Journal of Advances in Biology & Biotechnology

Volume 27, Issue 11, Page 515-531, 2024; Article no.JABB.125940
ISSN: 2394-1081

Standardization of Panchagavya for Enhanced Nutrient Content and Seed Germination in Sustainable Organic Farming

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i111636

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/125940

Original Research Article

Received: 04/09/2024
Accepted: 06/11/2024
Published: 09/11/2024

ABSTRACT

The detrimental effects of chemical-intensive agriculture have spurred interest in eco-friendly farming practices, particularly organic farming. Central to organic farming are organic manures, including various liquid organic formulations such as Panchagavya, which are rooted in Indigenous

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Cite as: *Mol, Raseena, Gowry Priya, B. Rani, V. I. Soumya, P. P. Gopinath, and B. Aparna. 2024. "Standardization of Panchagavya for Enhanced Nutrient Content and Seed Germination in Sustainable Organic Farming". Journal of Advances in Biology & Biotechnology 27 (11):515-31. https://doi.org/10.9734/jabb/2024/v27i111636.*

Technical Knowledge (ITK). Due to the variability in local production methodologies, there is a pressing need to standardize the production techniques of liquid organic manures, specifically Panchagavya, and to characterize their properties. The study standardizes Panchagavya production to reduce local variability. Eight ingredients were used, with 81 different combinations. Physical and chemical properties of prepared Panchagavya were analyzed, and principal component analysis was performed to determine optimal combinations for improved soil health and crop productivity.

The nitrogen content of different combinations of Panchagavya ranged from 1.12% to 2.66%, phosphorus between 0.12% to 0.385%, potassium between 0.345% to 0.65%. The Ca content ranged between 186.3 mg L^{-1} and 256.66 mg L^{-1}. Mg content the range was between 52.1 mg L-1 to 92.4 mg mg L-1, S varies between 0.08% and 0.3%, the Fe content in Panchagavya ranged from 49.7 mg L^{-1} to 53.1 mg L^{-1}, Mn content ranged from 2.60 mg L^{-1} to 5.05 mg L^{-1}, Zn content ranged from 4.1 mg L^{-1} to 6.35 mg L^{-1}, and Cu content ranged from 12.50 mg L^{-1} to 14.95 mg L^{-1}. with higher levels associated with increased quantities of cow urine, milk, curd, and ghee.

Germination study indicated that Panchagavya positively affected seed germination and root growth increased from 3.45% to 114.66%. The growth hormone indole acetic acid values was between 56.6 µg mL^{-1} and 104.19 µg mL^{-1}. Similarly, the gibberellic acid values ranged from 138.34 µg mL^{-1} to 185.23 µg mL^{-1}. From the 81 treatment 10 best treatment was selected by principle component analysis of nutrient content of Panchagavya.

Microbial analysis of selected Panchagavya demonstrated significant populations: bacteria (7.57 to 8.03 log cfu mL^{-1}), fungi (4.3 to 4.73 log cfu mL^{-1}), and actinomycetes (3.15 to 3.9 log cfu mL^{-1}).

The presence of IAA and GA further substantiates its efficacy as an organic fertilizer. This research confirms that Panchagavya enhances nutrient content, microbial activity, and hormone levels, resulting in improved seed germination and root development. These findings highlight its potential as a sustainable alternative to chemical fertilizers, promoting organic farming practices and contributing to healthier soils.

Keywords: Germination study; liquid organic manure; organic farming; organic fertilizer; panchagavya; sustainable agriculture; soil health.

1. INTRODUCTION

The need for eco-friendly farming practises to be adopted for sustainable agriculture is strongly emphasised by the current world situation facing the multiple threats of climate change, soil degradation and population explosion. Chemical agriculture has a negative effect on the health of the soil, beneficial microbial communities and plants. This ultimately resulted in a strong demand for organic produce from the modern, health-conscious population, and farmers all over the world have since undertaken sporadic attempts to detoxify the land by switching to organic farming and doing away with chemical fertilizers and pesticides. Organic management techniques may be able to maintain the agricultural output for a longer period of time while also maintaining the health of the soil. As a result of the resource-poor farmers' inability to afford expensive inputs like chemical fertilizer, insecticides, etc., 65% of the cultivated land in India is organic by default. Therefore, liquid organic fertilizers and low-cost packages of sustainable/organic farming technologies using locally accessible resources can play a crucial part in bringing about India's second and final green revolution by incorporating the country's needy farmers. The crops receive soluble and readily accessible nutrients from liquid organic fertilizers. Additionally, they provide plant nutrients in a quicker-acting form than solid fertilizers. Panchagavya is part of the Indigenous Technical Knowledge (ITK) of the Indian farmers and is prepared from five products obtained from cow, i.e. dung, urine, milk, curd and ghee. There are several reports that this preparation is rich in nutrients, auxins, gibberellins, and microbial fauna and acts as tonic to enrich soil, induce plant vigour with quality production. The Panchagavya is an efficient plant growth stimulant that enhanced the biological efficiency of crops. It is used to activate biological reactions and to protect the plants from disease incidence. Panchagavya application may enhance plant growth by nitrogen fixation, growth hormone production and control phytopathogens of many plantation crops (Chandra et al. 2019).

Studies have shown that Panchagavya application leads to higher plant height, dry matter accumulation, and improved yield

attributes such as seed weight and fruit size. For instance, trials on crops like wheat and black gram demonstrated significant increases in yield metrics when treated with Panchagavya compared to conventional fertilizers. Crops treated with Panchagavya not only yield more but also exhibit better quality parameters, including higher protein content and shelf life (Behera et al. 2024).

It is essential to ensure the quality of the liquid organic manures with respect to nutrient content as well as its physical, chemical and biological properties. Application of poor quality input is a threat to soil health and safe food production. The production methods of on-farm liquid organic manures like Panchagavya are not standardized and the quality specifications are not yet included in Fertilizer (Control) Order of the Government of India. Quality standards for various liquid organic manures are to be established and enforced strictly to ensure quality protection of soil health as well as agricultural produce. With this background, a study was conducted to develop a standardized production technique for the liquid organic manure (Panchagavya) and characterize its quality aspects.

2. MATERIALS AND METHODS

2.1 Production of Panchagavya

The most commonly adopted method of preparation of Panchagavya involves mixing cow dung (7 kg) and cow ghee (1kg) in a plastic drum and keeping it aside for three days, stirring thoroughly both in the morning and evening. After three days cow urine (10L) and water (10 L) are added. The mixture is kept for fifteen days with regular mixing both in morning and evening hours. After fifteen days, cow milk (3L), cow curd (2L), tender coconut water (3litres), jaggery (3kg) and well ripened poovan banana (12 numbers, which is approximately 0.5kg) are added. The contents should be stirred twice a day both in morning and evening and Panchagavya will be ready for use after thirty days (Selvaraj et al. 2007).

In order to standardize the production technique of Panchagavya, we prepared the liquid manure using raw materials in varying proportions. Among the eight components used in preparation of Panchagavya, cow dung (7 kg), tender coconut water (3 litres), jaggery (3 kg) and ripe poovan banana (0.5 kg) were taken uniformly as per the conventional method. The remaining ingredients (cow urine, cow ghee, cow milk, and curd) were incorporated at three distinct levels: traditional, one elevated level, and one reduced level. The experiment was conducted in a Completely Randomised Design with 81 treatments and two replications. The proportions in which the raw materials were mixed in each treatment are given in Table 1.

Cow urine @ 8, 10 and 12 litres
Cow ghee @ 0.75, 1 and 1.25 kg
Cow milk @ 2 ,3 and 4 litres
Curd @ 1.5, 2 and 2.5 litres

The Panchagavya obtained from all the treatment combinations were characterized for physical and chemical properties as per standard procedures. pH and electrical conductivity were measured a pH meter (Systronics, Digital pH meter 335) and EC meter (Systronics, Conductivity meter 304), respectively. Nitrogen content was estimated by the Microkjeldahl digestion and distillation method. Available phosphorus and sulphur were determined using diacid digestion (HNO_3: $HClO_4$ in the ratio 9:4) and analyzed using a spectrophotometer (Systronics, VIS Double Beam Spectro 1203). Available potassium was also analyzed using diacid digestion (HNO_3: $HClO_4$ in the ratio 9:4) and measured with a flame photometer (Systronics, Flame Photometer 130). Available calcium and magnesium were estimated using diacid digestion (HNO_3: $HClO_4$ in the ratio 9:4) and concentrations determined using atomic absorption spectrophotometry (PerkinElmer, PinAAcle 500). Micronutrients such as Fe, Mn, Zn, and Cu were extracted using diacid digestion (HNO_3: $HClO_4$ in the ratio 9:4) and estimated using atomic absorption spectrophotometry (PerkinElmer, PinAAcle 500) (Jackson 1973).

A germination study was also carried out from which twenty best products were selected for determining biochemical constituents like IAA and Gibberellic acid. IAA was extracted with Salkowski reagent and analyzed using a spectrophotometer (Systronics, VIS Double Beam Spectro 1203) (Gordon and Weber 1951). GA was extracted with zinc acetate and potassium ferrocyanide solutions and analyzed using a spectrophotometer (Systronics, VIS Double Beam Spectro 1203) (Holbrook et al. 1961). The data obtained from the characterization study were analyzed statistically by a standard procedure using GRAPE 1.0.0 (General R-shiny based Analysis Platform Empowered by Statistics) software. Means of

different treatment combinations were compared based on the least significant difference (LSD) at 0.05 probability level. Principal component analysis was done to select ten superior Panchagavya combinations (Gopinath et al. 2021). The biological properties of the selected products were analysed. For microbial enumeration, serial dilution plate technique was employed (Timonin 1940).

Table 1. Proportions of raw materials for Panchagavya preparation

Treatment	Cow urine (L)	Ghee (kg)	Milk (L)	Curd (L)
T1	8	0.75	2	1.5
T2	8	0.75	2	2
T3	8	0.75	2	2.5
T4	8	0.75	3	1.5
T5	8	0.75	3	2
T6	8	0.75	3	2.5
T7	8	0.75	4	1.5
T8	8	0.75	4	2
T9	8	0.75	4	2.5
T10	8	1	2	1.5
T11	8	1	2	2
T12	8	1	2	2.5
T13	8	1	3	1.5
T14	8	1	3	2
T15	8	1	3	2.5
T16	8	1	4	1.5
T17	8	1	4	2
T18	8	1	4	2.5
T19	8	1.25	2	1.5
T20	8	1.25	2	2
T21	8	1.25	2	2.5
T22	8	1.25	3	1.5
T23	8	1.25	3	2
T24	8	1.25	3	2.5
T25	8	1.25	4	1.5
T26	8	1.25	4	2
T27	8	1.25	4	2.5
T28	10	0.75	2	1.5
T29	10	0.75	2	2
T30	10	0.75	2	2.5
T31	10	0.75	3	1.5
T32	10	0.75	3	2
T33	10	0.75	3	2.5
T34	10	0.75	4	1.5
T35	10	0.75	4	2
T36	10	0.75	4	2.5
T37	10	1	2	1.5
T38	10	1	2	2
T39	10	1	2	2.5
T40	10	1	3	1.5
T41	10	1	3	2
T42	10	1	3	2.5
T43	10	1	4	1.5
T44	10	1	4	2
T45	10	1	4	2.5
T46	10	1.25	2	1.5

Treatment	Cow urine (L)	Ghee (kg)	Milk (L)	Curd (L)
T47	10	1.25	2	2
T48	10	1.25	2	2.5
T49	10	1.25	3	1.5
T50	10	1.25	3	2
T51	10	1.25	3	2.5
T52	10	1.25	4	1.5
T53	10	1.25	4	2
T54	10	1.25	4	2.5
T55	12	0.75	2	1.5
T56	12	0.75	2	2
T57	12	0.75	2	2.5
T58	12	0.75	3	1.5
T59	12	0.75	3	2
T60	12	0.75	3	2.5
T61	12	0.75	4	1.5
T62	12	0.75	4	2
T63	12	0.75	4	2.5
T64	12	1	2	1.5
T65	12	1	2	2
T66	12	1	2	2.5
T67	12	1	3	1.5
T68	12	1	3	2
T69	12	1	3	2.5
T70	12	1	4	1.5
T71	12	1	4	2
T72	12	1	4	2.5
T73	12	1.25	2	1.5
T74	12	1.25	2	2
T75	12	1.25	2	2.5
T76	12	1.25	3	1.5
T77	12	1.25	3	2
T78	12	1.25	3	2.5
T79	12	1.25	4	1.5
T80	12	1.25	4	2
T81	12	1.25	4	2.5

2.2 Statistical Analysis

The production and characterization of Panchagavya was done in completely randomized design (CRD). R-package grapesagri1 was used for data analysis (Gopinath et al. 2021).

3. RESULTS AND DISCUSSION

3.1 Chemical Characterization of Panchagavya

The Panchagavya preparations obtained from all the treatment combinations were acidic and it ranged from 5.11 to 5.76. Lowest pH was for T9 and highest for T73. The production of weak organic acids during fermentation might have resulted in acidic pH of Panchagavya (Pathak and Ram 2002). The treatment having high level of curd and milk showed a lower pH. Prepared Panchagavya generally showed a higher EC range from 6 (T19) to 7.15 (T81). The high value of EC in Panchagavya may be due to a hike in soluble salts in the Panchagavya combination with increased level of milk, curd, urine and ghee. Similar pH and EC values of Panchagavya were recorded by (Kavya 2019), (Rameeza 2014) and (Sreya 2017). pH levels can affect the solubility of nutrients present in Panchagavya, further impacting its effectiveness as a fertilizer. Therefore, adhering to the specified pH range is essential for maximizing the benefits derived from its application in organic farming systems (Das et al. 2013).

Table 2. pH and EC of panchagavya

Treatments	pH	EC (dSm^{-1})
T1	5.48	6.01
T2	5.32	6.03
T3	5.16	6.05
T4	5.42	6.29
T5	5.27	6.33
T6	5.17	6.38
T7	5.35	6.63
T8	5.24	6.69
T9	5.11	6.75
T10	5.47	6.00
T11	5.30	6.03
T12	5.15	6.06
T13	5.46	6.30
T14	5.24	6.33
T15	5.14	6.37
T16	5.37	6.63
T17	5.22	6.68
T18	5.14	6.76
T19	5.43	6.00
T20	5.35	6.04
T21	5.14	6.05
T22	5.41	6.29
T23	5.29	6.33
T24	5.13	6.37
T25	5.36	6.64
T26	5.19	6.69
T27	5.13	6.75
T28	5.65	6.29
T29	5.45	6.34
T30	5.38	6.36
T31	5.55	6.57
T32	5.49	6.60
T33	5.32	6.64
T34	5.55	6.86
T35	5.41	6.93
T36	5.28	6.96
T37	5.63	6.29
T38	5.47	6.33
T39	5.37	6.36
T40	5.56	6.56
T41	5.44	6.61
T42	5.32	6.64
T43	5.55	6.87
T44	5.37	6.92
T45	5.28	6.96
T46	5.66	6.30
T47	5.49	6.33
T48	5.37	6.36
T49	5.57	6.56
T50	5.46	6.60
T51	5.31	6.65
T52	5.56	6.86
T53	5.41	6.92
T54	5.30	6.96

Treatments	pH	EC (dSm^{-1})
T55	5.72	6.50
T56	5.61	6.04
T57	5.48	6.57
T58	5.67	6.74
T59	5.56	6.79
T60	5.46	6.83
T61	5.61	7.03
T62	5.51	7.08
T63	5.40	7.14
T64	5.72	6.51
T65	5.61	6.53
T66	5.50	6.57
T67	5.68	6.74
T68	5.53	6.79
T69	5.48	6.83
T70	5.62	7.03
T71	5.53	7.08
T72	5.42	7.14
T73	5.76	6.50
T74	5.67	6.53
T75	5.43	6.57
T76	5.66	6.75
T77	5.55	6.80
T78	5.46	6.83
T79	5.63	7.04
T80	5.52	7.08
T81	5.41	7.15
CD	0.027	0.156
SEM	0.01	0.055

The nutrient analysis of various Panchagavya combinations revealed significant variations in macro and micronutrient content. Nitrogen levels ranged from 1.12% to 2.66%, phosphorus from 0.12% to 0.37 %, and potassium from 0.35% to 0.65%. Additionally, calcium content varied between 186.3 mg/L and 256.66 mg/L, magnesium between 52.1 mg/L and 92.4 mg/L, and sulfur between 0.08 % and 0.32 %.

The nutrient content in Panchagavya increases with elevated ingredient levels due to enhanced microbial activity, which promotes mineralization. Its beneficial properties stem from its components, including milk, curd, cow urine, and ghee (Rajesh and Jayakumar 2013). The nutrient profile of organic liquid manures depends on the quantity, quality, and fermentation period of the ingredients (Gore and Srinivasa 2011), with variations arising from the types and amounts of materials and environmental factors (Sreenivasa et al. 2010). Liquid organic manure serves as a crucial source of essential plant nutrients, supporting in-situ nutrient recycling and enhancing nitrogen, phosphorus, and potassium cycles within agroecosystems (Mukherjee et al. 2023).

The Iron (Fe) content of Panchagavya ranged from 49.7 mg L^{-1} in T1 to 59.45 mg L^{-1} in T81. Manganese (Mn) content in Panchagavya was highest for T81 (5.05 mg L^{-1}) and lowest was for T1 (2.60 mg L^{-1}). Zinc (Zn) content ranged from 4.1 mg L^{-1} (T1) to 6.35 mg L^{-1}. (T81. Similarly, the Copper (Cu) content was highest for T81 (14.95 mg L^{-1}) and lowest for T1 (12.50 mg L^{-1}). The nutrient content was found to be higher in treatments with elevated levels of ingredients, attributed to enhanced mineralization resulting from the increased growth of the microbial population. Carbon and hydrogen bonds in both natural and synthetic organic fertilizers slow down the release of nutrient ions, leading to a sustained availability of nutrients without the toxicity and loss associated with inorganic fertilizers (Shaikh and Patil 2013). Panchagavya is known to be rich in essential micronutrients such as zinc, copper, iron, and manganese, which play a vital role in enhancing soil fertility and promoting healthy plant growth (Das et al. 2023, Borgohain et al. 2020).

Table 3. Primary and secondary nutrient contents of Panchagavya

Treatment	N (%)	P (%)	K (%)	S (%)	Ca (mg L^{-1})	Mg (mg L^{-1})
T1	1.12	0.12	0.35	0.08	186.30	52.10
T2	1.19	0.13	0.37	0.09	193.60	54.65
T3	1.26	0.15	0.40	0.11	198.80	57.25
T4	1.26	0.14	0.40	0.12	198.60	56.95
T5	1.33	0.16	0.40	0.14	204.70	59.25
T6	1.40	0.19	0.43	0.14	207.20	62.95
T7	1.40	0.19	0.43	0.16	207.20	63.60
T8	1.47	0.20	0.46	0.18	212.10	65.80
T9	1.54	0.23	0.47	0.18	220.10	68.25
T10	1.19	0.13	0.37	0.09	193.30	54.30
T11	1.26	0.15	0.39	0.11	198.60	57.80
T12	1.33	0.15	0.41	0.12	204.00	59.10
T13	1.37	0.15	0.41	0.14	204.40	59.45
T14	1.40	0.18	0.42	0.14	207.10	63.75
T15	1.47	0.20	0.44	0.15	212.80	65.20
T16	1.47	0.20	0.44	0.18	212.10	65.60
T17	1.58	0.22	0.47	0.18	219.90	68.85
T18	1.68	0.25	0.49	0.21	225.60	71.30
T19	1.26	0.14	0.37	0.11	198.50	57.45
T20	1.33	0.16	0.38	0.12	204.70	59.60
T21	1.44	0.19	0.41	0.14	207.20	63.15
T22	1.44	0.19	0.41	0.15	207.10	63.90
T23	1.51	0.22	0.43	0.15	212.80	65.10
T24	1.61	0.22	0.45	0.17	219.00	68.70
T25	1.58	0.23	0.45	0.18	219.70	68.35
T26	1.75	0.26	0.48	0.20	225.40	71.55
T27	1.86	0.26	0.50	0.21	230.30	76.75
T28	1.65	0.19	0.44	0.13	192.20	57.40
T29	1.75	0.22	0.47	0.14	195.50	59.85
T30	1.82	0.23	0.49	0.14	200.00	63.10
T31	1.86	0.23	0.49	0.16	200.30	63.70
T32	1.93	0.24	0.50	0.18	207.40	65.60
T33	2.03	0.25	0.51	0.19	213.80	68.30
T34	2.03	0.25	0.52	0.21	213.80	68.35
T35	2.10	0.27	0.54	0.21	218.40	70.90
T36	2.17	0.29	0.56	0.23	224.10	76.80
T37	1.75	0.21	0.45	0.14	195.40	59.50
T38	1.86	0.22	0.48	0.14	200.30	63.25
T39	1.93	0.25	0.49	0.15	207.20	65.90
T40	1.93	0.25	0.50	0.18	207.80	65.10
T41	1.93	0.26	0.50	0.18	213.60	68.60
T42	2.03	0.27	0.50	0.21	218.00	71.80
T43	2.10	0.28	0.50	0.21	218.30	71.40
T44	2.17	0.28	0.56	0.22	224.80	76.30
T45	2.24	0.32	0.57	0.24	229.45	79.70
T46	1.86	0.23	0.46	0.15	200.40	63.90
T47	1.93	0.24	0.47	0.15	207.50	65.10
T48	2.03	0.25	0.50	0.18	213.80	68.80
T49	2.03	0.25	0.51	0.19	213.80	68.30
T50	2.10	0.28	0.51	0.21	218.90	71.40
T51	2.17	0.24	0.52	0.22	224.20	76.60
T52	2.17	0.29	0.52	0.22	224.30	79.60
T53	2.24	0.31	0.57	0.25	229.60	79.70
T54	2.31	0.34	0.58	0.26	235.50	82.10

Treatment	N (%)	P (%)	K (%)	S (%)	Ca (mg L^{-1})	Mg (mg L^{-1})
T55	2.10	0.25	0.53	0.15	207.00	59.40
T56	2.17	0.27	0.54	0.18	213.80	63.20
T57	2.24	0.28	0.56	0.19	218.35	65.40
T58	2.24	0.28	0.56	0.20	218.60	65.90
T59	2.31	0.30	0.59	0.21	224.60	68.10
T60	2.38	0.35	0.62	0.23	229.30	71.90
T61	2.38	0.35	0.62	0.25	229.70	71.20
T62	2.45	0.36	0.62	0.26	235.90	76.30
T63	2.52	0.36	0.65	0.27	241.10	79.50
T64	2.17	0.26	0.54	0.18	213.60	65.90
T65	2.24	0.29	0.55	0.18	218.20	68.10
T66	2.31	0.31	0.57	0.21	224.70	71.45
T67	2.31	0.31	0.57	0.21	224.45	71.30
T68	2.38	0.34	0.62	0.23	229.10	76.50
T69	2.45	0.34	0.62	0.24	235.40	79.20
T70	2.45	0.34	0.62	0.26	235.80	79.80
T71	2.52	0.37	0.63	0.27	241.90	82.40
T72	2.59	0.38	0.65	0.29	250.00	87.35
T73	2.24	0.28	0.55	0.19	218.80	68.20
T74	2.31	0.31	0.56	0.21	224.20	71.60
T75	2.38	0.33	0.58	0.22	229.70	76.80
T76	2.38	0.34	0.58	0.23	229.60	76.50
T77	2.45	0.36	0.61	0.24	235.90	79.50
T78	2.52	0.36	0.63	0.26	241.10	82.90
T79	2.52	0.36	0.63	0.27	241.40	82.05
T80	2.59	0.37	0.64	0.29	250.60	87.70
T81	2.66	0.39	0.66	0.32	256.60	92.40
CD	0.203	0.039	0.033	0.02	0.02	4.591
SEM	0.072	0.014	0.012	0.007	0.007	1.632

Table 4. Micronutrient content of Panchagavya

Treatment	Fe (mg L^{-1})	Mn (mg L^{-1})	Zn (mg L^{-1})	Cu (mg L^{-1})
T1	49.70	2.60	4.10	12.50
T2	50.60	2.85	4.25	12.75
T3	51.50	3.00	4.45	12.90
T4	52.25	3.15	4.60	13.05
T5	53.05	3.35	4.75	13.25
T6	53.85	3.50	4.80	13.40
T7	54.35	3.65	4.95	13.55
T8	54.70	3.80	5.05	13.70
T9	55.35	3.90	5.15	13.80
T10	50.60	2.85	4.25	12.75
T11	51.50	3.00	4.45	12.90
T12	52.25	3.15	4.60	13.05
T13	53.05	3.35	4.75	13.25
T14	53.85	3.50	4.80	13.40
T15	54.35	3.65	4.95	13.55
T16	54.70	3.80	5.05	13.70
T17	55.35	3.90	5.15	13.80
T18	56.00	4.05	5.30	13.95
T19	51.50	3.00	4.45	12.90
T20	52.25	3.15	4.60	13.05
T21	53.05	3.35	4.75	13.25
T22	53.85	3.50	4.80	13.40
T23	54.35	3.65	4.95	13.55

Treatment	Fe (mg L^{-1})	Mn (mg L^{-1})	Zn (mg L^{-1})	Cu (mg L^{-1})
T24	54.70	3.80	5.05	13.70
T25	55.35	3.90	5.15	13.80
T26	56.00	4.05	5.30	13.95
T27	56.75	4.20	5.45	14.10
T28	52.25	3.15	4.60	13.05
T29	53.05	3.35	4.75	13.25
T30	53.85	3.50	4.80	13.40
T31	54.35	3.65	4.95	13.55
T32	54.70	3.80	5.05	13.70
T33	55.35	3.90	5.15	13.80
T34	56.00	4.05	5.30	13.95
T35	56.75	4.20	5.45	14.10
T36	57.15	4.35	5.55	14.25
T37	53.05	3.35	4.75	13.25
T38	53.85	3.50	4.80	13.40
T39	54.35	3.65	4.95	13.55
T40	54.70	3.80	5.05	13.70
T41	55.35	3.90	5.15	13.80
T42	56.00	4.05	5.30	13.95
T43	56.75	4.20	5.45	14.10
T44	57.15	4.35	5.55	14.25
T45	57.45	4.50	5.70	14.40
T46	53.85	3.35	4.80	13.25
T47	54.35	3.50	4.95	13.40
T48	54.70	3.65	5.05	13.55
T49	55.35	3.80	5.15	13.70
T50	56.00	3.90	5.30	13.80
T51	56.75	4.05	5.45	13.95
T52	57.15	4.20	5.55	14.10
T53	57.45	4.35	5.70	14.25
T54	57.90	4.50	5.85	14.40
T55	54.35	3.50	4.95	13.40
T56	54.70	3.65	5.05	13.55
T57	55.35	3.80	5.15	13.70
T58	56.00	3.90	5.30	13.80
T59	56.75	4.05	5.45	13.95
T60	57.15	4.20	5.55	14.10
T61	57.45	4.35	5.70	14.25
T62	57.90	4.50	5.85	14.40
T63	58.45	4.70	6.05	14.60
T64	54.70	3.65	5.05	13.55
T65	55.35	3.80	5.15	13.70
T66	56.00	3.90	5.30	13.80
T67	56.75	4.05	5.45	13.95
T68	57.15	4.20	5.55	14.10
T69	57.45	4.35	5.70	14.25
T70	57.90	4.50	5.85	14.40
T71	58.45	4.70	6.05	14.60
T72	58.90	4.85	6.20	14.75
T73	55.35	3.80	5.15	13.70
T74	56.00	3.90	5.30	13.80
T75	56.75	4.05	5.45	13.95
T76	57.15	4.20	5.55	14.10
T77	57.45	4.35	5.70	14.25
T78	57.90	4.50	5.85	14.40
T79	58.45	4.70	6.05	14.60

Treatment	Fe (mg L^{-1})	Mn (mg L^{-1})	Zn (mg L^{-1})	Cu (mg L^{-1})
T80	58.90	4.85	6.20	14.75
T81	59.45	5.05	6.35	14.95
CD	0.192	0.095	0.116	0.095
SEM	0.541	0.034	0.041	0.034

Table 5. Seed germination of Okra after treatment with Panchagavya

Treatment	Germination %	Root length (cm)	% increase of root length from control
T1	100.0	2.40	3.45
T2	95.0	2.43	4.74
T3	100.0	2.52	8.62
T4	95.0	2.52	8.62
T5	100.0	2.68	15.52
T6	100.0	3.09	33.19
T7	100.0	3.04	31.03
T8	100.0	3.28	41.38
T9	100.0	3.61	55.60
T10	100.0	2.40	3.45
T11	100.0	2.43	4.74
T12	100.0	2.57	10.78
T13	100.0	2.54	9.48
T14	100.0	2.70	16.38
T15	95.0	3.13	34.91
T16	100.0	3.09	33.19
T17	100.0	3.33	43.54
T18	100.0	3.71	59.91
T19	95.0	2.42	4.31
T20	100.0	2.47	6.47
T21	100.0	2.59	11.64
T22	100.0	2.58	11.21
T23	100.0	2.74	18.10
T24	100.0	3.16	36.21
T25	100.0	3.13	34.91
T26	100.0	3.38	45.69
T27	100.0	3.75	61.64
T28	100.0	2.99	28.88
T29	100.0	3.20	37.93
T30	99.5	3.47	49.57
T31	100.0	3.44	48.28
T32	100.0	3.80	63.79
T33	100.0	3.95	70.26
T34	100.0	3.90	68.10
T35	100.0	4.21	81.47
T36	95.0	4.32	86.21
T37	100.0	3.01	29.74
T38	100.0	3.24	39.66
T39	100.0	3.55	53.02
T40	95.0	3.50	50.86
T41	100.0	3.82	64.66
T42	100.0	3.99	71.98
T43	100.0	3.95	70.26
T44	95.0	4.25	83.19
T45	100.0	4.33	86.64
T46	100.0	3.06	31.90
T47	100.0	3.30	42.24

Treatment	Germination %	Root length (cm)	% increase of root length from control
T48	100.0	3.67	58.19
T49	100.0	3.58	54.31
T50	100.0	3.84	65.52
T51	100.0	4.06	74.79
T52	100.0	4.01	72.84
T53	100.0	4.28	84.48
T54	95.0	4.40	89.66
T55	100.0	3.84	65.52
T56	100.0	4.06	75.00
T57	100.0	4.31	85.78
T58	100.0	4.30	85.35
T59	95.0	4.40	89.66
T60	100.0	4.60	98.28
T61	100.0	4.57	96.98
T62	95.0	4.72	103.24
T63	100.0	4.87	109.91
T64	100.0	3.88	67.24
T65	100.0	4.11	77.16
T66	100.0	4.39	89.23
T67	95.0	4.36	87.93
T68	100.0	4.43	90.95
T69	100.0	4.65	100.43
T70	95.0	4.60	98.28
T71	100.0	4.79	106.25
T72	100.0	4.92	111.86
T73	95.0	4.93	112.50
T74	100.0	4.15	78.88
T75	100.0	4.31	85.78
T76	95.0	4.37	88.36
T77	100.0	4.45	91.81
T78	100.0	4.68	101.72
T79	95.0	4.65	100.43
T80	100.0	4.81	107.33
T81	100.0	4.98	114.66
CD	2.152	0.027	1.144
SEM	NS	0.009	0.407

3.2 Germination Study

All combinations of Panchagavya improved the germination percentage of okra seed over control. But germination percentage values of the different combinations of Panchagavya did not show any significant difference. The root length of okra seed was significantly influenced by the application of different combinations of Panchagavya. Root length ranged from 2.4 cm (T1) to 4.98 cm(T81). The percentage increase in root length compared to control (2.56 cm) was the lowest value in T10 (3.45 %) which is on par with T1, and highest value was for T81 (114.66 cm).

Liquid organic manures contain free-living nitrogen fixers, phosphorus solubilizers, and bacteria that produce substances promoting plant growth, as well as those with biological deterrent properties. The presence of this beneficial microbial biomass and nutrient content likely contributed to enhanced seed germination, increased seedling length, and improved seed vigour, suggesting that liquid organic manures are an effective plant growth stimulant (Sreenivasa 2009). Similar result was found by (Reddy and Chaurasia 2022) and (Saritha et al. 2013).

Based on the results of seed germination experiment, the twenty superior treatments were: T54, T59, T60, T61, T62, T63, T66, T67, T68, T68, T69, T70, T71, T72, T73, T76, T77, T78, T79, T80, and T81.

3.3 IAA and GA Content of Panchagavya

The highest value of the IAA was for T81 (104.19 μgmL^{-1}) and the lowest value (56.6 μgmL^{-1}) was recorded in T54. Likewise, the highest value of the GA was for the T81(185.23 μgmL^{-1}) and the lowest value was shown by T54 (138.34 μgmL^{-1}).

Beneficial microorganisms present in Panchagavya produce IAA and GA (Shubha 2014). The variation in hormonal contents among the treatments could be due to difference in the microbial activity (Rajesh and Jayakumar 2013, Chakraborty and Sarkar 2019). Auxin is a plant hormone that stimulates growth by promoting root and stem development, speeding up germination, encouraging cell division, and aiding in fruit ripening. It also helps decrease seed count in fruits. This hormone acts in coordination with gibberellin to enhance these growth functions (Sodiq et al. 2019).

3.3.1 Principal component analysis

The results of laboratory analysis of Panchagavya combinations were subjected to principal component analysis (PCA) (Table 7, Fig. 1) in order to find out the best combination. The parameters used for PCA were the content of pH, N, P, K, and S in the products. The PCA extracted 5 principal components.

From the biplot (Fig. 1) entire subset denoted with circle can be termed as treatment with highest observations of the selected variables. All the variables are correlated since they are in same direction. The entire dataset of variable covered by 2 PCs highest eigen values. So, both the PCs explain 95.85% variables. So that from biplot, treatment inside circle in figure were identified to be potential candidate for preferred treatment, since which has high pH and nutrient content compared to extreme values and also while considering the economic aspects. Then PCA based index values were calculated based on the loadings on the first PCA, as first PCA explain more of the variance of the data.

$$I=0.206\ pH + 0.497\ N + 0.495\ P + 0.5\ K + 0.464\ S$$

One-way analysis (completely randomized design) of the index values (Table 8) were done and 10 treatments were taken as best which were T59, T60, T61, T62, T67, T68, T69, T70, T76, T77, which are marked inside the oval in the Fig. 1.

Table 6. IAA and GA content of Panchagavya

TRT	IAA (μgmL^{-1})	GA (μgmL^{-1})
T54	56.60	138.34
T59	71.33	143.61
T60	77.02	153.76
T61	84.85	159.10
T62	88.54	163.82
T63	93.15	176.13
T66	65.02	143.02
T67	71.71	149.42
T68	77.52	153.77
T69	84.91	159.09
T70	90.80	163.84
T71	93.82	169.49
T72	100.29	176.87
T73	71.91	148.57
T76	77.17	153.83
T77	84.93	159.09
T78	88.97	163.83
T79	93.90	169.67
T80	100.44	176.82
T81	104.19	185.23
CD	3.403	4.493
SEM	1.153	1.523

Table 7. Principal component analysis

Principal component	Eigen value	Percentage of variance	Cumulative percentage of variance
PC1	3.899	77.971	77.971
PC2	0.894	17.881	95.852
PC3	0.174	3.489	99.341
PC4	0.019	0.371	99.712
PC5	0.014	0.288	100

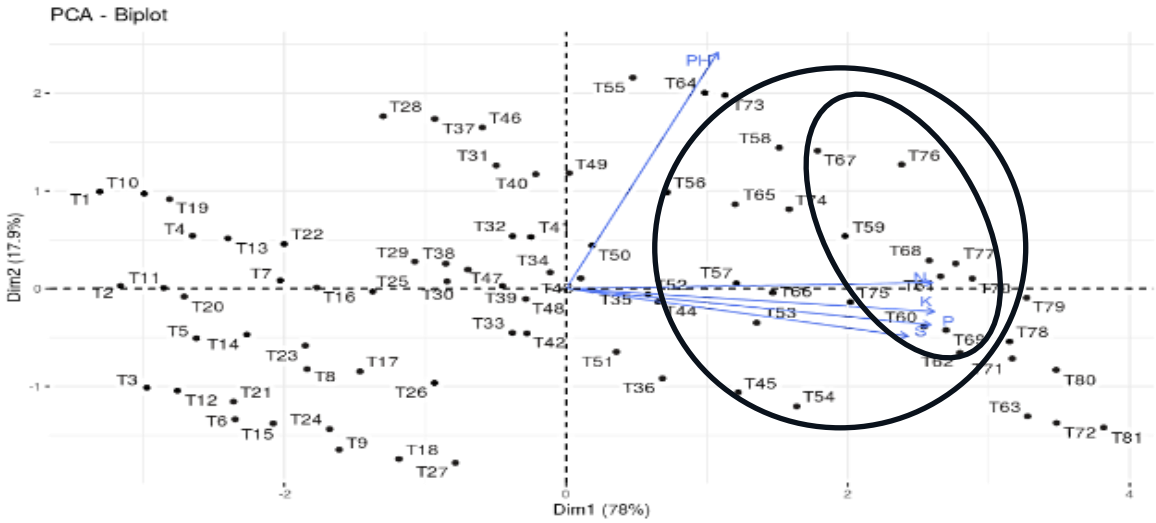

Fig. 1. Principal component analysis biplot with different combinations of Panchagavya

Table 8. One-way ANOVA of index values

Treatment	Index value
T45	2.718
T53	2.739
T54	2.775
T55	2.659
T56	2.734
T57	2.734
T58	2.779
T59	2.829
T60	2.884
T61	2.901
T62	2.927
T65	2.730
T66	2.781
T67	2.828
T68	2.898
T69	2.924
T70	2.946
T76	2.890
T77	2.930
SEM	0.03
CD	1.477

Table 9. Microbial count of Panchagavya

Treatment	Bacteria (log cfu mL^{-1})	Fungi (log cfu mL^{-1})	Actinomycetes (log cfu mL^{-1})
T59	7.574	4.341	3.151
T60	7.763	4.579	3.540
T61	7.763	4.554	3.540
T62	8.009	4.716	3.952
T67	7.579	4.301	3.151
T68	7.761	4.531	3.540
T69	8.009	4.715	3.972
T70	8.025	4.732	3.977
T76	7.748	4.554	3.540
T77	8.017	4.715	3.954
CD	0.089	0.099	0.261
SEM	0.028	0.032	0.083

3.3.2 Biological properties of liquid organic manure

Microbial population present in selected best 10 combination of Panchagavya are given in Table 9. It was found that bacterial count ranges from 7.57 to 8.03. T70 showed highest value (8.03 log cfu mL^{-1}) which is on par with that of T77, T62, T69. A similar trend was seen for fungal and actinomycetes counts. T70 recorded the highest fungal (4.73 log cfu mL^{-1}) and actinomycetes (3.9 log cfu mL^{-1}) counts.

This variation in microbial population among the treatments points at the impact of different doses of ingredients used in the preparation of Panchagavya. The microbial richness in Panchagavya had been reported by several workers. Panchagavya has demonstrated a notably higher acidity and microbial biomass carbon content than other organic amendments like vermicompost and farmyard manure, indicating its unique biochemical properties (Amalraj et al. 2013). It harbors a potent plant growth-promoting bacterium, *Bacillus* sp. PG-8, which exhibits beneficial traits enhancing the growth of *Arachis hypogea* and underscores its potential as a bioinoculant and biofertilizer in sustainable agriculture (Gohil et al. 2022). Among various organic farming inputs, Panchagavya showed the highest microbial population, including bacteria, fungi, and actinomycetes, thus promoting soil fertility and microbial activity (Jain et al. 2021). Additionally, metagenomic analyses highlight Panchagavya's diverse microbial community, which further supports its capacity to enrich soil health through microbial diversity (Krishnareddy et al. 2022).

4. CONCLUSION

This study shows that the traditional liquid organic manure, Panchagavya, is a nutrient-rich product that supports plant growth. The superior combinations of Panchagavya identified in the study were T59, T60, T61, T62, T67, T68, T69, T70, T76, and T77 which had notably higher nutrient levels, microbial activity, and hormone content, which helped boost seed germination and root growth. Based on this study we can recommend to organic farmers to prepare Panchagavya using cow dung 7 kg, tender coconut water 3 litre, jaggery 3 kg, ripe poovan banana 0.5 kg, cow urine 12 L, cow ghee 0.75 kg, cow milk 4 L and curd 2 L for 30 L of Panchagavya. The findings also suggest that Panchagavya could be a sustainable alternative to chemical fertilizers, promoting healthier soil and supporting organic farming methods.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

ACKNOWLEDGEMENTS

The authors hereby acknowledge the research facilities and funding provided by Kerala Agricultural University.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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