-1} S; T_9 - 30 kg ha^{-1} S) while in T_1 no sulphur was added. The treatments were replicated thrice. The Bentonite-S and SSP were applied during the land preparation. The calculated amount of fertilizers needed were also applied in the form of urea, DAP and MoP maintaining proper agronomic schedule. The dose of DAP as P source was adjusted taking into consideration of SSP applied as S source. The seeds were sown keeping the spacing of 30 cm × 10 cm in 5 m × 3 m plot. The crop was harvested at ground level when 80% of siliquae and grains were matured. For the determination of oil content 2g of seeds were crushed and oil was extracted using hexane in SOCS PLUS oil extractor (Pelican, SCS04R). The observed data were analyzed statistically using statistical analysis system (version 9.2, SAS Institute Inc., Cary, North Carolina, USA).

Results and Discussion

The organic S constituted major fraction (76%) of the total S content of the initial soil. The high organic S may be attributed to the higher organic matter status (0.98%) of this soil. The sulphate sulphur constituted the least component among the inorganic S forms of soil. This lower SO_4^{-2} concentration may be due to the uptake of S by the vegetation and lower sorption in soil due to the charge negativity. The non-sulphate S of this soil was 58.1 mg kg^{-1} which is 21.7% of the total S found in this soil. The adsorbed S content was also found lower for this soil. This may be due to the lower clay (15.2%) content of the soil resulting in the less adsorption of S on clay surfaces. The heat soluble S was higher (25.83 mg kg^{-1}) than the sulphate S, adsorbed S and water soluble S. The water soluble S accounted for 0.05% of the total S. This result indicated the preponderance of various S forms in the order: organic sulphur> non-sulphate sulphur> heat soluble sulphur> adsorbed sulphur> water soluble sulphur > sulphate sulphur.

Total sulphur decreased at harvest from the initial soil in control plot (T_1) and treatments T_2 and T_3 where S was applied at 15 kg ha^{-1} and 20 kg ha^{-1}, respectively in the form of Bentonite-S (Figure 1). The total S also decreased in the treatments T_6 and T_7 where the S was added as SSP. But in both the sources total S increased where the S doses were 25 and 30 kg ha^{-1}. The SSP was found as more efficient for enriching the soil with S than the Bentonite. It was also noted that mustard removed more S than the S addition upto 20 kg ha^{-1}. But the soil increased its total sulphur status with the S addition of equal or more than 25 kg ha^{-1}. The single super phosphate was found more efficient to increase the total S status in soil than Bentonite-S. The highest value of total S was recorded with S dose of 30 kg ha^{-1} (T_9) using SSP as the S source.

The organic S status of soil also increased gradually with the increased addition of S (Figure 1). But it was noted that the organic S content decreased from the initial soil in each treatment due to the rapid mineralization of organic S to meet the crop demand. The status of the SO_4^{-2}-S in the soil at harvest did not vary across the treatments. The non-sulphate sulphur content also increased progressively with the addition of S irrespective of sources.

The adsorbed-S content of soil at harvest also increased in three fold over the control soil in each treatment. The heat soluble S which considered as mineralizable S did not show much difference in all the treatments. The water soluble S, increased much with the addition of S externally over the control.

The grain yield of the mustard was found to be significantly affected by the application of S from both the sources. The grain yield increased 9.06%, 12.25%, 13.58%, and 10.16% with the application of S @ 15, 20, 25 and 30 kg ha^{-1} respectively in the form of Bentonite-S. For the SSP the increment was recorded as 11.15%, 13.94%, 12.74% and 7.27%. The highest yield (1242.67 kg ha^{-1}) was observed for T_8. The oil content of the grain has also shown significant increase with the successive application of S. It was found that the oil content increased 9.19%, 14.71%, 18.57%, 11.06% for Bentonite-S and 7.65%, 12.53%, 19.22%, 13.23% for SSP with the addition of increased doses as mentioned above. The highest oil content was found in treatment T_8. It was noted that the seed yield and the oil content reached maximum at the S dose of 25 kg ha^{-1}. With excess addition of S beyond T_4 and T_8 the oil content diminished. It was noted that the grain yield and oil content had positive relation with all the forms of S. The highest positive correlation was found between grain yield and sulphate-S (0.95**) revealing that the yield of crop depends on the accessibility of plant available form of S *i.e.*,

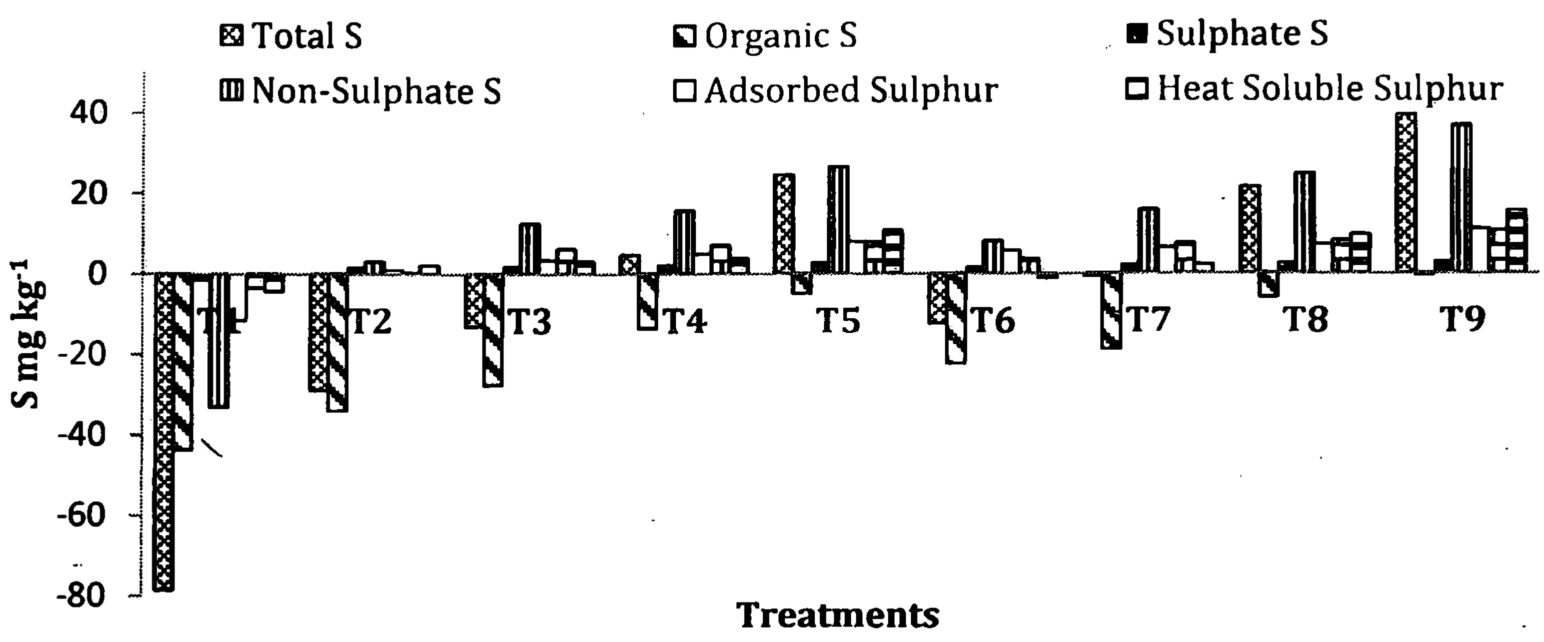

Figure 1: Deviations of amount of sulphur in different forms from initial to harvested soil

sulphate-S in the soil. The oil content was also observed to have significantly positive correlation with the sulphate-S (0.78*).

The increase in the dose of S increased the nutrient use efficiency by both the sources but there was a decline in highest dose observed in T_9 *i.e.*, 30 kg ha^{-1} through SSP. In the case of Bentonite-S T_5 *i.e.*, 30 kg ha^{-1} of S has shown more S use efficiency than all other treatments because of higher availability of S than that of in SSP. As said earlier the decrease in S use efficiency in highest dose of SSP may be due to several kinds of loses but in Bentonite-S it was positive.

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