The Nutrient Content of Organic Liquid Fertilizers in Zimbabwe

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ABSTRACT

This paper assessed the nutrient content of three organic liquid manures made from Water Hyacinth (*Eichhornia Crassipes*), Russian Comfrey (*Symphytum officinale)* and Pig Weed red-root *(Amaranthus retroflexus)* plants. The liquid manures were made by shredding plant materials and fermenting them in water for 30 days. Samples were analyzed weekly for nitrogen, phosphate and potassium (NPK) and trace elements. Water Hyacinth liquid manure had significantly high N (3.72%) and P (2.86%) contents indicating its suitability as a macronutrient fertilizer. All liquid manures had high K contents, particularly Russian Comfrey (3.90%), hinting against direct foliar application. Pig weed had high levels of Ca, Zn and Mg suggesting its suitability as a sufficient micronutrient fertilizer. All liquid manures had NPK contents greater than common solid organic fertilizers such as cattle manure used in Zimbabwe.

Keywords – **Organic farming, liquid manure, Water Hyacinth, Russian Comfrey, Pig Weed**

1. Introduction

Organic farming is an internationally regulated, legally enforced and standardized alternative agricultural paradigm that relies on ecological processes, biodiversity and cycles adapted to local conditions with the aim of sustaining the health of soils, ecosystems and people [1]. Originating in Germany in the early 19th century from the pseudo-scientific roots of biodynamic farming, organic farming has evolved into an ecologically friendly substitute of conventional farming systems which have been shown to have adverse environmental and health impacts due to intensive use of synthetic inputs such as pesticides, herbicides and fertilizers [2, 3, 4].

The substitution of synthetically manufactured agricultural inputs, such as chemical fertilizers, by minimally processed naturally-occurring organic inputs, such as organic fertilizers, forms the core tenet of organic farming [5]. Organic fertilizers are soil amendments containing the minimum contents of, at the minimum, nitrogen, phosphate and potash (NPK) that is derived solely from the vestiges or derivatives of an organism [6, 7]. The NPK in organic fertilizers must come solely from organic reserves that are inherently high in NPK and not from petroleum or ammonia- derived fertilizers like ammonium nitrate or synthetic urea [7]. The application of organic fertilizers has been shown to have positive impacts on soil fertility, soil physical properties and consequently crop yield [8, 9, 10].

Depending on the raw materials, method of production and environmental conditions organic fertilizers vary widely in form and nutrient content . Organic fertilizers include solid organic fertilizers (farm yard manure, green manure and compost) as well as liquid organic fertilizers (plant extracts, compost watery extracts, compost leachate, compost teas, liquid manures and manure teas) [11] .Globally there is prevalent use and scientific knowledge of solid organic fertilizers. Table 1 below highlights some common solid organic fertilizers used in Zimbabwe and their nutritive capacity. Cattle manure and green manure are the most nutritive organic fertilizers with an average nitrogen (N) content of 1.50% [12]. Elsewhere, beyond Zimbabwe, bat-guano (feces) harvested from caves has been shown to be an excellent source of nutrients with an NPK value of 10-3-1 [7]. Other organic fertilizers with high NPK values include fish meal (10-6-2); blood meal (12-0-0) and bone meal (3-15-0) [13].

Table 1: Mean nutrient quality of solid organic fertilizers used by small farmers in Zimbabwe

Fertilizer type	N (%)	P (%)	K (%)
Cattle Manure	1.50	0.15	0.78
Leaf litter	1.40	-	-
Anthill soil	0.23	0.05	-
Compost	0.34	0.12	-
Crop residue	0.45	0.06	-
Legumes	1.50	0.08	-

Source: [12]

Liquid organic fertilizers have largely remained in the background of mainstream scientific literature and what little knowledge exists about them is mainly confined to biodynamic farming literature [14]. Seaweed liquid fertilizer (also known as SLF, kelp or seaweed extract) is a popular liquid fertilizer in India, Europe and America with a history of use dating back from Ancient China [15]. Seaweed extract has been found to contain negligible amounts of N and P but high levels of all trace elements and plant hormones (IAA and IBA) cytokinins, gibberellins and vitamins [16].

In India the traditional liquid fertilizer called Panchagavya, a manure tea made by fermenting cow dung in water , has been shown to have a modest NPK content of 0.03-0.02-0.04 but a high iron content of 0.84%. Other Indian liquid manure teas such as Jeevamrut and Beejamrut are reportedly used not as sources of nutrients but of plant growth hormones [17, 18].

Early biodynamic teachings by Rudolf Steiner in 1924 popularized liquid manures as a common gardening experience in Europe and America [19]. Liquid manures are made by fermenting plant material and extracts in water [20]. The upsurge in organic farming popularity in Europe and America has turned organic liquid fertilizer production into a big commercial business with products such as Biolizer XN and Tomarite sold on the international market. However their unsubstantiated high N content claims (above 6%) have introduced a lot of controversy with some products being withdrawn following objections from organic certifiers and growers [6].

Typical of Africa, Zimbabwe has traditional agricultural practices which are compatible with organic farming [21]. Rural communities and smallholder farmers generally lack capital to buy synthetic pesticides and inorganic fertilizers and rely heavily on organic fertilizers [22]. In recent years several non-governmental organizations promoting organic farming in Zimbabwe such as the Zimbabwe Organic Agricultural Producers and Promoters Association (ZOAPPA) have emerged. Their work is hampered by limited data on aspects such as organic fertilizers and pesticides.

This research sought to determine the NPK and micronutrient (Ca,Mg, Zn, S) content of liquid manures made from three common plant materials in Zimbabwe; Water Hyacinth (*Eichhornia Crassipes*), Russian Comfrey (*Symphytum officinale)* and Pig Weed red-root *(Amaranthus retroflexus).*

2. Materials and Methods

2.1 Study Site

The study was conducted in Harare (lon: 31.0^{0}E and lat: 17 .8^{0}S) in Zimbabwe at Tese Tigute Organic Plot in the North –Eastern suburb of Highlands. The study area is an open door learning centre, with an agricultural area characterized by a smallholder organically certified intensive farming system with vegetation marked by the main crop, maize (the staple food grain), vegetables and diversified herbal plants. The area experiences three main seasons, a warm wet season from November to March/April; a cool dry season from May to August and a hot dry season in September/October. The area has a humid sub tropical climate of average temperature 17.95 °C.

2.2 Experimental Design

An experimental design approach was used whereby the 3 treatments of Water Hyacinth (*Eichhornia Crassipes*), Russian Comfrey (*Symphytum officinale)* and Pig Weed *(Amaranthus retroflexus* fermenting in water acted as the experiments. For each treatment they were 4 replicates.

2.3 Selection of Plant Material

The rationale behind the selection of the plants used for the liquid manure production was based on the ease of availability of the plant, documented plant NPK content and its biomass production. Russian Comfrey (*Symphytum officinale*) is a prolific exotic plant that propagates rapidly by seeds and root stems and produces 4-5 kg of leaves per plant per cutting during the growing season [23]. It has a high nutrient content due to its deep root system that mines minerals from the subsoil . Water hyacinth (*Eichhornia Crassipes*) is a perennial aquatic weed which has proved to be a environmental nuiance in polluted water bodies in Zimbabwe such as Lake Chivero and Lake Kariba [24]. It has a high mineral nutrient absorption and accumulation capacity and thus its application in wastewater treatment, animal fodder and organic fertilizer [25]. Pig Weed red-root *(Amaranthus retroflexus)*, apart from being a noxious weed in maize and bean plots, is common along Zimbabwean roadsides and open waste sites. Pigweed red-root belongs to the Amaranth family, a grain crop, and under certain conditions accumulates nitrates in its leaves and stems [26]. The only effective cultural way of managing both Water Hyacinth and Redroot Pigweed the weeds is through cultivation, physical removal and dumping of the plant residue. Given the high biomass produced by the weeds the use of Water Hyacinth and Pigweed in liquid manures could be an ecologically sound way of depositing the weed residue.

2.4 Fermenting Process

In this study a plant to water weight ratio of 1:8 was used to allow the extraction of the highest amount of nutrients. Normal plant to water weight ratios used in both biodynamic and organic farming range between 1:8 to 1:10 [23, 27].

Healthy Comfrey (*Symphytum)* and Amaranthus specimens not yet in the flowering stage were sourced from Tigute Organic Plot. Water Hyacinth (*Eichhornia Crassipes*) was sourced from Lake Chivero. The plants were collected and cleaned and the root section was cut and discarded. Only the leaves and stem were used in the experiment. Using an analytical balance 5 kg of the plant material was weighed, shredded and then placed in a 40 litre container. Forty liters of water was added and the container was sealed to exclude rainwater, prevent evaporation and contain flies and odors. The material was fermented for 30 days but periodically stirred every 7 days.

2.5 Chemical Tests

Samples of 200ml from each fermenting container were collected, filtered and centrifuged at 10,000rpm for 30 minutes at 4EC. The resulting supernatant was taken for nutrient analysis (%N, % P, %K, %S, %Mg, %Ca, %Zn) by standard chemical analysis as shown in Table 2.. Samples were collected after every five days from the 15th day to the 30th day of the study.

Table 2: Chemical Analysis

Method	Analysis
pH	pH meter
Nitrogen	Kjeldahl Method
Phosphorus	UV-VIS Spectrophotometer
Potassium, Zinc, Magnesium, Calcium, Sulphur	Atomic Absorption Spectrophotometer

The data was analyzed using Genstat (version 6) statistical package.

3. Results

A summary of the results for macronutrients and micronutrients content in liquid manures after 30 days of fermenting are presented in Table 3 below.

Table 3: Mean Macro and micronutrient content in Liquid Manures.

	Water Hyacinth	Pig weed	Russian Comfrey	Water
pH	6.7	6.8	7.8	6.8
TDS	980±40	1844±20	972±88	91
%N	3.72±0.33	1.54±o.37	2.90±0.1	0.00
%P	2.86±0.41	2.98±0.24	2.94±0.05	0.00
%K	2.89±0.02	2.01±0.4	3.90±0.06	0.00
%S	0.91±0.21	0.70±0.34	1.60±0.34	0.05
%Mg	0.08±0.02	0.16±0.03	0.08±0.02	0.00
%Ca	0.06±0.01	0.38±0.11	0.06±0.03	0.00
%Zn	0.05±0.01	0.05±0.01	0.04±0.02	0.05

3.1 Nitrogen

Results show that Water Hyacinth liquid manure had the highest N content (3.72%) after 30 days of fermentation (see Fig 1). Russian Comfrey liquid manure had an N content of 2.90% and Pig Weed liquid manure had the lowest N content of 1.54%. There was a significant difference (p= 0.05) between the N content in all the liquid manures (see Fig 1). All the liquid manures had an N content higher than most conventional organic fertilizers (compare Table 1). This suggests that liquid manures can be employed as more nutritive substitutes to solid organic fertilizers such as legume green manure and cattle manure.

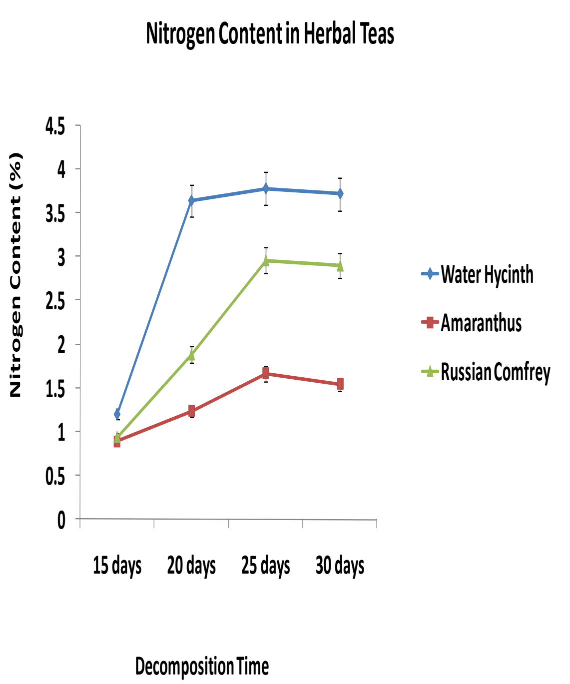

Figure 1: N content in liquid manures

The source of the nitrogen in the liquid manures is the inherent N contained in the plant matter. Water Hyacinth is known to have high protein content [28]. In organic agriculture 6.2% protein content is equivalent to 1% nitrogen content [6]. Water Hyacinth leaves may contain as a high as 15.17% protein which might yield more than 2% nitrogen during decomposition [29, 30]. There is great variation in the documented total nitrogen content of Water hyacinth leaves as reported by various authors depending on whether it is collected from a polluted (nutrient rich) or an unpolluted (nutrient poor) water source [25]. The Water Hyacinth for this study was collected from Lake Chivero a polluted water source and thus might contain high N content.

It took 20 days for Water Hyacinth liquid manure to reach its maximum N content compared to the other two liquid manures which took 25 days to ferment indicating a faster decomposing rate for the Water Hyacinth plant. Russian Comfrey liquid manure and Pig Weed liquid manure had a slight reduction in the N content by the 30th day suggesting N losses due to volatilization can occur.

The faster decomposition time for the Water hyacinth plant and the N losses via volatilization for the Russian Comfrey and Pig Weed can be explained by the C: N ratio. Water Hycinth has a C: N ration of 36:1 [30], Pig Weed 11:1 [31] and Russian Comfrey **9.8:1 [28].**For optimum decomposition to occur microorganisms require a suitable C: N ratio of 30: 1 (between 20/1 and 35/1) [32]. Thus Water Hyacinth has a suitably high C:N ratio which facilitates faster decomposition by microbes. A low C: N ratio results in N losses due to volatilization. Nitrogen loss due to excess nitrogen in the pile (a low C/N ratio) can be over 60%. At a C/N ratio of 30 or 35 to 1, only one half of one percent of the nitrogen will be lost [32].

3.2 Phosphate

Although results show that Pig Weed liquid manure has the highest P content of (2.98%) followed by Russian Comfrey liquid manure (2.94%) and Water Hyacinth liquid manure (2.86%) there was no statistical difference (p= 0.05) between the P content in the liquid manures (see Fig 2). All liquid fertilizers had P content greater than most common organic fertilizers used by small scale farmers in Zimbabwe (see Table 1).

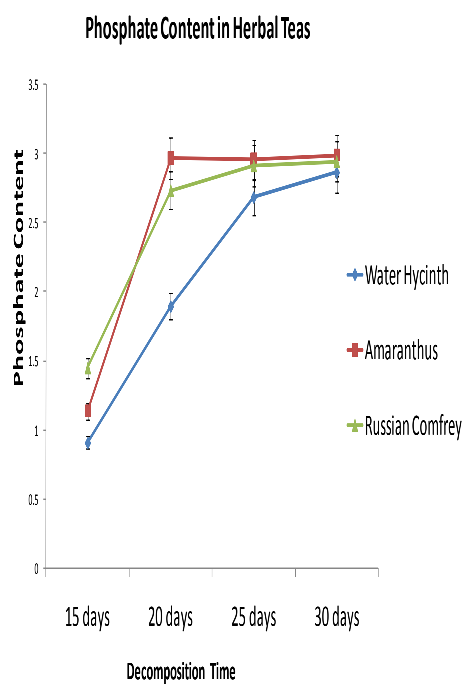

Figure 2: P content in liquid manures.

Phosphate in solution exists as $H_2PO_4^-$ and HPO_4^{2-} with the former more abundant at acidic pH (pH< 72). Plant uptake of $H_2PO_4^-$ is more rapid than HPO_4^{2-}. Comparing the pH values of the liquid manures it can be theorized that Water Hyacinth liquid manure might be the better source of P due to the acidic pH of 6.7 [37]. Phosphate availability is further compromised by Ca2+ which precipitates insoluble Dicalcium Phosphate and Hydroxyapatite. Thus the high Ca content in Pig weed liquid manure may inhibit P availability to plants [33].

3.3 Potash

Russian Comfrey liquid manure had the highest potash content of 3.90% whilst Water hyacinth liquid manure had 2.89% and Pig weed liquid manure had 2.01%. The potassium content in all 3 liquid manures was statistically different (p=0.05) (see Fig 3). The potassium content in all liquid manures is greater than that of cattle manure (see Table 1). The high K concentration of the liquid manures for seems to discourage foliar application. Nutrient concentration of generally less than 1-2% is employed to avoid injury to foliage [34].

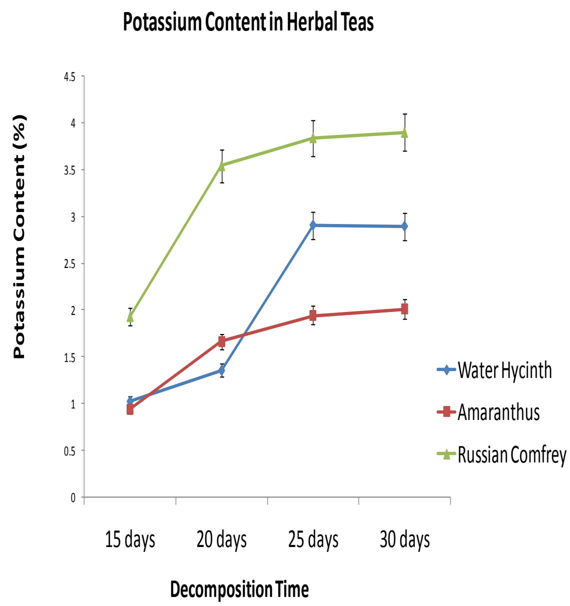

Fig 3: K content in liquid manures.

Effectiveness of solution K for crop uptake is influenced by Ca and Mg ion presence. High concentration of both Ca and Mg inhibit crop uptake of k and is qualitatively assessed by the activity ratio (AR_e^k) equation [33].

$$AR_e^k = a_k/\sqrt{(a_{Ca} + a_{Mg})} \quad (i)$$

AR_e^k is governed by the potassium activity (a_k), calcium activity (a_{Ca}) and magnesium activity (a_{Mg}). The higher the AR_e^k the higher the plant K. Calculating the AR_e^k of the liquid manures shows that Russian Comfrey liquid manure has more available plant K (11.47) compared to Water Hyacinth liquid manure (7.7) and Pig Weed liquid manure (2.73).

3.4 Trace Elements

Results of trace element analysis shows that Russian Comfrey Liquid Manure has the highest sulphur content of 1.6%; Pigweed had the highest Calcium (0.38%) and Magnesium (0.16%)`content. Zinc contents were equally high in Water Hyacinth and Pig weed liquid manures. From the results Pigweed might be the best source of all trace elements. The Pigweed Liquid Manure provides the highest amount of Zn, Ca and Mg. Although Pigweed had the lowest Sulphur content (0.7%) it is still sufficient to meet plant requirements.

4. Conclusion

The paper reported on a study that evaluated the nutritional component of liquid fertilizers derived from three common plants in Zimbabwe namely, Water Hyacinth, Russian Comfrey and Pigweed. Water Hyacinth liquid manure had the highest N and P content and on that basis can be concluded as the more superior macronutrient fertilizer. In addition it has no N losses due to volatilization and generally tskes less time (25 days) to prepare due to a higher C:N ratio. Generally all liquid manures were of higher nutrient content than common solid organic fertilizers used by farmers.

All the liquid manures had an equally high P content (> 2.90) which is greater than the P content of most organic fertilizers used by small farmers in Zimbabwe. Russian Comfrey liquid manure had the highest K content (3.90%) than all the liquid manures.

All three Liquid Manures had equal Zinc contents. Besides Sea Weed extract few studies have documented the trace element content of Liquid Manures.

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