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**Research article**

# Evaluating growth attributes and soil heath under long term implementation of organic farming in fodder cowpea

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## Abstract

A study was conducted to evaluate the impact of organic and conventional production system on fodder cowpea growth and soil health. This study was conducted in a farmers field of Erode, Tamil Nadu in a randomized block design with three replications. For the study, six farmers' fields involving organic (ORG) practices and one conventional (CON) production system were selected. Soil and plant samples were collected at the time of harvest and analyzed for growth, and soil health parameters. The results revealed that significant differences were found in the growth parameters of fodder cowpea among the organic and conventional production system. The analyzed chemical properties *viz*., soil reaction, electrical conductivity (EC), macro nutrients, and biological indicators *viz*., soil organic carbon (SOC), organic matter (SOM), microbial biomass carbon (MBC), culturable microbes, and yield were found to be higher in organically managed soils than the conventional farming method.

**Keywords:** Conventional farming, Cowpea, Organic farming, Soil health, Yield

## Introduction

Environmental concerns have prompted scientists, farmers, and policymakers around the world to consider alternate farming methods, which has sparked interest in organic farming. For continuous nutrient supply, the organic method of cultivation relies on farm-based organic inputs and farm waste recycling, as well as a cropping system and biological pest management strategies. With the tremendous rise in interest in organic farming, India is now one of the world's leading organic farming countries (3.42 million ha) and ranks ninth in the world. India is also the world's leading organic producer (ranked 1), with 8,35,000 numbers. Growing worries about the environment and human health have sparked interest in organic agriculture, which has grown increasingly popular, with acreage under cultivation gradually expanding in Tamil Nadu (31687 acres in 2018-19). Over the last ten years, certified farmers in the State's western agro-climatic zone have increased to fulfil market demands.

The impact of organic agricultural practices on the physical, chemical and biological aspects of the soil has not been studied in Tamil Nadu. Due to flexible crop rotations, less application of synthetic nutrients and the absence of pesticides, several studies from various countries found that organic farming increased soil quality with higher microbiological activities than conventional farming (Srinivasan *et al*., 2016). Organic fields have a suitable pH, organic carbon and nitrogen and its mineralization capacity, as well as actinobacteria quantity and diversity, according to Suja *et al*. (2017).

Pulse crops are the second most important group of food crops of mankind after cereals. Pulse cultivation can be done in locations with little to no rain because it doesn't require extensive irrigation. From an environmental standpoint, pulses can boost soil fertility and fix atmospheric nitrogen, which lessens farmers' reliance on fertilizers. The main advantages of pulses over other cultivated crops are their high nutritional content, use as forage and fodder, improvement of soil fertility, and their capacity to be intercropped without using much water (Day, 2013). Recently there has been a great demand for organically produced pulses among affluent Asians and Africans living in Europe, USA and Middle East. Cowpea is a vital pulse crop for food security and population health around the globe with major nutritional and nutraceutical qualities (Hall Anthony, 2012). In less developed regions, it is primarily planted for grain and leaves, and occasionally for green pods (Gerrano *et al*., 2017). Cowpea is a potential climate resilient food legume for the twenty-first century because of its high protein content, capacity for fixing nitrogen, resistance to drought, and ability to thrive in harsh environments. In Tamil Nadu, intercropping of cowpea is still practiced, but the majority of the crop is produced under sole-cropping with either organic or chemical inputs. The performance of cowpea as a fodder under the organic farming is still unknown. With this background, the present study was conducted to assess the impact of organic vs conventional production system on fodder cowpea growth and soil health.

**Materials and Methods**

***Study area:*** The experiment consists of seven farmers field as treatments which include six organic farming system (ORG 1 to 6) varying in number of years belong to organic farming and one conventional farming system (CON) was selected for the study from Erode district of Tamil Nadu State during September, 2020. The management methods (as treatments) practiced in the two production system were recorded (Table 1).

***Growth and yield characters:*** The growth characters (shoot length, root length, number of nodules, nodule dry weight, dry matter, nodule number, nodule dry weight, biomass) and yield attributes (pod numbers, pod weight) were recorded at harvest stage. Vegetable pod yield was assessed in the single plot and converted to a hectare area.

***Soil sample collection:*** Soils were collected from diferent treatments immediately after harvest of cowpea adopting a random sampling technique at two diferent soil depths (top soil: 0 to 15 cm). Sampling points in each site were demarcated in a random manner to have a representative sample collection from the entire feld using a core sampler. The collected soil samples from diferent points in each treatment were cleared of any organic debris; pooled, homogenized, and flled in clean polyethylene bags; and labeled and brought to the laboratory for analyses. In the laboratory, the fresh samples from each site were portioned into two halves. One portion was stored in a deep freezer for microbial analysis, and another portion was air dried, processed (<2 and 0.5 mm), and stored at 4 °C for each plot for performing other analysis.

***Physio-chemical properties*:** Soil pH and EC were determined using a soil suspension of 1:2.5 ratios. Soil organic carbon (SOC) was determined by dichromate oxidation (Walkley and Black, 1934). Soil mineralizable or available nitrogen (N) was extracted with 2 M KCl for 1 h and determined by Kjeldahl method (Waring and Bremner, 1964). Available phosphorus (P) was extracted with Olsen's reagent [0.5 M $NaHCO_3$ (pH 8.5)] using soil-extractant ratio of 1:10, quantified by molybdenum–blue colorimetry (Olsen, 1954). Available potassium (K) was extracted with neutral normal ammonium acetate (pH 7.0), measured by flame photometry (Stanford and English, 1949). The fumigation-extraction method (Vance *et al*., 1987) was adopted to determine soil microbial biomass carbon (MBC) using kEC of 0.45.

***Culturable microbe analysis:*** Collected soil samples were enumerated for total culturable aerobic bacteria (TCB), fungi (TCF), actinobacteria (ACT) in soil extract agar medium, potato dextrose agar medium and Kenknight's agar medium, respectively, following dilution plating viable count method (Weaver *et al*., 1994).

***Statistical analysis:*** The study was carried out in a randomized block design with three replicates. Statistical analyses were carried out using IBM SPSS Statistics 25 for Windows (IBM, Inc., Armonk, NY, USA) and results were expressed as mean values with standard error (SE) of three replicated analysis. The significant differences between means were identified using Fisher least significant differences (LSD) at P = 0.05.

**Results and Discussion**

***Growth performance:*** The growth attributes of cowpea *viz*., shoot and root length were significantly (P<0.05 and P<0.01) impacted by production systems (Table 2). In comparison to CON, the mean shoot and root lengths of ORG fields are increased by 11% and 4%, respectively. This might be due to the availability of nutrients from inorganic sources and favourable conditions to facilitate uptake of plant nutrients by the crop. An initial boost of nitrogen, which might have helped in higher chlorophyll formation and ultimately higher photosynthesis resulted in more shoot length (Joshi *et al*., 2016).

The increase in nodule number (11%) and nodule dry weight (37%) with biofertiliser and enriched compost application was due to their multiplication in the roots

**Table 1.** Crop management practices adopted in selected fodder cowpea fields

| Agronomic practices | ORG 1 | ORG 2 | ORG 3 | ORG 4 | ORG 5 | ORG 6 | CON |
|---|---|---|---|---|---|---|---|
| Years of organic farming | 5 years | 12 years | 10 years | 5 years | 4 years | 7 years | Regular conventional |
| Soil health | Green manure incorporation @ 25kg/ha | Cumbu incorporation @ 25kg/ha | Green manure incorporation @ 25kg/ha, sheep penning | Green manure incorporation @ 25kg/ha | Waste decomposer @litre/ha | Cumbu incorporation @ 25kg/ha | FYM 12.5t/ha |
| Nutrient management | Biofertilisers (2kg), enriched vermicompost (1 ton), FYM (5 ton) | Enriched vermicompost (1 ton) | Enriched vermicompost (1 ton) | FYM (8 ton) | Cow dung solution and cow urine (2:1) | Jeevamirtham (200 litres), EFYM (1 ton) | Fertilizers |
| Micronutrient deficiency | Panchagavya (3%) | *Amudham* solution (7%) | Fermented plant extract (2%) | *Amudham* solution (7%) | *Panchagavya* (3%) | Fermented plant extract (5%) | $ZnSO_4$, $Fe_2SO_4$, DAP |
| Irrigation | Drip | Drip | Drip | Drip | Drip | Drip | Drip |
| Growth promotion | Panchagavya (3%) | *Amudham* solution (7%) | Fermented plant extract (2%) | *Amudham* solution (7%) | *Panchagavya* (3%) | Fermented plant extract (5%) | Nil |
| Weed control | Mulching @ 1 ton | Mulching @ 1 ton | Mulching @ 1 ton | Hand weeding (2 times) | Hand weeding (2 times) | Mechanical weeding (2 times) | Pendimethalin @ 3.5 L a.i./ha |
| Pest control | 3G extract (Garlic, chilli, ginger extract) @ 5% | Biocontrol agents | Biocontrol agents | Biocontrol agents | Biocontrol agents | Biocontrol agents 3G extract, | Dimethoate 30 EC 500ml $ha^{-1}$ and Imidochloprid 17.8 SL 100-125 ml $ha^{-1}$ |

to form nodules (Table 2). Organic seed treatment helped in improving nodules in the plant. This increase was due to their penetration through root hairs to the root cortex. Their colonization as bacteroids helped in nodule formation. Nodules were also formed in uninoculated CON plants too. However, the strains responsible for nodule formation were lower in soil, thus their nodule numbers were low and also their dry weight. The total biomass production was higher (15%) under organic management. The general growth promoting effect of organic sources might have contributed to the greater total biomass production and its effective partitioning to the storage structures.

***Yield attributes and yield:*** The pod numbers of fodder cow pea did not show any variation due to the production systems (Table 3). However, higher number of pods were observed with ORG 3 which was put under organic cultivation for 12 years. Regarding pod weight, significantly higher pod weight was associated with ORG 2 which was on par with ORG 3. In a similar way, higher pod yield was observed with ORG 2 which was 20% higher over CON. The major soil health parameters attributed to the higher yield were good aggregation, reduced bulk density, increased SOM content, higher microbial and enzyme activity and essentially the increased availability of nutrients which were contributed to betterment in ORG 2. Organic source of nutrient helped the soil to retain moisture and nutrients while also enhancing soil quality indicators, all of which had a significant impact on the yield. Therefore, individual farmer's nutrient management practice appeared to be more significant in realizing high yield.

***Soil pH and EC:*** Soil reaction (pH) was not significantly ($P<0.05$) influenced by the different nutrient management practices (Table 4). In general, soil pH values were neutral in all the ORG soils, mean soil pH of ORG soils ranged from 7.00 to 7.90 and interestingly soil reaction tended to decrease to neutral with organic nutrient management practices. Bulluck *et al*. (2002) observed that soils with alternate

**Table 2.** Influence of organic and conventional production system on fodder cowpea growth attributes

| Production system | Shoot length (cm plant$^{-1}$) | Root length (cm plant$^{-1}$) | Number of nodules plant$^{-1}$ | Nodule dry weight (mg plant$^{-1}$) | Total dry matter accumulation (g plant$^{-1}$) |
|---|---|---|---|---|---|
| ORG 1 | 56.5 ± 0.30$^{abc}$ | 17.7 ± 0.24$^{a}$ | 4.1 ± 0.06$^{bcd}$ | 3.02 ± 0.04$^{cd}$ | 32.5 ± 0.45$^{abc}$ |
| ORG 2 | 61.5 ± 4.24$^{a}$ | 18.1 ± 0.10$^{a}$ | 4.5 ± 0.02$^{a}$ | 3.31 ± 0.02$^{ab}$ | 34.5 ± 0.18$^{a}$ |
| ORG 3 | 60.8 ± 0.99$^{a}$ | 17.8 ± 0.22$^{a}$ | 4.2 ± 0.05$^{abc}$ | 3.38 ± 0.04$^{a}$ | 33.9 ± 0.42$^{ab}$ |
| ORG 4 | 53.4 ± 0.66$^{bc}$ | 15.4 ± 0.25$^{b}$ | 4.4 ± 0.07$^{ab}$ | 3.11 ± 0.05$^{bcd}$ | 30.8 ± 0.50$^{c}$ |
| ORG 5 | 54.1 ± 0.25$^{bc}$ | 15.3 ± 1.05$^{bc}$ | 3.9 ± 0.27$^{cd}$ | 2.91 ± 0.20$^{d}$ | 29.9 ± 2.06$^{cd}$ |
| ORG 6 | 57.8 ± 0.21$^{ab}$ | 16.3 ± 0.08$^{bc}$ | 3.9 ± 0.02$^{cd}$ | 3.19 ± 0.01$^{abc}$ | 31.8 ± 0.15$^{bc}$ |
| CON | 51.8 ± 0.71$^{c}$ | 14.8 ± 0.05$^{c}$ | 3.7 ± 0.01$^{d}$ | 2.30 ± 0.01$^{e}$ | 27.9 ± 0.10$^{d}$ |

Data are the mean values of three replicates with±standard error; Means followed by the same letter within each column are not significantly different at 5% level; ORG: Organic production; CON: Conventional production.

**Table 3.** Influence of organic and conventional production system on fodder cowpea yield attributes and yield

| Production system | Pod numbers$^{ns}$ | Pod weight (g) | Green fodder yield (t ha$^{-1}$) |
|---|---|---|---|
| ORG 1 | 48.8 ± 2.19 | 136.1 ± 1.87$^{bcd}$ | 6.70 ± 0.09$^{bcd}$ |
| ORG 2 | 53.7 ± 2.94 | 148.9 ± 0.79$^{a}$ | 7.35 ± 0.04$^{a}$ |
| ORG 3 | 55.1 ± 3.29 | 147.0 ± 1.82$^{ab}$ | 7.25 ± 0.09$^{ab}$ |
| ORG 4 | 44.1 ± 3.13 | 132.7 ± 2.16$^{cd}$ | 6.54 ± 0.02$^{cd}$ |
| ORG 5 | 43.1 ± 2.21 | 129.9 ± 2.82$^{cd}$ | 6.39 ± 0.44$^{d}$ |
| ORG 6 | 47.1 ± 1.44 | 138.9 ± 0.65$^{abc}$ | 6.85 ± 0.03$^{abc}$ |
| CON | 40.9 ± 2.16 | 124.4 ± 0.45$^{d}$ | 6.27 ± 0.11$^{cd}$ |

Data are the mean values of three replicates with±standard error; Means followed by the same letter within each column are not signifcantly diferent at 0.05 level; NS: Non-significant; ORG: Organic production; CON: Conventional production amendments had a lower soil pH than soils with synthetic fertilizers. The pH (8.72) of CON was higher showing the effect of continuous use of synthetic fertilizers.

Regardless of the effects of different nutrient management practices, the best nutrient regime for decreasing EC was ORG 2 and could be attributed to the continuous practice of organic management for more than 12 years. Inorganic fertilizers applied (CON) soils had significantly higher EC (Table 4). Accumulation of salts from the continuous application of synthetic chemical fertilizers or pesticides might increase the EC levels in conventionally managed soils (Velmourougane, 2016).

***Available nutrients:*** The nutrient availability (N, P, K) was significantly higher in ORG soils than conventional soil (Table 5). The continuous incorporation of more nitrogen rich biomass through green manures, crop residues and manures increased the availability of mineral N as demonstrated by Marschner *et al*. (2003). Organic acids released during the decomposition of retained crop residues, might have solubilized the native soil phosphorous. In similar way, the addition of organic manures increased K availability in soil by reducing leaching losses and increasing the labile pool in soil (Partey *et al*., 2014). The loss of nitrogen through leaching, fixation etc could be the cause for low availability of N under mineral fertilizers amended CON soil (Diez *et al*., 1997).

***Soil organic carbon and matter***: On an average, the SOC in ORG soils was observed to be 161% higher over CON soil (Table 5). The current study demonstrated that the longer the site was detained under organic management, the higher was the soil organic C, concurring with the previous research (Meng *et al.,* 2005). Though study sites were under the tropical region where the decomposition takes place at a faster rate led to low retention of soil organic matter, ORG soils were able to sequester and

**Table 4.** Changes in physio- chemical parameters of fodder cowpea cultivated soils influenced by organic and conventional production system

| Production system | pH | EC (dS $m^{-1}$) | SOC (g $kg^{-1}$) | SOM (g $kg^{-1}$) | Mineral N (kg $ha^{-1}$) | Available P (kg $ha^{-1}$) | Exchangeable K (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| ORG 1 | 7.90 ± 0.68$^{ns}$ | 0.54 ± 0.05$^{bc}$ | 11.5 ± 0.16$^{c}$ | 19.7 ± 0.27$^{c}$ | 269 ± 23.1$^{bc}$ | 49 ± 4.21$^{c}$ | 329 ± 28.3$^{cd}$ |
| ORG 2 | 6.97 ± 0.64$^{ns}$ | 0.36 ± 0.03$^{d}$ | 14.3 ± 0.08$^{a}$ | 24.6 ± 0.13$^{a}$ | 346 ± 31.8$^{a}$ | 61 ± 5.57$^{ab}$ | 446 ± 41.1$^{a}$ |
| ORG 3 | 7.24 ± 0.43$^{ns}$ | 0.39 ± 0.02$^{d}$ | 13.6 ± 0.17$^{ab}$ | 23.4 ± 0.29$^{ab}$ | 327 ± 19.5$^{ab}$ | 67 ± 3.99$^{a}$ | 406 ± 24.2$^{ab}$ |
| ORG 4 | 7.60 ± 0.54$^{ns}$ | 0.65 ± 0.05$^{b}$ | 10.9 ± 0.18$^{c}$ | 18.7 ± 0.30$^{c}$ | 241 ± 17.1$^{cd}$ | 38 ± 2.70$^{d}$ | 324 ± 23.0$^{cd}$ |
| ORG 5 | 7.77 ± 0.40$^{ns}$ | 0.55 ± 0.03$^{bc}$ | 9.9 ± 0.68$^{d}$ | 17.0 ± 1.17$^{d}$ | 229 ± 11.7$^{cd}$ | 30 ± 1.54$^{d}$ | 262 ± 13.4$^{de}$ |
| ORG 6 | 7.49 ± 0.23$^{ns}$ | 0.53 ± 0.02$^{c}$ | 13.0 ± 0.06$^{b}$ | 22.3 ± 0.11$^{b}$ | 251 ± 7.70$^{cd}$ | 55 ± 1.69$^{bc}$ | 345 ± 10.6$^{bc}$ |
| CON | 8.72 ± 0.46$^{ns}$ | 0.99 ± 0.05$^{a}$ | 4.2 ± 0.01$^{e}$ | 7.20 ± 0.03$^{e}$ | 195 ± 10.3$^{d}$ | 17 ± 0.91$^{e}$ | 236 ± 12.5$^{e}$ |

Data are the mean values of three replicates with±standard error; Means followed by the same letter within each row are not significantly different at 5% level; NS: Non-significant; ORG: Organic production; CON: Conventional production

**Table 5.** Microbial biomass carbon and colony forming units of culturable microbes of fodder cowpea cultivated soils as influenced by organic and conventional production system

| Farm | Microbial biomass carbon (mg $kg^{-1}$) | Bacterial population (CFU x $10^6$ $g^{-1}$ soil) | Fungal population (CFU x $10^3$ $g^{-1}$ soil) | Actinobacteria (CFU x $10^5$ $g^{-1}$ soil) |
|---|---|---|---|---|
| ORG 1 | 348 ± 29.9$^{abc}$ | 62.6 ± 5.38$^{b}$ | 30.0 ± 2.58$^{ab}$ | 29.6 ± 0.41$^{b}$ |
| ORG 2 | 412 ± 37.9$^{a}$ | 100.9 ± 9.29$^{a}$ | 32.4 ± 2.98$^{ab}$ | 33.7 ± 0.18$^{a}$ |
| ORG 3 | 394 ± 23.5$^{ab}$ | 94.9 ± 5.66$^{a}$ | 34.6 ± 2.06$^{a}$ | 34.8 ± 0.43$^{a}$ |
| ORG 4 | 343 ± 24.3$^{bc}$ | 85.3 ± 6.05$^{a}$ | 28.4 ± 2.01$^{b}$ | 30.3 ± 0.49$^{b}$ |
| ORG 5 | 310 ± 11.7$^{c}$ | 67.8 ± 3.48$^{b}$ | 27.1 ± 1.03$^{b}$ | 24.8 ± 1.71$^{c}$ |
| ORG 6 | 376 ± 17.0$^{abc}$ | 86.6 ± 2.66$^{a}$ | 28.6 ± 1.29$^{b}$ | 19.5 ± 0.09$^{d}$ |
| CON | 117 ± 6.2$^{d}$ | 27.2 ± 1.44$^{c}$ | 9.60 ± 0.51$^{c}$ | 13.9 ± 0.05$^{e}$ |

Data are the mean values of three replicates with±standard error; Means followed by the same letter within each column are not significantly different at 5% level; ORG: Organic production; CON: Conventional production maintain higher SOM. The retention of biomass in soils under ORG led to accumulation of more SOC. This was highlighted by Kumar *et al*. (2021). The results showed that continuous cultivation of CON soil could accelerate depletion of the soil organic carbon without the addition of carbon biomass in soil and chemical fertilization reduced the SOC accumulation (Hamer *et al*., 2009). The findings confirmed that diversified sources of organic inputs with sufficient carbon inputs as supplements in a routine manner over the years were a vital key for improvement of SOC, thus SOM. Hence, a number of years of practicing organic farming with various sources of organic inputs were identified as a strong factor for maintaining soil organic matter perhaps other related soil indicators. Meena *et al*. (2017) reported that increase in organic carbon when manures were applied in a integrated manner.

***Soil microbial biomass carbon:*** The average values of the ORG soils for MBC ranged from 367 mg/kg in the ORG 6 to 587 mg/kg in ORG 2 (Table 5). An increase in soil microbial biomass carbon with the adoption of organic farming and could be ascribed to the steady source of organic C by the continuous supply of additional mineralizable nutrients for microbial build up and in turn to microbial biomass carbon. This was witnessed in the study where the ORG farmers were leaving all the harvested residues and mulched materials in the soil, which ultimately enhanced the soil MBC compared to CON soil where residues were not returned back to the field. It was identified that the ORG soils influenced the MBC but not all ORG soils affected the MBC value to the same degree. This could be ascribed to the variation in the number of years of practicing organic farming among the ORG soils. Hence, the number of years under organic farming was also an essential parameter to maintain the MBC in addition to the diversified sources of manures for high SOM.

The magnitude of increase in microbial population over the CON soil were 191, 180 and 282% for bacteria, fungi and actinobacteria, respectively in ORG soils (taken as a mean of all ORG soils) (Table 5). The continuous addition of organic substrates in ORG soils acted as a food and energy source for microbes (Bunemann *et al*., 2006) which resulted in rapid stimulation of microbial growth and subsequent increase in their population. This was in line with the fndings of Suja *et al*. (2017) who observed a similar increase in microbial biomass and activity in the organic farming feld compared with chemical fertilizer enforced soils. The results of the present study suggested that the SOM controls the population of soil-dwelling microfauna. The microbial activity and numbers were decreased in the CON soil because they did not leave crop residue in the soil and did not add adequate SOM.

## Conclusion

Despite the fact that there is significant debate about organic vs. conventional agriculture, the current study showed that organic management of fodder cowpea was an environmentally benign choice for reliable yields and high-quality fodder cowpea production with minimal soil degradation. The soil properties were also improved under an organic system in fodder cowpea. The present study also demonstrated that for a less nutrient required crop like fodder cowpea, higher yield coud be obtained by using cheaper and on-site generated organic manures, and green manure. In addition, a number of years of practicing organic farming with various sources of organic inputs were identified as a strong factor for maintaining soil organic matter.

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