Conservation Agriculture Approaches in Banana to Improve Soil Quality and Farm Productivity

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ABSTRACT

In an investigation carried out at the Horticultural Research Station of Orissa University of Agriculture and Technology, Bhubaneswar during 2012-13 and 2013-14 banana was tried along with 4 intercrops, Glyricidia maculeata leaf manure and polyethylene mulch to mitigate the effects of reducing soil quality and productivity and improve farm profitability. Green manuring crops in the banana plantation improved soil organic carbon, microbial biomass carbon and available nutrients of the soil besides maintaining overall soil quality. The leguminous cowpea yielded highest total banana equivalent yield (41.37 t ha$^{-1}$) and fetched highest net return (Rs. 231723 ha$^{-1}$) but horsegram achieved highest cost: benefit ratio due to its low cost of cultivation.

Keywords: Agriculture, Soil quality, Banana

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Introduction

Indian agriculture has made great strides in achieving increased food grain production albeit at a low level of satisfaction. Increasing production has also been unwantly accompanied by widespread problems of resource degradation, which now pose a serious challenge to the continued ability to meet the demand of an increasing population coupled with nutritional security.

The past strategies to increase food grain production, however, have resulted in massive exploitation of natural resources, contributing to unsustainable growth; there is a need to change this in the future. There has been continuous neglect of vast areas under rainfed agriculture, where productivity continues to remain low. These are the areas where vast majority of the poor live. Rainfall regimes and soil characteristics are the key determinants of rainfed cropping potential. In the absence of cost effective moisture retention and conservation technologies the soil suffers from rapid water runoff and erosion reducing the productive capacity. Persistent use of conventional farming practices based on extensive tillage combined with in situ burning of crop residues have magnified soil erosion losses and degradation of soil resource base steadily. Conservation agriculture which relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes, such as nitrogen fixation, nutrient recycling, soil regeneration and protection of natural enemies of pest and
diseases as well as targeted use of inputs has come up as a new paradigm to achieve the goal of sustained agricultural production.

Banana has been utilized as a major fruit crop in many tribal dominated farming situations. In the degraded land management systems of the tribal areas leguminous intercrops/ cover crops can provide quick soil coverage and check soil erosion, add crop residues and cast favourable influence on many main crops, besides, providing additional returns (Yadukumar, 2007). Therefore, the present investigation was undertaken to find out the effects of various intercrops on soil properties, residual soil fertility, nutrient uptake, productivity and profitability in a banana based cropping system.

**Materials and Methods**

The study was carried out at the Horticultural Research Station, University of Agriculture and Technology, Bhubaneswar (20° 15’ N and longitude of 85° 52’ E and 25.5 m above mean sea level), Odisha from June, 2011 to June, 2013. The climate is hot and humid with a mean annual rainfall of 1450 mm. The soil of the experimental site was sandy loam in texture, slightly acidic with a pH of 5.5, organic carbon of 6.0 g kg⁻¹ and available NPK of 273.1, 10.5 and 93.6 kg ha⁻¹, respectively. Mean annual rainfall at the site averages 1450 mm, unimodally distributed, with the rainy season lasting from mid-June to September. The experimental design was a complete randomized block with four replications. The seven treatments included four intercrops, one polyethylene mulch, green manuring of *Glyricidia maculeata* and a control without any intercrop or mulch in the interspaces of banana plants. At the end of summer season the field was laid out after a minimum primary tillage. Cv. Bantal of banana was used as the test variety. The spacing adopted for banana plants was 2.2 m X 2.0 m. Each banana plant received a recommended fertilizer dose of 200:50:200 g N, P and K in form of Urea, Diammonium Phosphate and Muriate of Potash. The intercrops were sown/planted two weeks after the planting of banana. *Glyricidia* leaves were added as mulch in T₅ @ 5 t ha⁻¹ twice at an interval of 15 days starting from 30 days after planting (DAP). Except fertilizer application the soil was not disturbed in any other stage of the crop as the experiment was conducted on the principles of conservation agriculture.

The details of treatments are as under.

T₁: Banana + Cowpea,
T₂: Banana + Horsegram,
T₃: Banana + Bottle gourd,
T₄: Banana + Sweet potato,
T₅: Banana + *Glyricidia maculeata* incorporation @ 5 t ha⁻¹
T₆: Banana + Polythene mulch,
T₇: Banana (Control)

The soil samples from individual experimental plots drawn from a depth of 0–15 cm after the end of 2nd cropping cycle were placed in plastic bags and brought to the laboratory immediately for analysis. A portion of fresh soil samples were sieved through a 2 mm sieve and stored at 4°C for determination of microbial biomass carbon (MBC). The MBC was measured by determining the organic carbon in chloroform fumigated and non-fumigated soils by dichromate digestion method described by Vance *et al.*, (1987). The MBC was estimated from the equation:

\[
\text{MBC} = 2.64 \times \text{Ec}
\]

where Ec is the difference between organic carbon extracted from the K₂SO₄ extract of fumigated and non-fumigated soils. Another portion of the sieved soils were air dried (2–3 days) and used for determination of pH, water holding capacity, organic carbon, available N, P and K (Page *et al.*, 1982). Undisturbed core samples from each layer were collected with a core sampler.
(5.0 cm diameter) for determination of soil bulk density (Blake et al., 1986). The nutrient concentrations of both main product and by product of banana and intercrops were estimated by standard procedures.

Five random plants were selected from each treatment for recording observation. Data recorded were statistically analyzed for all quantitative characters. Intercrop yields in terms of equivalent banana yield has been derived by the following formula:

Banana equivalent yield (BEY) from intercrop (t ha\(^{-1}\)) = (Yield of intercrop (t ha\(^{-1}\)) x Sale price of intercrop (Rs. t\(^{-1}\)))/Sale rate of banana (Rs. t\(^{-1}\))

Total banana equivalent yield from the complete crop cycle have been worked out for comparison among the treatments. For economic analysis cost of all the inputs in the local market and sale price of produce at the farm gate has been used.

**Results and Discussion**

**Nutrient uptake**

The nutrient uptake of banana and different intercrops are presented in Table 1. The nitrogen removal was maximum in banana + cowpea intercropping system (317.5 kg ha\(^{-1}\)) and was minimum in sole cropping of banana (168.9 kg ha\(^{-1}\)). Green manuring of banana with *Glyricidia maculeata* leaves resulted in the nitrogen uptake in banana (212.5 kg ha\(^{-1}\)) and among intercrops, legumes removed maximum nitrogen of 109.2 and 93.5 kg ha\(^{-1}\), in cowpea and horsegram, respectively. The phosphorus uptake of different banana based cropping systems exhibited similar trend as that of nitrogen. Addition of green manure or intercropping with cowpea enhanced phosphorus uptake in banana and the increase was to the tune of 12.9 % over the control plot of sole banana (18.9 kg ha\(^{-1}\)). Intercropping of legumes in banana resulted in the highest phosphorus removal from the system with values of 34.5 and 33. 7 kg ha\(^{-1}\) in banana + cowpea and banana + horsegram, respectively. Enrichment of the soils with green manuring also enhanced the potassium uptake of banana to the maximum (321.6 kg ha\(^{-1}\)) as compared to other systems. Intercropping of legumes exhibited the highest system uptake of potassium accounting 393.6 kg ha\(^{-1}\) for banana + cowpea and 388 kg ha\(^{-1}\) for banana + horsegram. Enhanced uptake of nutrients by banana legume intercropping systems has also been reported by McIntyre et al., (2001).

**Soil properties**

The soil organic carbon (SOC) content (Table 2) was maximum in green manuring with *Glyricidia* (8.3 g kg\(^{-1}\)) followed by intercropping of cowpea (7.8 g kg\(^{-1}\)) and horsegram (7.7g kg\(^{-1}\)). Green manuring and legume intercropping helped in buildup of SOC and the elevation was to the tune of 28.3 - 38.3 % over the initial status (6.0 g kg\(^{-1}\)). Increase in SOC contents in the soil due to green foliage lopping of *Glyricidia* has also been observed by Vanilarasu and Balakrishnamurthy (2014). Buildup of SOC contents in legume intercropping is attributed to the accumulation of root residues and shedding effect of leaves (Shalini Pillai et al., 2007). Banana based cropping systems did not have any significant effects on pH, bulk density and water holding capacity of the soils at the end of second cropping cycles. However, marginal improvement in bulk density and water holding capacity of the soils were noticed with green manuring and legume intercropping. Green manuring in banana with leaves of *Glyricidia* enhanced the MBC to the maximum (208.9 µg C g\(^{-1}\) soil) and the increase was to the tune of 62.8 % over the initial status (128.3 µg C g\(^{-1}\) soil).
Table 1: Nutrient uptake as influenced by banana based intercrops (data pooled over two years)

| Treatments                  | Nitrogen uptake (kg ha\(^{-1}\)) | Phosphorus uptake (kg ha\(^{-1}\)) | Potassium uptake (kg ha\(^{-1}\)) |
|-----------------------------|-----------------------------------|------------------------------------|----------------------------------|
|                             | Main crop | Intercrop | Total | Main crop | Intercrop | Total | Main crop | Intercrop | Total |
| Banana + Cowpea             | 208.3     | 109.2     | 317.5 | 21.7      | 12.8      | 34.5  | 319.1     | 74.5     | 393.6 |
| Banana + Horse gram         | 196.2     | 93.5      | 289.7 | 21.4      | 12.3      | 33.7  | 316.6     | 71.4     | 388.0 |
| Banana + Bottle gourd       | 190.3     | 62.7      | 253.0 | 17.8      | 10.6      | 28.4  | 296.8     | 66.7     | 363.5 |
| Banana + Sweet potato       | 191.1     | 67.5      | 258.6 | 18.5      | 10.9      | 29.4  | 291.3     | 64.4     | 355.7 |
| Banana + Glyricidia maculeata | 212.5     | -         | 212.5 | 21.7      | -         | 21.7  | 321.6     | -        | 321.6 |
| Banana + Polythene mulch    | 188.6     | -         | 188.6 | 19.3      | -         | 19.3  | 306.6     | -        | 306.6 |
| Banana (Control)            | 168.9     | -         | 168.9 | 18.9      | -         | 18.9  | 281.8     | -        | 281.8 |
| SEM(±)                      |           |           | 10.17 |           | 2.897     |       | 14.433    |           |       |
| CD (P = 0.05)               |           |           | 20.95 |           | 5.97      |       | 29.73     |           |       |

Table 2: Effect of banana based cropping system on soil properties

| Treatments                  | pH (1:2.5) | BD (Mg m\(^{-3}\)) | WHC (%) | SOC (g kg\(^{-1}\)) | MBC (µg C g\(^{-1}\) soil) |
|-----------------------------|------------|--------------------|---------|----------------------|----------------------------|
| Banana + Cowpea             | 5.45       | 1.43               | 46.4    | 7.8                  | 192.4                      |
| Banana + Horse gram         | 5.44       | 1.43               | 46.0    | 7.7                  | 190.2                      |
| Banana + Bottle gourd       | 5.48       | 1.45               | 44.6    | 6.5                  | 158.4                      |
| Banana + Sweet potato       | 5.49       | 1.45               | 44.2    | 6.4                  | 154.2                      |
| Banana + Glyricidiamaculeata | 5.42      | 1.42               | 47.2    | 8.3                  | 208.9                      |
| Banana + Polythene mulch    | 5.50       | 1.47               | 43.4    | 6.2                  | 138.4                      |
| Banana (Control)            | 5.51       | 1.46               | 43.1    | 6.1                  | 136.8                      |
| SEM(±)                      | 0.078      | 0.016              | 1.718   | 0.280                | 5.883                      |
| CD (P = 0.05)               | NS         | NS                 | NS      | 0.86                 | 18.13                      |
| Initial status              | 5.53       | 1.46               | 43.1    | 6.0                  | 128.3                      |

BD: Bulk density, WHC: Water holding capacity, SOC: Soil organic carbon, MBC: Microbial biomass carbon
Table 3 Balance nutrient status of the soils as influenced by banana based intercrops

| Treatments                  | Nitrogen (kg ha\(^{-1}\)) | Phosphorus (kg ha\(^{-1}\)) | Potassium (kg ha\(^{-1}\)) |
|-----------------------------|----------------------------|------------------------------|-----------------------------|
|                             | Initial   | Final   | Gain/loss | Initial | Final   | Gain/loss | Initial | Final   | Gain/loss |
| Banana + Cowpea             | 273.1     | 297.4   | 24.3      | 10.5    | 10.3    | -0.2      | 93.6    | 89.4    | -4.2      |
| Banana + Horse gram         | 273.1     | 291.6   | 18.5      | 10.5    | 10.2    | -0.3      | 93.6    | 88.6    | -5.0      |
| Banana + Bottle gourd       | 273.1     | 270.5   | -2.5      | 10.5    | 10.1    | -0.4      | 93.6    | 90.7    | -2.9      |
| Banana + Sweet potato       | 273.1     | 268.2   | -4.9      | 10.5    | 9.9     | -0.6      | 93.6    | 88.6    | -5.0      |
| Banana + Glyricidiamaculeata| 273.1     | 306.4   | 33.3      | 10.5    | 14.0    | 3.4       | 93.6    | 109.4   | 15.8      |
| Banana + Polythene mulch    | 273.1     | 272.2   | -1.1      | 10.5    | 9.2     | -1.3      | 93.6    | 88.8    | -4.8      |
| Banana (Control)            | 273.1     | 263.8   | -9.3      | 10.5    | 9.1     | -1.4      | 93.6    | 87.4    | -6.2      |
| SEM(±)                      | 7.267     | 0.844   |           |         |         |           |         |         |           |
| CD (P = 0.05)               | 22.39     | 2.60    |           |         |         |           |         |         |           |

Table 4 Yield and return from the complete cycle of crops (pooled data of two years)

| Treatment                  | Banana yield (t ha\(^{-1}\)) | Intercrop yield (t ha\(^{-1}\)) | Equivalent banana yield from intercrop (t ha\(^{-1}\)) | Total equivalent banana yield (t ha\(^{-1}\)) | Total gross return (Rs.) | Total cost of cultivation (Rs.) | Total net return (Rs.) | Benefit: cost of the complete crop cycle |
|----------------------------|-------------------------------|----------------------------------|-------------------------------------------------------|-----------------------------------------------|--------------------------|----------------------------------|--------------------------|----------------------------------------|
| T1 Banana + Cowpea         | 34.67                         | 4.34                             | 6.70                                                  | 41.37                                         | 434406                   | 202683                           | 231723                   | 2.14                                   |
| T2 Banana + Horse gram     | 32.54                         | 1.67                             | 3.65                                                  | 36.19                                         | 380016                   | 172265                           | 207751                   | 2.21                                   |
| T3 Banana + Bottle gourd   | 28.96                         | 9.80                             | 4.01                                                  | 32.97                                         | 346206                   | 182226                           | 163980                   | 1.90                                   |
| T4 Banana + Sweet potato   | 30.25                         | 15.06                            | 6.16                                                  | 36.42                                         | 382379                   | 199124                           | 183255                   | 1.92                                   |
| T5 Banana + G. maculeata leaves | 31.72                     | 0.00                             | 0.00                                                  | 31.72                                         | 333081                   | 162016                           | 171065                   | 2.06                                   |
| T6 Banana + Polyethylene mulch | 34.46                       | 0.00                             | 0.00                                                  | 34.46                                         | 361788                   | 223752                           | 138036                   | 1.62                                   |
| T7 Banana (Control)        | 22.41                         | 0.00                             | 0.00                                                  | 22.41                                         | 235326                   | 136239                           | 99087                    | 1.73                                   |
| CD (P = 0.05)              | 1.99                          | -                                | -                                                     | 3.01                                          | -                        | -                                | -                        | -                                      |
Legume intercropping in banana also increased the MBC of soils by 48.2 to 50.0 per cent. Elevated MBC of the soils are related to the increased soil organic matter contents that supply substrate C for proliferation of microbial population in the soil (Singh et al., 2008). The supply of additional mineralizable C due to increased organic matter results in higher microbial activity and thus higher MBC (Ingle et al., 2014). The ratio of MBC to SOC expressed as ratio or percentage is known as microbial quotient and is very often used as a measure of C availability to micro-organisms. The microbial quotient of different banana based cropping systems is presented in Figure 1. Banana with Glyricidia green manuring registered the highest microbial quotient of 2.52 followed by the intercropping of legumes (2.47 each with cowpea and horsegram). Higher microbial quotient of these soils is related to higher substrate availability through accumulation of organic matter in the soils (Jacobs et al., 2009).

**Balance nutrient status of the soil**

The residual nutrient status of the soils after two years of different banana based cropping systems is presented in Table 3. Growing of *Glyricidia* as a green manure crop in banana elevated the available N, P and K contents of the soil and the gain was to the tune of 33.3, 3.4 and 15.8 kg ha\(^{-1}\), respectively over the initial contents of 273.1 kg ha\(^{-1}\) N, 10.5 kg ha\(^{-1}\) P and 93.6 kg ha\(^{-1}\) K. Inclusion of legumes like cowpea and horsegram also improved the available N contents with gain of 24.3 and 18.5 kg ha\(^{-1}\), respectively. Increase in available N, P and K contents of the soils with green manuring is due to the decomposition of organic matter and converting the organic...
bound nutrients to inorganic forms during mineralization (Vanialarasu and Balakrishnamurthy, 2014). Inclusion of legumes has contributed higher nitrogen fixation resulting in availability of more residual N in the soils (Himmatrao et al., 2014). However, there was mining of available soil P and K as they were actively utilized by both banana and intercrops.

Yield

The banana bunch yield was in the range of a lowest 22.41 t ha\(^{-1}\) in T\(_7\) to a highest 34.67 t ha\(^{-1}\) in T\(_1\) (Table 4). Highest banana bunch weight with cowpea was at par with that under polyethylene mulch. High bunch yield under polythene mulch was observed due to very less incidence of weeds which is confirmed by Paul et al., (2008) and Solia et al., (2010). Increased bunch yield from banana plants intercropped with cowpea was probably due to increased nitrogen availability through nitrogen fixation by their root nodules in the soil.

Economics

The results show a significant difference among the treatments in total BEY from the complete cycle of crops (Table 4). T\(_1\) achieved a significantly highest yield of 41.37 t ha\(^{-1}\) followed by T\(_2\) with 36.19 t ha\(^{-1}\), whereas, T\(_7\) showed the least (22.41 t ha\(^{-1}\)). Following a similar trend, T\(_1\), T\(_2\) and T\(_7\) could generate a total net return of Rs. 231723 ha\(^{-1}\), Rs. 207751 ha\(^{-1}\) and Rs. 99087 ha\(^{-1}\), respectively. But, a critical economic analysis of the complete crop cycle indicated that the highest benefit: cost ratio (return per rupee investment) of 2.21 is obtained in T\(_2\) followed by 2.14 in T\(_1\), 2.06 in T\(_3\) and a lowest of 1.62 in T\(_6\). The lowest C: B ratio under polyethylene mulch is due to the high cost of cultivation from polyethylene mulch sheets and no returns from any intercrop. Similar results have also been reported by Jain and Raut (2004).

The study on the effect of intercrops on banana based intercropping systems revealed that inclusion of green manures in the cropping system is beneficial in improving SOC, MBC and available nutrients of the soil and maintaining overall soil quality. Banana with legume intercrops, though improved the SOC and available N of the soils, there was depletion of available P and K from the soils. In accordance with the improvement in soil qualities and nutrient status the leguminous vegetable cowpea could yield highest total banana equivalent yield (41.37 t ha\(^{-1}\)) and fetch highest net return (Rs. 231723 ha\(^{-1}\)) whereas horsegram could achieve highest cost: benefit ratio (2.21) in view of its low cost of cultivation.

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