**Aerobic Composting of Sapropel with Cow Manure: Efficiency as Organic-mineral Fertilizer**

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**Abstract.** In this study, we evaluated aerobic composting of lake sapropel from the Syrdarya region (Uzbekistan) mixed with cattle manure (70:30 ratio) to improve its agrochemical properties and evaluate the agronomic efficiency of organic organo-mineral fertilizer produced on cotton (Gossypium hirsutum L.). By the end of 150 days of composting, pH (7.30-7.15) and moisture (42-43%) remained stable with relative increasing content of humic (2.87-3.33%), fulvic (2.97-3.44%) and water-soluble organic matter (2.80-3.25%), suggesting that the material has obtained intense humification and establishment of a stable humus complex. The compost maturity was obtained in 90-105 days. In vegetative trials, both raw sapropel and the composted mix stimulated cotton growth and yields, but the stimulatory effect of compost appeared stronger, causing a 10.9% improvement in seed yield and boll mass value, compared to NPK control, and an earlier maturation of boll and fiber. In combining sapropel-manure compost, an improved use of organic waste is achieved and a non-traditional resource of great value is introduced into the sustainable farming sector. These results emphasize the effective agronomic potential of sapropel compost to perform as a sustainable soil amendment for cotton cultivation under arid conditions.

**Keywords:** sapropel; composting; organo-mineral fertilizer; humic substances; cotton yield; soil fertility; sustainable agriculture; Uzbekistan

**INTRODUCTION**

By the green technology perspective, this has been an effective and technically feasible challenge to improve green technologies in the enrichment of sapropel. The combination of mechanical (mechanical grinding, drying), chemical, and biochemical processes in addition to process improvements can be highly effective in the recovery of precious components, reducing the extraction time, the energy and reagents and producing more environmentally friendly products. Scientific papers on the application of sapropel based products such as mixtures, composts, organo-mineral fertilizers, soil-enhancing preparations etc., have been increasing very recently. Yet, such studies exhibit considerable variability in the methodology used and based on the origin, composition and pre-treatment of the raw material as well as combinations of the selected constituent, as well as the desired final products [1-3]. Interests in sapropel as local organic material has increased significantly in the last decades [4-5]. Sapropel has been used as an independent fertilizer, compost and organo-mineral mixture addition, the extracts of sapropel have been studied as biostimulants in seed pre-treatment and foliar application [4-5]. Especially in depleted and alkaline soils, an improved effect of using sapropel directly to soil can be observed, be it as an ameliorant or organic fertilizer, either pure or a dried or granulated product. This approach, however, has the limitation of requiring large amounts of application and the efficiency greatly relied upon the original organic matter content of the sapropel. Sapropel-based mixtures and composts are better solutions, making them more suitable for modifying the composition of the final product, enhancing organic matter, and adding macronutrient as required by soil and crop needs. Generally sapropel is composted with manure, straw, wood residues or biowaste [6, 7]. Integration of the compost into soil is not only replacing various organo-mineral parts of the soil but also provides physiologically active parts, such as humic and amino acids, enzymes, hormone-like compounds, and beneficial soil microorganisms. Reviews of composting consistently point to the effectiveness of compost amendments as ground conditioners and mulches. Sapropel is used in restoring soil that has been eroded or salinated, especially when used, as liming or biochar that increase the permeability and lessen plant stress [8, 9]. Furthermore, sapropel contributes to carbon sequestration and restoration of soil biota. In a number of projects, soil structure, organic matter accumulation and some indicators of crop yield improve in favour of sapropel, are reported [10-12]. Moreover, sapropel has bioavailable silicon that enhances plant growth and resistance to various stress. However, the efficiency and practicality of these applications is strongly influenced by the source of material, and application rates and use methods of sapropel material. Safety concerns, including potential to contribute heavy metals, organic contaminants, microbial contamination and the requirement for raw material homogenization [13, 14], are just as important. Considering the increasing market requirements for alternative sources of organomineral fertilizers, in consideration of the need to use non-conventional raw materials to meet such demand, the aim of this research study was to evaluate the efficiency of generating organomineral fertilizers derived from composted sapropel deposits in Uzbekistan and cattle manure, as well as to verify its applicability in the new agricultural technologies. Organizing, applying and storing is the core of fertilizer industry.

Sapropel was taken from the Gayrat Fayzli Dalasi fish farm, in the Syrdarya region of Uzbekistan, at a freshwater lake source. Sampling was performed from the lake bottom and shoreline in February 2024. At collection time, ambient temperature was 12 °C, relative humidity 55%, and atmospheric pressure was 632 mm Hg. Cattle manure was collected during the same period from the same farm. The raw materials, sapropel and manure, have been given their initial physicochemical composition in Table 1.

**TABLE 1**.The material composition of sapropel, %

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Initial components** | **pH of 10% suspension** | **Moisture, %** | **OM** | **HA** | **FA** | **WOM** | **NOR** | **Ash** | **N** | **C** | **С/N** |
| Syrdarya Sapropel | 7.24 | 2.01 | 9.49 | 4.85 | 3.74 | 0.33 | 0.57 | 54.75 | 0.36 | 0.73 | 2.03 |
| Cattle manure | 7.25 | 19.01 | 54.2 | 4.85 | 6.42 | 6.06 | 18.68 | 26.75 | 0.96 | 7.07 | 7.3 |

*Note: here and later OM - Organic Matter; HA - Humic acid; FA –Fulvic acid; WOM - Water-soluble Organic Matter; NOR -Non-hydrolysable Organic Residue; N - Nitrogen; C - Carbon; С/N- Carbon/Nitrogen rate*

Before using the compost mix, sapropel was pre-dried at 80 °C and crushed into 2-3 mm particles. Air-dried cattle manure was also ground down to a 3-5 mm particle size. Each component was mixed 70 parts sapropel to 30 parts manure (by weight) and the particles were made whole. The resultant mixture was thoroughly moistened up to about 50% of its maximum water-holding capacity and incubated under aerobic conditions for 150 days. Biochemical analyses were done on samples every 15 days to measure the changes in some essential physicochemical parameters throughout the composting process. Moisture content of the sapropel, manure and compost samples is determined gravimetrically following GOST 26712-85. The mass fraction of organic matter (OM) was determined based on GOST 27980-80 and GOST R 54000-2010 [15-17]. Measurement of pH was carried out electrometrically with a Mettler Toledo FiveGo pH meter (Switzerland) in a 10% (w/v) aqueous suspension. Humic acids (HA) were extracted with 0.1 N NaOH at a temperature not exceeding 80 °C for 24 h.

The alkaline extract was acidified to pH 2 with concentrated hydrochloric acid and the precipitate was filtered and weighed for determining HA values [18, 19]. The fulvic acid (FA) content was identified by determination of the difference between amount of alkali-soluble organic matter and humic acids [20]. The amount of water-soluble organic matter (WOM), which was obtained by heating sapropel samples in a water bath at ≤ 80 °C for 2 h, was categorized as the non-hydrolyzable organic residue (NOR), being the difference between alkali-soluble and alkali-insoluble organic fractions. Total nitrogen was calculated using the Kjeldahl method [20, 21]. The overall chemical equation can be briefly expressed as (see Fig.1):

|  |
| --- |
| catalyst distillation titration  **Organic –N (NH4)2 SO4** **NH3 N (**is determined **)**  H2SO4 NaOH H3BO3 |

**FIGURE 1.** The overall chemical equation of the calculation of total nitrogen.

Chemical composition analyses and composting experiments were performed in triplicate for every composite sample. Table 2 presents the temporal dynamics of compost composition during maturation.

**RESULTS AND DISCUSSION**

Throughout the composting of the manure-sapropel mix the physicochemical characteristics showed uniformity of the various permafloric compositions, indicating each state or phase of organic matter biotransformation and establishment of a stable humus complex.

**TABLE 2**. Dynamics of the chemical composition of the composted mixture, %

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Mass ratio Sapropel: Cow manure** | **Moisture** | **pH of 10% suspension** | **С** | **N** | **OM** | **HA** | **FA** | **WOM** | **С/N** |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1st day sapropel | 39.50 | 7.54 | 0.73 | 0.24 | 9.25 | 1.05 | 1.09 | 1.03 | 3.05 |
| 1st day Cow manure | 19.01 | 7.25 | 7.07 | 0.96 | 54.24 | 6.20 | 6.42 | 6.06 | 7.36 |
| 1st day 70:30 | 43.20 | 7.30 | 3.44 | 0.46 | 23.76 | 2.87 | 2.97 | 2.80 | 7.48 |
| 15th day 70:30 | 46.01 | 7.32 | 3.43 | 0.45 | 24.07 | 2.75 | 2.85 | 2.68 | 7.62 |
| 30th day 70:30 | 43.10 | 7.27 | 3.47 | 0.48 | 23.47 | 2.98 | 3.08 | 2.91 | 7.23 |
| 45th day 70:30 | 43.08 | 7.25 | 3.52 | 0.51 | 23.27 | 3.10 | 3.21 | 3.03 | 6.90 |
| 60th day 70:30 | 43.04 | 7.21 | 3.54 | 0.52 | 22.92 | 3.26 | 3.37 | 3.18 | 6.81 |
| 75th day 70:30 | 43.04 | 7.21 | 3.54 | 0.52 | 22.92 | 3.26 | 3.37 | 3.18 | 6.81 |
| 90th day 70:30 | 42.95 | 7.23 | 3.55 | 0.53 | 22.79 | 3.31 | 3.42 | 3.23 | 6.70 |
| 105th day 70:30 | 42.80 | 7.21 | 3.55 | 0.55 | 22.72 | 3.32 | 3.43 | 3.24 | 6.45 |
| 120th day 70:30 | 42.26 | 7.18 | 3.61 | 0.56 | 22.71 | 3.33 | 3.44 | 3.25 | 6.45 |
| 135th day 70:30 | 42.10 | 7.15 | 3.62 | 0.57 | 22.70 | 3.33 | 3.44 | 3.25 | 6.35 |
| 150th day 70:30 | 42.05 | 7.15 | 3.62 | 0.56 | 22.70 | 3.33 | 3.44 | 3.25 | 6.46 |

The moisture content at day one (day 1) of the application mixture of compost was 43.2%; the moisture content on day 15 increased to 46.0%, and the soil was subject to microbial-mediated leachate decomposition and metabolic water. At 30 days’ moisture was stabilised at 42-43%, which was the ideal range for maturation. Correlate phenomena have also been described in aerobic composting of manure [22]. The mixture was slightly alkaline with pH 7.30 in the beginning and decreased slightly to pH 7.15-7.18 at the end of the 150-day composting period. This slow decrease is characteristic of the maturing of compost and matches the date of ammonification-humic acid conversion and completion of the active mineralization transition. Similar pH regimes in the dynamics of humus complex formation have been reported in earlier work [6]. The relative amount of total C in the compost mixture had a starting carbon (C) value of 3.44% and increasing slowly to 3.61 to 3.62% on the trials period of day 135 to 150. Although carbon typically diminishes during classical aerobic composting processes, this increase probably corresponds to more fixation of carbon into stable humic compounds and accumulation of humic substances that contribute to increasing the stability of the organic phase. In earlier works [8, 9] similar patterns of carbon retention and humification during compost proliferation have been observed.

The N (nitrogen) content dynamics also contribute to the indication of compost maturation. Nitrogen concentration increased from 0.46% to 0.57% over 150 days, showing the fixation of the ammonium forms within the humus and porous structures of the sapropel, as well as the reduction of nitrogen losses as ammonia after the first 30 days of observation. Increased organically bound nitrogen deposition should be considered an indicator of the steady state of the system and the transition towards a stable humus stage. Organics content ranged from 23.76% to 22.70%, confirming moderate mineralization and maintaining a significant quantity of organic phase. The stabilising influence of sapropel helps retain organic compounds and restrict excessive releases of carbon. Examination of the fractional content of humic material indicated a uniform change throughout the composting period: Humic acids (HA): 2.87% and 3.33% increase, fulvic acids (FA): 2.97% and 3.44%; Water soluble organic matter (WOM): 2.80% and 3.25%. From day 45 onwards, the composition of HA and FA were measured and were continually up continuously as a result of the active formation of humus complex, and stabilization of organic matter. Similar trends have been found in previous studies [10-14], with an increasing proportion of humic fractions becoming a good indicator of maturity of compost. The C/N ratio declined from 7.48 to 6.35 slowly after composting. Although the normal values for mature compost contain in the range of 10 to 15, the lower ratio displayed here can be seen through the high mineral nitrogen content, and the strong ammonium-fixing capacity of sapropel. Based on these findings, we suggest that the active stage of organic matter decomposition is finished at 90-105 days. Composting to the extent described above is, however, not recommended at that stage; nutrient loss occurs, but the organic humination level does not increase substantially. Finally, the manure- and sapropel-derived compost had a high degree of organic matter decomposition, stabilized pH, low C/N ratio, and enriched humic fractions, attesting the growing and appropriateness of the compost for agronomic use. Several important stages of compost formation were observed from the composition changes (see Table 3).

**TABLE 3.** The main phases of transformation of organic matter during compost maturation

|  |  |  |
| --- | --- | --- |
| **Stage** | **Period** | **Characteristics of processes** |
| **Active fermentation** | Days 1-30 | Increased humidity, ammonification, heat release, weak mineralization |
| **Humus formation** | Days 30-90 | Stabilization of pH, growth of HA and FA, accumulation of bound N |
| **Maturation (stabilization)** | Days 90-120 | Minimal changes in indicators, stabilization of composition |
| **Over-ripeness** | > Days 120 | Minor fluctuations, possible loss of biological activity |

Several indicators (moisture stabilization, pH reduction, humic and fulvic acids enhanced, and C/N ratio balance) have proven that the optimal duration of composting of the sapropel-manure mixture (70:30) is 90-105 days which produces mature compost applicable for agronomic use. The results of vegetation experiments assessing the application of this organomineral compost on cotton clearly revealed its efficacy in enhancing plant growth, development, and raw cotton yield. The experiments were performed in accordance with the design as described in plan.

1. N200P140K100;

2. N200P140K100 + sapropel 5 tones /ha;

3. N200P140K100 + compost 5 tones/ha.

As is found in this vegetative experiment, beneficial changes in phenological growth and development parameters were found. Natural sapropel application raised main stem growth by 5.8-7.2%, increased the number of fruiting branches by 2.0-7.0%, raised the number of flower buds by 8.2%, and also produced over 150 bushy boll growth and raised raw cotton yield by 6.1%. The compost application using a rate of same as natural sapropel increased, the parameters even improved by 6.2-10% with raw cotton crop yield increasing by 10.9% vs NPK control. Interestingly, under compost treatment, cotton matured earlier and to a greater extent, with as much as 93% of the crop yield collected on the first picking. These findings are in accordance with previous researches [11, 12, 23, 24] which showed an accelerated maturation of crops after incorporating organic and humus-based amendments, especially on low fertility soils. In contrast, whereas natural sapropel had a good effect on plant physiology, it only slightly prolonged the vegetative period by 7-15 days, giving 75.5% of the yield that was recorded at the first picking and 24.5% at the second picking. In addition, boll mass in composted plants was 12% higher than natural sapropel plants.

**CONCLUSION**

Aerobic composting with cattle manure was employed to enrich lake sapropel from the Syrdarya region of Uzbekistan and optimize its physicochemical and nutrient properties. Composting the sapropel-manure mixture (70:30) resulted in an increase in carbon, nitrogen, and humic fractions (humic acids, fulvic acids, and water-soluble organic matter), indicating the formation of a stable, chemically diverse humus complex. The C/N ratio falls to 6.3, which indicates that mineralization is high while the organic portion is relatively large. After 90-105 days the active decomposition phase has been finished and the benefits of continued composting were marginal. Such compost can be considered mature, stable, and appropriate for its application as an organic-mineral fertilizer. From the vegetative experiment, results indicated that both natural sapropel and the prepared compost encouraged growth and development of cotton plants. A 70:30 sapropel-manure combination compost showed a greater stimulatory effect and resulted in a 10.9% increase of raw cotton yield in comparison to the control with an accelerated maturation of fibres and bolls. Natural sapropel helped to enhance plant morphological properties but it slightly extended the vegetative period. In summary, application of sapropel-manure compost was effectively a useful agro-industrial technique to improve the yield and quality of the cotton as a whole, and it has high bioproductive activity. Also, the integration of the mixed compost facilitates usage of the valuable organic resource-cattle manure and sapropel and introduces into use of farmers.

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