Organic Farming | 2019 | Volume | Issue | Pages 14–22
DOI: 10.12924/of2019.05010014

Review

Fermented Leaf Fertilizers—Principles and Preparation

Roland Ebel[1,*] and Susanne Kissmann[2]

[1] Montana State University, Montana, USA
[2] Intercultural Maya University of Quintana Roo, Quintana Roo, Mexico

* Corresponding author: E-Mail: roland.ebel@gmx.com; Tel.: +1 (406) 994-0211; Fax: +1 (406) 994-7360;
Address: MSU Campus Reid Hall 345, Bozeman, MT 59717

Submitted: 17 September 2018 | In revised form: 6 Juni 2019 | Accepted: 26 June 2019 |
Published: 6 August 2019

Abstract: Fermented leaf fertilizers (FLF) are made of anaerobically fermented plant and/or animal resources and principally used for foliar plant nutrition, as they provide a quick nutrient supply, especially of micronutrients. Their use is most common in horticultural production as a complementary measure to organic basal fertilization in the case of nutrient deficiencies. Since FLF are commonly made of farm residues, their formulation varies according to the available resources and the treated crops. The most common raw materials are cattle manure, cow milk, cane molasses, and water. Within Latin America, the production of FLF is popular with smallholders. Most of these farmers produce them on-farm using adapted plastic barrels as fermenters. Industrial production is conceivable. FLF have been successfully tested in banana, bean, broccoli, carrot, cucumber, lettuce, maize, papaya, and spinach production. This review highlights the principles of this sustainable and promising organic fertilization strategy, emphasizing the preparation of FLF.

Keywords: Biofertilizer; foliar fertilizer; organic plant nutrition; sustainable agriculture

1. Introduction

Plants can absorb water and nutrients through their leaves, which is believed to be a heritage of their evolutionary origin as water plants [1]. Although soil application is still the most common plant nutrition strategy in organic farming [2], plant sprays based on compost, excrements and diverse plant materials have been used for foliar plant nutrition for over a hundred years [3].

Fermented liquid fertilizers (FLF) describe anaerobically fermented animal or plant residues (or a mixture of both) used as liquid organic fertilizers. Other liquid organic fertilizers include compost teas, humic acids, algae extracts, and manure tea [4]. FLF can be distinguished from the (partially overlapping) concepts of biofertilizers and biostimulants, which are produced similarly but do not directly supply nutrients. Biostimulants promote plant growth without providing nutrients. Biofertilizers, a subcategory of biostimulants, increase the soil fertility by enhancing the soil activity through living microorganisms, for example, rhizobacteria [5,6]. FLF are also labelled as fermented foliar fertilizers, liquid organic fertilizers [7], fermented organic fertilizers [8], or biol (due to their importance in Latin America)[9]. Some of the latter terms can also refer to biofertilizers. Normally, FLF are used for foliar fertilization, where they have shown superior immediate nutrient supply compared to common solid organic fertilizers [10]. Their micronutrient content is reported to meet the requirements of numerous horticultural crops [11].

Regularly, they serve as corrective measures (additional to basal fertilization) when nutrient deficiencies are observed [12]. There are indications that these products could also be used to prevent plant stress in periods of intensive vegetative growth activity and when a plant initiates its reproductive stage [13]. Occasionally, FLF are applied to the soil (*e.g.* through drip irrigation) or mixed with solid fertilizers to improve their quality. They are used for a variety of annual and perennial crops [14] but most frequently for nourishing vegetables, fruits and ornamentals.

High-quality FLF are characterized by balanced nutrient content and satisfactory plant assimilation of these nutrients [12]. Since FLF can be produced on-farm using accrued residues [8], they increase both the environmental and economic sustainability in agricultural production. Further advantages involve an easily accomplishable preparation process; early harvesting and extended harvest periods; increased post-harvest stress-resistance; a positive impact on harvest taste and quality; the principal absence of toxic residues on harvested food; and a low health risk for producers [11]. Some of the problems of using FLF is that they may excessively contain Na [10]. There is also a risk of contamination with pathogenic microorganisms (*e.g. Escherichia coli, Salmonella* sp., or *Shigella* sp.) and with heavy metals (As, Cd, Cr, Hg, Ni, Pb), which is why in the European Union and the USA, the use of FLF is legally restricted [8]. A correctly implemented fermentation process using lactobacilli decreases the risk of contamination with pathogenic microorganisms [15]. As for the risk of heavy metal contamination, explicit studies are necessary.

2. Formulation and Preparation

2.1. Raw Materials

Biofertilizers are mainly provided through the activity of microorganisms such as *Rhizobium* sp., while FLF refer to fermented organic materials as principal source of nutrients [5]. FLF are made of four basic components: organic nutrient resources, energy resources, microorganism resources, and water (Table 1). There are no standard recipes for FLF. Their composition depends on the skills and experience of the producers, the crop, organic farming regulation, and available resources. Therefore, producers usually experiment with diverse compositions until finding the FLF they need for their crops [16].

Cattle manure is the most common organic nutrient resource. Fresh dung is used since the animal excrement is not only a source of nutrients but also of microbes. This stands in contrast to its use in composts. Fresh dung contains all microorganisms that are required to initiate the fermentation process: inoculums of yeasts, fungi, protozoa, and bacteria. Alternatives to cattle dung are sheep, goat, hare, and chicken manure. Some gardeners prefer vegetative nutrient resources to avoid potential biological contamination. Stinging nettle, fruit mash, pods of legumes, oat and wheat groats, arnica, or comfrey are potential options in this context [11,16,17]. Energy resources guarantee an efficient and correct fermentation process. Cane molasses is the standard ingredient. Apart from providing energy, molasses also contains nutrients, especially K, Ca, S, Fe, and B. Unrefined raw sugar is a popular alternative to cane molasses [11,17].

Fresh cow milk is the most common source of microorganisms for the fermentation process. It is, therefore, rarely substituted by other materials [11]. Besides, milk provides enzymes, fats, amino acids, vitamins and minerals. Whey is a similar alternative. Yeasts are another potential microorganism source, but commonly, they are an additional ingredient to dairy products. Further alternatives or supplements include fresh forest humus (of deciduous forests), composts, sauerkraut pickle, other fermented food, rice, and corncobs [11,16,17]. A commercial option consists of the so-called effective microorganisms (EM). EM combine selected microorganisms such as *Rhodopseudomonas palustris*, *R. sphaeroides, Lactobacillus plantarum, L. casei, Streptococcus lactis, Mucor hiemalies, Saccharomyces cervisiae*, or *Streptomyces albus*, which are physiologically compatible with one another in a liquid medium [18,19]. Water is essential for the fermenting microorganisms and as a vehicle used to transfer the final product to the plant metabolism. The water should be neutral, of low salinity and must not contain chlorine [16].

Table 1. Raw material used to produce common FLF formulations (material used to fill a fermenter of 200 L).

Formulation	Fresh cattle manure (kg)	Fresh Cow-milk (L)	Cane molasses (L)	Yeast (kg)	Water (L)	Herbs^z (kg)	Legumes^y (kg)	Rock flour (kg)	Lime sulfur (L)	Vitamin C (g)	Vegetable ash (kg)	Salts^x (g)	Source
Standard	50	4	4		145								[17]
Standard with yeast	50	2	2	0.4	140						4		[20]
Standard with ash	50	2–4	2–4		140						3–5		[11]
Standard with rock flour	50	2–4	2–4		140			4			3–5		[11]
FLF with legumes	50	2	2	0.4	135		5				4		[20]
FLF for vegetative growth	10	2	2		180				2.25	7		160 $MgSO_4$, 225 K2SO_4, 30 $FeSO_4$, 315, $ZnSO_4$, 40 Na_2MoO_4	[11]

^{z} Native herbs (not specified), ^{y} Fresh legume herbs (especially *Medicago* spp.), ^{x} Commercial dissolvable products

Minerals are frequently added to the basic mixture. Highly soluble salts, lime, dolomite, vegetative ash, or rock flour can be used to raise the nutrient content. Lime helps maintain the FLF solution neutral, which is essential for a correct fermentation process. Crushed fishbones, shells, animal bones or feathers are alternative mineral resources. Such material is used in numerous commercial FLF. Plant teas can partially substitute minerals. Furthermore, there are gardeners who add soluble synthetic fertilizers to their FLF [17].

2.2. Equipment

Since the preparation of FLF is widely restricted to small farms with limited economic resources, farmers commonly use improvised, farm-made fermenters (also referred to as bio-digestors) based on the adaptation of easily available material (similar to the on-farm production of biogas). However, large-scale production in industrial fermenters is conceivable.

In on-farm production, barrel-like plastic containers 1, commonly of 200 L volume, are often used as fermenters [10] Since they must be closed hermetically, a metal ring and screw caps are commonly used to lock them. The only aperture is a perforation of their lid, where a ¾ inch PVC hose is plugged into the raw FLF. To avoid air inlet, this perforation is sealed with silicone. In more sophisticated arrangements, a valve and a nipple are used for this purpose. The hose enables the escape of fermentation gases (principally methane and hydrogen sulphide). The other end of the hose is usually plugged in a water-filled plastic bottle so that gases can escape the hose without air entering it.

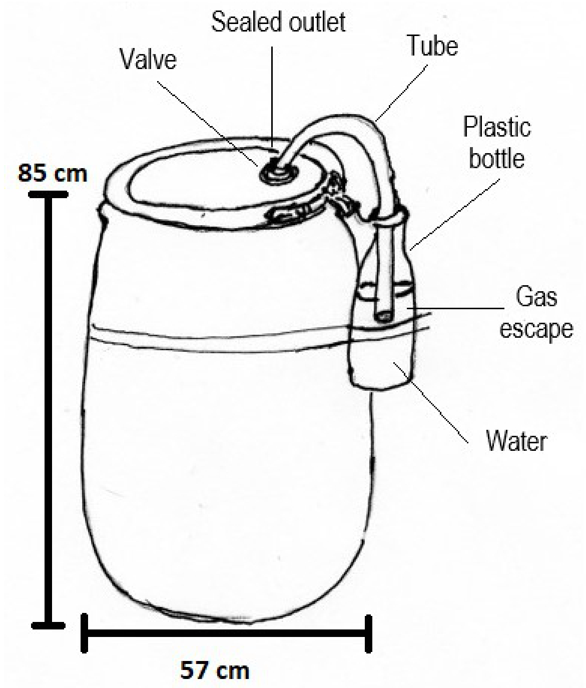

Figure 1. Latin American peasants use adapted plastic barrels (55 US gallon drum) as fermenters to produce FLF.

2.3. Preparation

During the fermentation process, the bio-digester must be protected from all light, as light stimulates the oxidation process of organic materials. To protect the bio-digester from a physical movement that may cause inlet of oxygen, it must also be protected from wind and rain and must be stored outdoors due to the emitted gases [11].

All vegetative material must be shredded to a length of maximum 2 cm in the preparation of FLF. Then, the barrel is filled with the vegetative material, fresh animal excrements and 100 L of water. After stirring intensively, ash may be added. After this, the energy resources and the milk are mixed with 10-20 L of water in a separate container. Upon stirring, this mixture is added to the barrel. Mineral salts may then be added in the same way. The barrel is then filled with water, filling 90-95% of the total volume of the fermenter, leaving enough space for the fermentation gases. Finally, the barrel is locked. From the tenth day forward, some farmers open the barrel for a short time to check the quality of the preparation and to stir it [11,17].

2.4. Fermetation

Apart from animal excrements, dairy produce, EM, or already produced FLF are potential microorganism resources for fermentation. The process involves an aerobic followed by an anaerobic phase. Essential to the fermentation process are three groups of microorganisms: lactobacilli, photosynthesizing bacteria, and yeasts. Lactobacilli, particularly *Lactobacillus plantarum, L. casei*, and *Streptococcus lactis*, release lactic acids, processing sugars, carbohydrates, lignin and cellulose [18]. Lactic acid has strong antimicrobial effects, which is why FLF may be even used to control tomato wilt diseases like damping off and *Fusarium* wilt [21]. This effect also avoids the contamination of FLF with germs such as *Salmonella* sp. [8]. In the aerobic phase, photosynthetic bacteria, especially *Rhodopseudomonas palustris*, and yeasts such as *S. cerevisiae* decompose the organic matter and produce amino acids, polysaccharides, nucleic acids, and sugars [18,22,23].

Anaerobic fermentation begins after all oxygen is consumed by aerobic organisms [7]. The organic matter is initially decomposed by anaerobic bacteria that hydrolyse water soluble substances, transforming them into monomers and soluble compounds (disintegration and hydrolysis); then the acidogenesis follows, in which alcohols, aromatic compounds, and fatty acids are decomposed and H_2, CO_2, and acetic acid are produced. Finally, methanogenesis occurs, where CH_4 is obtained from CO_2 and H [15,24,25]. FLF ingredients such as slurry, or fruit residues increase the fermentation activity [26].

The fermentation process lasts from two weeks in a hot climate to eight weeks in a cold climate [15]. A correctly fermented product is identified by a light amber and almost translucent colouring, the presence of a white foam on its surface, and the absence of visible solid elements (except for a thin sediment layer on the bottom of the fermenter). The smell is similar to a silage fodder. The consistency of a correctly fermented FLF should be almost liquid with a density of maximum 1060 g L^{-1}. A failed fermentation process is distinguished by a bluish, purple, or green colouring as well as a turbid appearance, a putrid smell, and the presence of a greenish foam, fungi or many bubbles on the FLF surface. The best place to store FLF is the bioreactor where it was prepared. Alternatives are other dark containers made of glass or plastics. For storage, outside temperatures should not exceed 35°C. Under these conditions, FLF can be stored for up to 60 days. Care must be taken if the fermentation process is not concluded since this can lead to nutrient loss and damage of the container [11,17,20,27].

3. Nutritional Composition

All plant nutrients were evidenced in FLF solutions. In addition, FLF may contain Na, Si, I, Se, and diverse metals [11]. The most common FLF formulations, all based on cow manure (Table 1), have content of 2101-4800 mg N kg^{-1}, 27-32 mg P kg^{-1}, 1651-4493 mg K kg^{-1} , 931-3716 mg Ca kg^{-1}, and 348-1499 mg Mg kg^{-1} (Table 2).

During fermentation, nitrate is converted into ammonium and gaseous forms of N [15]. Consequently, the N content of FLF declines once most components are fermented, especially when it is heated as it can happen under direct exposure to sunlight [20]. Ito [8] found the highest total N content of an FLF at 30 days after starting the fermentation process, while the highest ammonium content was observed after 45 days.

Concerning P, the organic acids originating from the fermentation process facilitate its solubilization. The use of molasses and whey additionally stimulates the solubilization of P. The amount of plant-available P in FLF increases during the first ten days of fermentation and then decreases due to its consumption by microorganisms [14,15,20].

The K and the Mg content is directly related to the use of molasse as FLF ingredient. In contrast, the presence of Ca is linked to the use of both molasses and manure [8]. From the first day of the fermentation process, the content of ionic Ca decreases slightly, while the ionic K content increases. Furthermore, the methanogenesis reduces the content of ionic Fe and Mn [14,15].

As for vitamins, provitamins and enzymes, FLF usually contain thiamine, pyridoxine, niacin, pantothenic acid, riboflavin, cobalamin, ascorbic acid, folic acid, beta-carotene, ergosterol, and alpha-amylase [11].

Most FLF show a slightly acidic pH of approximately 6.5, which is a consequence of the formation of acid compounds during the fermentation process. There are also reports of strongly acid FLF with a pH of 4.5 [20] or even of 3.4 [27]. The electric conductivity of FLF is around 5 dS m^{-1}. Commonly, the salinity decreases slightly during the fermentation process [15,27].

4. Application

A FLF must be diluted with water before it is applied. Undiluted FLF increase the risk of low nutrient absorption, injury to the leaf surface, or general phytotoxicity [8]. Ideal concentrations of foliar-applied nutrient solutions depend on the plant species, plant age, nutritional status and weather conditions [28]. In the case of FLF, common concentrations range between 3% and 7%. If minerals are added, a dilution to reach a concentration of 2% is adequate. Used in short intervals, the dilution should be higher. Ash (150 g L^{-1}) and raw soap (2 g L^{-1}) can be added to the diluted FLF to enhance its adhesiveness on the crops. Cactus juice, aloe, and molasses have a similar adhesive effect [11].

Foliar-applied nutrients are ions that enter the plant metabolism following an aqueous pathway through a leaf's cuticular wax or the stomata. The penetration of foliar-applied substances is a passive process driven by concentration gradients and stimulated by light and soil moisture [1,2].

Micronutrient deficiencies can be corrected with one single foliar application (in the case of a crop like maize with a high micronutrient demand, it may be up to three applications). A micronutrient supply only using foliar fertilizers is accomplishable but only would make sense in entirely disturbed soils.

Table 2. Plant-available nutrient content, pH, and electric conductivity (EC) of standard FFF formulations after a minimum of 39 days of fermentation.

Formulation	N (ppm)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Fe (ppm)	Na (ppm)	pH	EC (dS m^{-1})	Source
Standard^{z}	2101	27	4493	3716	1499	1	12	7.7	8.2	[29]
Standard with yeast^{y}	4800	28	1651	978	348	8		5.4	8.3	[20]
FLF with legumes^{y}	3400	32	1691	931	370	8		5.1	8.7	[20]

^{z} After 39 days of fermentation, ^{y} After 45 days of fermentation

Macronutrient requirements are not entirely met with foliar applications, but (for example in very acid soils) foliar application are effective methods to correct macronutrient disorders. Furthermore, complementary foliar macronutrient supply during determined growth stages can significantly improve crop quality [2].

For an efficient absorption of foliar fertilizers, leaf stomata should be open; the treated plants should be cool and turgid; the temperature should not be above 20°C to avoid burning of the plant foliage, and the weather should be windy but not stormy. The ambient air humidity should not be too low since dryness may cause the evaporation of the applied solution, immobilizing its compounds. It should not rain for at least three hours after the application of the nutrient solution [2,28]. According to practitioners, these conditions are more likely to be met in the early morning; yet, Fageria *et al.* [2] also suggest the late afternoon as a prime opportunity for applying foliar fertilizers. FLF should not be mixed with other substances. The only exceptions are the mentioned adhesives such as cactus juice and whey [11].

5. Effectivity

Recent studies have emphasized the development of fertilizers made of solid and liquid farm residues. Most of this research (commonly from Asia) centres on biofertilizers, not on FLF [30].

Latin America, the region where FLF were developed, is still the place where most of the respective informal on-farm research on FLF is undertaken. Consequently, the proof of the effectivity of FLF frequently comes from countries like Peru and Ecuador. In such studies, a positive effect of the use of FLF on crop yield was evidenced for bean, broccoli, carrot, cucumber, lettuce, maize, and spinach; whereas a beneficial effect on fruit quality was shown for cucumber and lettuce. As for vegetative growth, FLF were successfully tested in maize and papaya fields; and in banana production for disease control Table 3.

6. Future Research Needs

Few extensive studies deal with FLF. Hence, it is necessary to deepen the research in this field. Particularly, more studies are needed emphasizing the concerns of farmers and organic farming authorities (especially about the acceptability of using FLF with different worldwide organic standards). Core research issues include the monitoring and reduction of health and quality risks (heavy metal and human pathogen contamination). Additionally, most FLF formulations are based on what is available in Latin American farming communities. Accordingly, it is necessary to implement research about optimum FLF formulations that work with resources available in other parts of the world. Similarly, research covering the FLF requirements of specific crops would be helpful. Today, most FLF are produced on-farm using easily achievable materials such as plastic barrels and bottles. Considering the high costs of commercial organic leaf fertilizers, this circumstance is vastly beneficial for small-scale producers in developing countries. Nevertheless, research regarding a larger-scale production of FLF would help increase their distribution in industrialized nations.

7. Coclusions

Despite their popularity in Latin America, FLF are still a new plant nutrition strategy at the global level. Yet, the technique has the potential to become a significant component of sustainable plant nutrition: Its many contributions include agricultural residues that are recycled to nourish plants and a considerably high micronutrient supply that may outperform organic basal fertilization. As they can be produced on-farm, FLF considerably may reduce fertilization and transportation costs, improving the sustainability of farming systems. Today, most FLF are used as a complementary measure to established organic fertilization techniques. However, they have the potential to become a universally important fertilization tool.

Table 3. Evidenced effects of FLF applied on diverse crops.

Crop	Cropping system, location (country)	Formulation	Significant positive effect	Details	Additional remarks	Significant negative effect	Source
Banana	Outdoor, Ecuador	Standard formulation, ash and lime added	Control of fungal disease	Positive effect on infestation with *Mycosphaerella fijiensis*			[31]
Bean	Outdoor, Ecuador	FLF made of cow manure, salts, ash, whey, alfalfa, yeast	Yield per area (sing a FFF dilution of 10%, 41% yield increase compared to control treatment with manure; 30% yield increase with dilution of 5%)	Superior to fertilization with manure, inferior to synthetic fertilization			[32]
Bean	Outdoor, Peru	Standard formulation with alfalfa and ensiled maize	Yield per area (using a FFF dilution of 30%, 23% yield increase compared to a control treatment without fertilization; 25% increase with dilution of 50%)	Best performance without dilution	Similar results with soil application of FLF		[33]
Broccoli	Outdoor, Ecuador	FLF made of sheep manure, blood flour, mineral P, ash, soil, alfalfa, yeast	Yield per area (234% yield increase compared to a control treatment without fertilization)				[34]
Carrot	Outdoor, Peru	NS^{z}	Yield per area (41% yield increase compared to a control treatment without fertilization; 14% yield increase compared to conventional fertilization with urea)		Positive effect on carrot diameter		[35]
Cucumber	Outdoor, Peru	NS^{z}	Yield per area (using a FFF dilution of 30%, 10% yield increase compared to a control treatment without fertilization; 14% increase with dilution of 50%) fruit length	Yield equivalent to the use of NPK root fertilizer; performance increases with dilution	Higher share of large fruits compared to synthetic products		[36]
Cucumber	Green-house, China	Fermented swine manurey	Fruit length, quality	Superior to the use of synthetic fertilizers	Higher chlorophyll content of leaves treated with FLF		[37]
Lettuce	Green-house, Italy	Bovine slurry co-digested with maize silage	Quality	More compact and denser lettuce heads		Yield per area inferior to synthetic fertilizers	[26]
Lettuce	Outdoor, Bolivia	Standard formulation with yeast, plants^{x}, bone flour and minerals	Yield per area (using a FFF dilution of 6%, 252% yield increase compared to a control treatment without fertilization; 226% increase with dilution of 4%)	Best performance at 6 % dilution and two-weekly application			[38]
Maize	Outdoor, Mexico	Standard formulation combined with urea	Yield per area (521% yield increase compared to a control treatment without fertilization), cob weight and length		Positive effect on plant survival		[12]
Papaya	Nursery, Costa Rica	Standard formulation with yeast and salts	Vegetative growth	Identic growth performance as with synthetic fertilizers		Negative impact on root growth	[14]
Spinach	Outdoor, Peru	NS^{z}	Yield per area (using a FFF dilution of 40%, 148% yield increase compared to a control treatment without fertilization; 131% increase with dilution of 20%)				[7]

^{z} Formulation not specified, ^{y} Applied as basal application, topdressing and FLF. ^{x} *Vicia sativa, Urtica dioica, Ambrosia peruviana*

References and Notes

[1] Eichert T, Kurtz A, Steiner U, Goldbach HE. Size Exclusion Limits and Lateral Heterogeneity of the Stomatal Foliar Uptake Pathway for Aqueous Solutes and Water-Suspended Nanoparticles. Physiologia Plantarum. 2008;134(1):151–160. doi:10.1111/j.1399-3054.2008.01135.x.

[2] Fageria NK, Filho MPB, Moreira A, Guimarães CM. Foliar Fertilization of Crop Plants. Journal of Plant Nutrition. 2009;32(6):1044–1064. doi:10.1080/01904160902872826.

[3] Kaffka S, Koepf HH. A Case Study on the Nutrient Regime in Sustainable Farming. Biological Agriculture & Horticulture. 1989;6(2):89–106. doi:10.1080/01448765.1989.9754508.

[4] Scheuerell S, Mahaffee W. Compost Tea: Principles and Prospects For Plant Disease Control. Compost Science & Utilization. 2002;10(4):313–338. doi:10.1080/1065657x.2002.10702095.

[5] du Jardin P. Plant Biostimulants: Definition, Concept, Main Categories and Regulation. Scientia Horticulturae. 2015;196:3–14. doi:10.1016/j.scienta.2015.09.021.

[6] Chojnacka K. Innovative Bio-products for Agriculture. Open Chemistry. 2015;13(1). doi:10.1515/chem-2015-0111.

[7] Siura S, Davila S. Effect of Green Manure Rotation, Biol and Cultivar on the Production of Organic Spinach (*Spinacea oleracea*). 2008;Available from: www.orgprints.org/12456.

[8] Ito S. Caracterización y Evaluación de los Factores que Determinan la Calidad Nutricional e Inocuidad en la Producción de Fertilizantes Orgánicos Fermentados.; 2006. CATIE. Available from: http://www.sidalc.net/repdoc/A0842e/A0842e.pdf.

[9] Moreira I, Delgado H, Baque C, Chila R, Muentes X, Chanca M. Fertilización Foliar con Biol en Cebolla de Bulbo (*Allium cepa l.*) Valorando Rendimiento; 2016. Available from: https://cienciasagronomicas.unr.edu.ar/journal/index.php/agronom/article/view/169.

[10] Burnett SE, Mattson NS, Williams KA. Substrates and Fertilizers for Organic Container Production of Herbs, Vegetables, and Herbaceous Ornamental Plants Grown in Greenhouses in the United States. Scientia Horticulturae. 2016;208:111–119. doi:10.1016/j.scienta.2016.01.001.

[11] Restrepo J, Hensel J. Manual Práctico de Agricultura Orgánica y Panes de Piedra. Impresora Feriva; 2009. Available from: https://www.academia.edu/3837612/Manual-Practico-de-Agricultura-Organica-y-Panes-de-Piedra.

[12] Vázquez G, Magallón R, Torres L. Evaluación de Biofertilizantes Líquidos en la Producción de Elote y Grano en Maíz. E-CUCBA; 2014. Available from: http://e-cucba.cucba.udg.mx/index.php/e-Cucba/article/view/7. 10.32870/e-cucba.v1i1.7.

[13] Girma K, Martin KL, Freeman KW, Mosali J, Teal RK, Raun WR, et al. Determination of Optimum Rate and Growth Stage for Foliar-Applied Phosphorus in Corn. Communications in Soil Science and Plant Analysis. 2007;38(9-10):1137–1154. doi:10.1080/00103620701328016.

[14] Galindo A, Jeronimo C, Spaans E, Weil M. Los Abonos Líquidos Fermentados y su Efectividad en Plántulas de Papaya (*Carica papaya L.*). Tierra Tropical. 2007;3(1):1–6.

[15] de Jesús SM, Ronald F, Jorge E, Gabriel A, José T, Lizette B, et al. Producción de Biofertilizantes mediante Biodigestión de Excreta Líquida de Cerdo. Terra Latinoamericana. 2001;19:353–362. Available from: https://www.redalyc.org/pdf/573/57319408.pdf.

[16] Garro JE. El Suelo y los Abonos Orgánicos. INTA; 2016. Available from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwin4PTw1qjjAhVKsVQKHbzGCBkQFjAAegQIAxAC&url=http%3A%2F%2Fwww.mag.go.cr%2Fbibliotecavirtual%2FF04-10872.pdf&usg=AOvVaw2QuS3mr9PrTY0ITIUhs8C8.

[17] Ebel R. Nachhaltige Pflanzenernährung mit Fermentierten Blattdüngern; 2017. Available from: https://www.gemuese-online.de/Archiv/PDF-Archiv/L0NNR1JfVE9DP0NGSUxURVI9MTc3ODQ4Jk1JRD0xMDk2OTU.html.

[18] Javaid A. Beneficial Microorganisms for Sustainable Agriculture. In: Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming. Springer Netherlands; 2010. pp. 347–369. doi:10.1007/978-90-481-8741-6_12.

[19] Kengo Y, Hui-Lian X. Properties and Applications of an Organic Fertilizer Inoculated with Effective Microorganisms. Journal of Crop Production. 2001;3(1):255–268. doi:10.1300/j144v03n01_21.

[20] Zagoya-Martínez J, Ocampo-Mendoza J, Ocampo-Fletes I, Macías-López A, Peñaloza PDLR. Caracterización fisicoquímica de biofermentados elaborados artesanalmente. BIOtecnia. 2015;17(1):14. doi:10.18633/bt.v17i1.9.

[21] Quirós A, Albertin A, Blázquez M. Elabore sus Propios Abonos, Insecticidas y Repelentes Orgánicos; 2004. Available from: https://www.bocashi.files.wordpress.com/2010/09/manual_organico.pdf.

[22] Kim MK, Choi KM, Yin CR, Lee KY, Im WT, Lim JH, et al. Odorous Swine Wastewater Treatment by Purple Non-sulfur Bacteria, *Rhodopseudomonas palustris*, Isolated from Eutrophicated Ponds. Biotechnology Letters. 2004;26(10):819–822. doi:10.1023/b:bile.0000025884.50198.67.

[23] Higa T. What is EM Technology?; 2000. Available from: https://cdn1.npcdn.net/userfiles/20596/attachment/2294285/20181217_18db269211db95f28d93d7ed2f1cd81d/1._EM_Brochure_EM_summary.pdf.

[24] Esposito G, Frunzo L, Giordano A, Liotta F, Panico A, Pirozzi F. Anaerobic co-digestion of organic wastes. Reviews in Environmental Science and Bio/Technology. 2012;11(4):325–341. doi:10.1007/s11157-012-9277-8.

[25] Stronach SM, Rudd T, Lester JN. The Microbiology of Anaerobic Digestion. In: Biotechnology Monographs. Springer Berlin Heidelberg; 1986. pp. 21–38. doi:10.1007/978-3-642-71215-9_2.

[26] Trinchera A, Baratella V, Rinaldi S, Renzaglia M, Marcucci A, Rea E. Greenhouse Lettuce: Assessing nutrient use efficiency of digested livestock manure as organic N-fertiliser. Acta Horticulturae. 2014;(1041):63–69. doi:10.17660/actahortic.2014.1041.5.

[27] Orellana T, Patricia Isabel MS, Chavez E, Ruiz O, Leon R, Orellana Manzano A, et al. Estándares de Fermentación y Maduración Artesanal de Bioles. Revista Científica Yachana. 2013;2:10–14.

[28] Fernández V, Eichert T. Uptake of Hydrophilic Solutes Through Plant Leaves: Current State of Knowledge and Perspectives of Foliar Fertilization. Critical Reviews in Plant Sciences. 2009;28(1-2):36–68. doi:10.1080/07352680902743069.

[29] Ebel R. Yield Response of a Polycropping System with Maize to Fermented Foliar Fertilizers. Ciencia ergo-um. 2019 *in press*;27.

[30] Lim SF, Matu SU. Utilization of Agro-wastes to Produce Biofertilizer. International Journal of Energy and Environmental Engineering. 2014;6(1):31–35. doi:10.1007/s40095-014-0147-8.

[31] Pino E. Determinación de la Mejor Dosis de Biol en el Cultivo de *Musa sapientum* Banano, como alternativa a la fertilización foliar química. Escuela Superior Politécnica del Litoral. 2005;Available from: https://www.researchgate.net/profile/Cristhian_Emilio/publication/48369882_Determinacion_de_la_mejor_dosis_de_Biol_en_el_cultivo_de_Musa_sapientum_Banano_como_alternativa_a_la_fertilizacion_foliar_quimica/links/5764b74108aeb4b99800a376.pdf.

[32] Bejarano C, Méndez H. Fertilización Orgánica Comparada con la Fertilización Química en el Cultivo de Fréjol *Phaseolus vulgaris*, para Minimizar el Efecto de Degradación del Suelo; 2004. Available from: http://repositorio.utn.edu.ec/handle/123456789/224.

[33] Siura S, Barrios F, Delgado J, Davila S, Chilet M. Vertientes del pensamiento agroecológico: fundamentos y aplicaciones. Altieri M, editor. SOCLA; 2009. Available from: https://www.researchgate.net/profile/Walter_Pengue/publication/280081818_VERTIENTES_DEL_PENSAMIENTO_AGROECOLOGICO/links/55a6ea4c08aeb4e8e646c8cf/VERTIENTES-DEL-PENSAMIENTO-AGROECOLOGICO.pdf#page=289.

[34] Basantes E. Elaboración y Aplicación de dos Tipos de Biol en el Cultivo de Brócoli (*Brassica oleracea* var. Legacy); 2009. Available from: http://dspace.espoch.edu.ec/handle/123456789/352.

[35] Valverde R. Efecto de la Fertilización Química y Biofertilizaciòn biol en la Producción del Cultivo de Zanahoria (*Daucus carota* L.) Var. Royal Chantenay; 2016. Available from: http://repositorio.upao.edu.pe/handle/upaorep/2842.

[36] Delgado J. Efecto de la Fertilización Foliar en el Cultivo de Pepinillo para Encurtido (*Cucumis sativus* L.); 2003. Available from: http://www.lamolina.edu.pe/hortalizas/Investigacion/Tesis/Tesis%20Sustentadas/Resumen%20Jaime%20Delgado.pdf.

[37] Duan N, Lin C, Gao RY, Wang Y, Wang JH, Hou J. Ecological and economic analysis of planting greenhouse cucumbers with anaerobic

fermentation residues. Procedia Environmental Sciences. 2011;5:71–76. doi:10.1016/j.proenv.2011.03.050.
[38] Pomboza-Tamaquiza P, León-Gordón O, Villacís-Aldaz L, Vega J, Aldáz-Jarrín J. Influencia del Biol en el Rendimiento del Cultivo de *Lactuca sativa* L. variedad Iceberg. Journal of the Selva Andina Biosphere. 2016;(4):84–92.