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Floor management of banana orchard using banana biomat mulch and leguminous cover crop for sustainable production

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Abstract
The experiment was carried out at ICAR-AICRP on Fruits, Mohanpur centre of Bidhan Chandra Krishi Viswavidyalaya, Mondouri, Nadia, West Bengal in Randomized Block Design with 6 treatments *viz*., T_1: Banana Biomat Mulch (BBM) @ 30 kg fresh/m^2 + Leguminous Cover Crops (LCC) @ 3g seeds/m^2 + 0% recommended dose of fertilizer (RDF), T_2: T_1 + 25% RDF, T_3: T_1 + 50% RDF, T_4: T_1 + 75% RDF, T_5: T_1 + 100% RDF and T_6: Control – conventional practices (no BBM & LCC) with 100% RDF. Treatments were imposed thrice a year on orchard floor of banana cv. Martaman. Observations were recorded on suppression of weed growth, weed control efficiency, soil moisture conservation, status of organic carbon content, bunch weight, finger weight, TSS and B: C ratio. The results of the investigation revealed that application of BBM+LCC with 75 or 100% of RDF (T_4 & T_5) significantly suppressed weed growth in orchard floors (176.01 g fresh weeds/ m^2) and increased weed control efficiency (87.85%) and soil moisture conservation (20.01% to 20.34% vegetative growth & 22.64% to 23.64% during reproductive growth), soil organic carbon content (0.81%) and higher bunch weight, finger weight, TSS and B: C ratio (19.43 kg, 118.31 g, 21.26 °Brix and 3.11, respectively), as compared with conventional practice (T_6 : control) and rest of the treatments T_1, T_2 & T_3 (BBM + LCC and RDF @ 0-50%).

Keywords: Banana biomat mulch, conservation, leguminous, orchard floor, weed control efficiency, organic carbon

Introduction
Banana (*Musa Paradisiaca*) is an herbaceous plant and nicknamed as Antique fruit crop/Apple of paradise/Kalpataru, belongs to the family Musaceae. Consumption of banana provides energy, nutrients and several health benefits (Kumar, 2012) [12]. India is the largest producer of banana in the world with annual production of 30808 metric tonnes from the area of 884 thousand hectares. It is the second most important fruit in India. The area of banana cultivation in West Bengal state is 49.30 thousand hectares with a production of 1200.00 metric tonnes. The average productivity in West Bengal is 24.34 metric tonnes per hectares (Anon, 2019) [1].
In commercial banana cultivation, out of the total biomass produced by a banana plant (cv. Martaman, Musa AAB), only 15-20% constitute the fruits and marketed immediately but rest biomass (80-85%) including pseudostem, leaf, rhizome etc. is a neglected waste and not used properly. The unutilized biomass was estimated to be about 150 tonnes/ha (Debnath *et al.* 2010) [8]. The process of composting from the banana waste offers many benefits including enhanced soil fertility and soil health and also improved soil biodiversity and reduced environmental risks (Bernal *et al.* 2009) [6]. Utilization of banana crop waste is a cheap source of nutrients, it increases organic matter, stimulate soil microbial life enhances water holding capacity and increases crop yields (Phirke and Kothari, 2005) [17]. While growing of cover crops effectively reduced the weed growth in the orchard and also improved physical and chemical properties of soil. The organic mulches as well as the leguminous cover crops have influences on conservation of soil moisture and regulation of soil temperature. Cover crops have long been used to reduce soil erosion and water runoff, and improve water infiltration, soil moisture conservation, and also helps in improving soil tilth, organic carbon and nitrogen (Sainju and Singh, 1997) [18].
Hence, the strategy for floor management in banana orchard could be developed based on the availability, cost and characteristics of organic mulch material and cover crop. Therefore, in

the present investigation, we used banana biomat mulch as an organic mulching material against the conventional practices like application of herbicides or inorganic mulch (black polythene). We also tried leguminous cover crops to observe its suppressing effect on weed growth, status of organic carbon and available nitrogen in banana orchard.

Based on the above background, the present experiment entitled "Floor management of banana orchard using banana biomat mulch and leguminous cover crop for sustainable production" was conducted with following objectives:

a) Suppression of weed growth in banana orchard.
b) Conservation of moisture and status of organic carbon in banana orchard.
c) Fruit yield, quality and B: C ratio.

Materials and Methods

The experiment was conducted at ICAR-AICRP on Fruits, Mohanpur centre of Bidhan Chandra Krishi Viswavidyalaya, Mondouri, Nadia, West Bengal, during the year 2018-19. Healthy and uniform sword suckers of banana cv. Martaman (500-750 g) were collected, treated and planted at 2 m x 2 m spacing as per the layout of experimental design in randomized block design (RBD) with 4 replications and 10 plants per replication. The recommended dose of fertilizer (RDF) used in the experiment of banana was 5kg FYM, N-200g + P_2O_5-50g + K_2O-250g/plant/year from source fertilizer urea, single super phosphate and muriate of potash. Application rate was between 0 and 100% of RDF based on treatments. The treatments consisted of application of banana biomat mulch (BBM), leguminous cover crop (LCC) and different level of fertilizer doses (T_1: BBM + LCC + 0% RDF, T_2: T_1 + 25% RDF, T_3: T_1 + 50% RDF, T_4: T1 + 75% RDF, T_5: T_1 + 100% RDF and T_6: Control – conventional practices with 100% RDF).

The orchard soil of banana was cultivated by power tiller and dose of fertilizer was applied to the banana field as per treatment layout, followed by irrigation. The overnight soaked seed of leguminous cover crop (LCC) was sown @ 3g/m^2 in the ground area of plants as per the treatment, about 48-36 hours after irrigation. Black gram var. Kalindi was sown during winter and spring months and moong bean var. Samrat was sown during summer and rainy months. The pseudostem of banana was collected from the harvested banana field. Strips were prepared by cutting the leaf sheath of pseudostem into 1.4-1.5 m in length and 10-15 cm in wide. The banana biomat mulch (BBM) was prepared by weaving the strips cross-wise and were spread onto the ground area of each plant @ 30 kg fresh/m^2. Pre-soaked moong bean seeds along with vermicompost was sown at 25-30 cm spacing in between the two banana strips of BBM. The grown up LCC was incorporated in soil during 50 to 60 days after sowing.

Application of treatments was repeated three times: i) First application at the time of planting (10-25 August, 2018), ii) Second application at 3 months after 1st application (10-25 November, 2018, at plant age of 3 months) and iii) Third application at 6 months after 1st application (10-25 February, 2019, at plant age of 6 months). Crop protection measures as recommended in crop calendar by BCKV and ICAR-AICRP on Fruits were followed as and when required. Observations were recorded on suppression of weed growth, weed control efficiency, soil moisture conservation, status of organic carbon content, bunch weight, finger weight, TSS and B: C ratio.

Methods of Observation

Weed control efficiency: For determination of weed control efficiency (WCE) the weeds along with their root was collected from one square meter of basal area of the plant of each treatment. The fresh weight and dry weight of weeds was taken with the help of electronic balance. After that WCE was calculated by the following formula suggested by Mani *et al*. (1973) [14] and expressed in percentage.

$$\text{WCE (\%)} = \frac{\text{Dry weight of weeds in unweeded control} - \text{dry weight of treatment plot}}{\text{Dry weight of weeds in unweeded control}} \times 100$$

Soil moisture: soil moisture in each treatment was recorded with the help of digital soil moisture meter at a soil depth of 10-15 cm, once in a week and expressed in %. Then the average data of one month was calculated and noted.

Organic carbon: it was determined by Valkley and Black's method as described by Jackson (1973) [10].

Bunch and fruit weight: The weight of the whole fruit (Bunch) was taken in kilogram (kg) unit and finger weight in gram (g) unit with the help of an electronic balance.

Total soluble solids (TSS): The total soluble solids content of the fruit was determined with the help of a hand refractometer and calibrated in °Brix at 20 °C.

Benefit: Cost ratio: Treatment cost per plant and per hectare was estimated. Cost of production and returns per ha and benefit: cost ratio was also estimated.

The experimental design was laid out as randomized block design (RBD) with 6 treatment and 4 replications and the data obtained from the experiment was analyzed statistically by the analysis of variance method for RBD, as suggested by Gomez and Gomez (1984) [9].

Results and Discussion

Fresh weight, dry weight and weed control efficiency in banana orchard: The data showed that the fresh and dry weights of weeds per m^2 of orchard floor were minimum (175.33 to 175.83g and 41.05 to 41.59g, respectively) due to the T_1 & T_2 treatments, i.e., application of banana biomat mulch, leguminous cover crops and lower levels (RDF < 50%) of fertilizers. While the fresh and dry weights of weeds were maximum (427.48 and 70.77 g, respectively) under the conventional practices i.e., application of 100% RDF but no BBM and LCC (T_6 treatment). The weed control efficiency was highest (87.85%) due to application of BBM and LCC with 100% RDF (T_5 treatment), which was statistically on par with T_4, T_3 and T_2 treatments.

Soil moisture content during vegetative and reproductive growth period and organic carbon content of soil in banana orchard

Higher soil moisture content during vegetative growth period (20.01 to 20.34%) and reproductive growth period (22.64 to 23.68%) of experimental banana plants were recorded as a result of organic mulching and cover crops on orchard floor of banana (T_5 to T_1 treatments), compared with lower soil moisture content (18.57 & 20.62%, respectively) in the un-

mulched and un-covered orchard floor of banana (T_6 treatment). The organic carbon content of soil was recorded higher (0.76 to 0.81%) when BBM and LCC were applied with RDF levels of 25 to 100% (T_2 to T_5 treatments). Decline in organic carbon content of soil was noted in absence of BBM and LCC (0.75% in T_6) and 0% RDF (0.74% in T_1).

Bunch weight, TSS, Finger weight and B: C ratio of banana after harvesting: The weight of harvested bunch of banana Var. Martaman varied from 14.01 to 19.43 kg due to different treatments. The highest mean bunch weight of 19.43 kg was obtained from the plants under BBM, LLC and 100% RDF (T_5 treatment), followed by statistically on par yield of 18.90 kg in T_4 treatment (i.e., BBM, LCC with 75% RDF). Finger weight varied between 113.03 and 118.31 g, whereas treatment effect on fruit weight was found statistically same for treatments T_2 to T_5. Total soluble solids content of fruit was statistically higher (20.62 to 21.26 ^{0}Brix) due to treatment with BBM, LCC and 50 to 100% of RDF, compared with RDF<50% (T_2 & T_1 treatments) and in absence of BBM & LCC (T_6 treatment). The benefit: cost ratio was estimated highest (3.11) due to application of BBM, LCC and 100% RDF (T_5 treatment), which was statistically on par with treatment with 50 and 75% RDF application (T_4 and T_3 treatments). B:C ratio was recorded lower (2.61 to 2.71) when BBM and LCC applied with lower (0 to 25%) RDF (T_1 and T_2 treatments) or 100% RDF applied without BBM and LCC (T_6 treatment).

In present experiment, six treatments were imposed, of which five treatments with banana biomat mulch, leguminous cover crop and varying dose of fertilizer (0, 25. 50, 75 and 100% of RDF) in the orchard of banana at planting time and at 3 and 6 months after planting. The leguminous cover crop was incorporated in orchard soil between 50-60 days after sowing. The conventional practice of applying only 100% of RDF but no organic mulching and leguminous cover crops (with manual weeding or cultivation twice a year) was included in the experiments as control. It was revealed from the experiments that treatment with banana biomat mulch and leguminous cover crops and 75 to 100% of RDF significantly suppressed the weed growth (176.01 g fresh weed/m²), increased weed control efficiency (87.85%) as compared with the conventional practices (427.48 g/m²). The effects of both 75% and 100% of RDF were statistically at par with respect to suppression of weeds and weed control efficiency in orchard floor of banana. Soil moisture conservation due to application of banana biomat mulch and leguminous cover crop with varying dose of fertilizer (0, 25, 50, 75, 100%) of RDF were significantly higher in orchard soil of banana (20.01 to 20.34% during vegetative growth period and 22.64 to 23.64% during reproductive growth period) over the conventional practices. The effect of treatments with 75 and 100% of RDF, banana biomat mulch and leguminous cover crops significantly increased the soil organic carbon content (0.81 and 0.84%, respectively) as compared with the conventional practices (0.75%). These findings with respect to weed growth suppression, soil moisture conservation and increase in soil organic carbon content by application of organic mulch (banana biomat mulch) and cover crops (leguminous) are corroborated with the findings of Bernal *et al.* (2009) [6] and Sainju and Singh (1997) [18].

The bunch weight (19.43 kg), finger weight (114.16 g), TSS (19.30 ^{0}Brix) content and B: C ratio (2.71) were recorded significantly higher due to treatment effects of applying banana biomat mulch and leguminous cover crops with 75 and 100% of RDF, as compared with the control treatment with no banana biomat mulch and leguminous cover crop but application of only 100% of RDF. Improvement in production, quality and profit of banana cultivation using banana biomat mulch, leguminous cover crop and 75-100% of RDF might be attributed to the beneficial effects of organic mulch and leguminous cover crops, due to additional source of nutrients, decreasing competition of crop with weeds, conservation of soil moisture and addition of organic carbon in orchard soil (Phirke and Kothari, 2005, Bernal *et al.*, 2009, Sainju and Singh, 1997) [17, 6, 18].

The treatment with banana biomat mulch (BBM) and leguminous cover crops (LCC) with varying dose of fertilizer effectively suppressed the weed growth in banana orchard (Nath *et al.* 1992) [15]. Conservation of soil moisture was also found less (Das *et al.*, 2010; Bakshi *et al.* 2015) [7, 2] due to less population of weed growth and evaporative soil loss resulting in less competition between crop and weeds and hence, increased in fruit yield and quality, improve organic carbon content of soil and soil moisture conservation and B: C ratio, compared with the conventional practices. The BBM was applied as organic mulch (@ 30 Kg fresh/m²), decomposed in orchard soil and served as organic source of nutrient (Blanco-Canqui and Lal, 2007) [5] and plant nutrient (Blanchart *et al.* 2006) [4]. The leguminous cover crop (LCC) was also grown as a cover crop and properly mixed in orchard soil after 50-60 days after broadcasting and hence, it supplies 30-40 Kg nitrogen/ha (Peoples *et al.* 2009) [16].

Hence, the effect of banana biomat mulch (BBM) and leguminous cover crop (LCC) along with varying dose of fertilizer caused significant effect on weed growth suppression, soil moisture conservation and increased in nutrient (nitrogen) content in orchard soil due to atmospheric nitrogen fixation by legume crops resulting in increased in fruit yield and quality and higher B: C ratio of banana cultivation compared with conventional practices i.e., application of only 100% RDF with no BBM and LCC.

Table 1: Effect of banana biomat mulch, leguminous cover crops and level of fertilizer dose on suppression of weed growth and weed control efficiency in banana orchard

Treatment	Fresh weight of weeds (g/m²)	Dry weight of weeds (g/m²)	Weed control efficiency (%)
T_1	175.33	41.05	84.95
T_2	175.83	41.59	85.96
T_3	175.87	42.09	86.43
T_4	176.01	42.40	87.11
T_5	176.02	42.44	87.85
T_6	427.48	70.77	0.00
SEm (±)	2.541	1.631	1.010
C.D. at 5%	5.410	3.480	2.162

Table 2: Effect of banana biomat mulch, leguminous cover crops and level of fertilizer dose on soil moisture and organic carbon content in soil of banana orchard

Treatment	Soil moisture (%) (Vegetative growth stage)	Soil moisture (%) (Reproductive growth stage)	Organic carbon content (%)
T_1	20.01	22.64	0.74
T_2	20.15	22.80	0.76
T_3	20.23	22.89	0.77
T_4	20.28	23.24	0.80
T_5	20.34	23.68	0.81
T_6	18.57	20.62	0.75
SEm (±)	-	-	-
C.D. at 5%	-	-	-

Table 3: Effect of banana biomat mulch, leguminous cover crops and level of fertilizer dose on bunch weight, TSS, finger weight and B: C ratio of banana after harvesting

Treatment	Bunch weight (kg)	TSS (°B)	Finger weight (g)	B:C ratio
T_1	14.01	18.06	113.03	2.61
T_2	17.56	19.78	115.49	2.81
T_3	18.18	20.62	117.09	2.91
T_4	18.90	20.83	117.75	3.03
T_5	19.43	21.26	118.31	3.11
T_6	16.93	19.13	114.60	2.71
SEm (±)	0.401	0.631	1.651	0.065
C.D. at 5%	0.861	1.340	3.532	0.139

Conclusion

It was recommended for the banana growers in the Gangetic Alluvium region of West Bengal to apply banana biomat mulch (webbed leaf-sheath of banana @ 30 kg fresh/m^2), leguminous cover crops (@ 3g/m^2; black gram cv. Kalindi in winter, mung bean cv. Samrat in summer) thrice a year in banana (at planting time and at 3 & 6 months after planting) and 75% of recommended dose of fertilizer (in 3 splits at 3, 6 & 9 months after planting), followed by incorporation of leguminous cover crops into the soil at 50-60 days after sowing for better management of orchard floors of banana, with beneficial effects of suppression of weeds growth, conservation of soil moisture, improvement of soil health (organic carbon) and higher fruit yield, better fruit quality and higher B:C ratio of cultivation.

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