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

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 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, Sustainableagriculture, 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 [1].

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 [2]

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 preparationof Panchagavya involves mixing cow dung (7 kg) and cow ghee(1kg) in aplastic 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 [3].

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. Theproportions 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

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
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

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 sulphurwere 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) [4].

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) [5]. GA was extracted with zinc acetate and potassium ferrocyanide solutions and analyzed using a

spectrophotometer (Systronics, VIS Double Beam Spectro 1203)[6]. 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 [7]. The biological properties of the selected products were analysed. For microbial enumeration, serial dilution plate technique was employed [8].

2.7 Statistical Analysis

The production and characterization of Panchagavya was done in completely randomized design (CRD). R-package grapesagri1 was used for data analysis [7].

3. RESULT 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[9]. 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 wererecorded by [10], [11] and [12].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 [13].

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
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 0.385%, and potassium from 0.345% 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 0.3%.

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 [14]. The nutrient profile of organic liquid manures depends on the quantity, quality, and fermentation period of the ingredients [15], with variations arising from the types and amounts of materials and environmental factors [16]. 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 [17].

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	0.120	0.345	0.076	186.30	52.10
T2	1.19	0.132	0.370	0.078	193.60	54.65
T3	1.26	0.145	0.400	0.082	198.80	57.25
T4	1.26	0.143	0.400	0.083	198.60	56.95
T5	1.33	0.162	0.400	0.086	204.70	59.25
T6	1.4	0.188	0.425	0.087	207.20	62.95
T7	1.4	0.185	0.430	0.088	207.20	63.60
T8	1.47	0.200	0.455	0.091	212.10	65.80
T9	1.54	0.225	0.470	0.095	220.10	68.25
T10	1.19	0.132	0.365	0.078	193.30	54.30
T11	1.26	0.145	0.385	0.082	198.60	57.80
T12	1.33	0.152	0.410	0.085	204.00	59.10
T13	1.365	0.150	0.410	0.085	204.40	59.45
T14	1.4	0.180	0.420	0.086	207.10	63.75
T15	1.47	0.200	0.440	0.088	212.80	65.20
T16	1.474	0.202	0.440	0.087	212.10	65.60
T17	1.575	0.222	0.470	0.090	219.90	68.85
T18	1.68	0.248	0.485	0.096	225.60	71.30
T19	1.26	0.140	0.370	0.080	198.50	57.45
T20	1.33	0.158	0.380	0.084	204.70	59.60
T21	1.435	0.190	0.410	0.086	207.20	63.15
T22	1.435	0.192	0.410	0.086	207.10	63.90
T23	1.505	0.215	0.425	0.088	212.80	65.10
T24	1.61	0.222	0.450	0.090	219.00	68.70
T25	1.575	0.228	0.450	0.090	219.70	68.35
T26	1.75	0.255	0.480	0.094	225.40	71.55
T27	1.855	0.260	0.500	0.098	230.30	76.75
T28	1.645	0.190	0.440	0.086	192.20	57.40

T29	1.75	0.215	0.470	0.090	195.50	59.85
T30	1.82	0.225	0.485	0.092	200.00	63.10
T31	1.855	0.228	0.490	0.092	200.30	63.70
T32	1.925	0.242	0.500	0.094	207.40	65.60
T33	2.03	0.245	0.505	0.098	213.80	68.30
T34	2.03	0.250	0.520	0.098	213.80	68.35
T35	2.1	0.265	0.540	0.100	218.40	70.90
T36	2.17	0.285	0.560	0.140	224.10	76.80
T37	1.75	0.213	0.450	0.087	195.40	59.50
T38	1.855	0.222	0.475	0.092	200.30	63.25
T39	1.925	0.248	0.490	0.101	207.20	65.90
T40	1.925	0.248	0.495	0.096	207.80	65.10
T41	1.925	0.255	0.500	0.098	213.60	68.60
T42	2.03	0.265	0.495	0.100	218.00	71.80
T43	2.1	0.275	0.500	0.109	218.30	71.40
T44	2.17	0.280	0.560	0.120	224.80	76.30
T45	2.24	0.318	0.570	0.161	229.45	79.70
T46	1.855	0.232	0.460	0.090	200.40	63.90
T47	1.925	0.240	0.465	0.094	207.50	65.10
T48	2.03	0.252	0.500	0.098	213.80	68.80
T49	2.03	0.252	0.505	0.098	213.80	68.30
T50	2.1	0.278	0.510	0.099	218.90	71.40
T51	2.17	0.242	0.515	0.141	224.20	76.60
T52	2.17	0.285	0.515	0.141	224.30	79.60
T53	2.24	0.310	0.570	0.166	229.60	79.70
T54	2.31	0.335	0.580	0.182	235.50	82.10
T55	2.1	0.252	0.530	0.098	207.00	59.40
T56	2.17	0.265	0.535	0.133	213.80	63.20
T57	2.24	0.275	0.560	0.179	218.35	65.40
T58	2.24	0.275	0.560	0.180	218.60	65.90
T59	2.31	0.300	0.590	0.204	224.60	68.10
T60	2.38	0.350	0.615	0.220	229.30	71.90
T61	2.38	0.350	0.615	0.221	229.70	71.20
T62	2.45	0.355	0.620	0.240	235.90	76.30
T63	2.52	0.362	0.645	0.280	241.10	79.50
T64	2.17	0.260	0.540	0.110	213.60	65.90
T65	2.24	0.285	0.550	0.119	218.20	68.10
T66	2.31	0.310	0.570	0.162	224.70	71.45
T67	2.31	0.310	0.570	0.163	224.45	71.30
T68	2.38	0.335	0.615	0.221	229.10	76.50

T69	2.45	0.340	0.615	0.240	235.40	79.20
T70	2.45	0.340	0.620	0.245	235.80	79.80
T71	2.52	0.365	0.630	0.260	241.90	82.40
T72	2.59	0.380	0.645	0.280	250.00	87.35
T73	2.24	0.280	0.550	0.121	218.80	68.20
T74	2.31	0.312	0.560	0.140	224.20	71.60
T75	2.38	0.332	0.575	0.180	229.70	76.80
T76	2.38	0.335	0.580	0.182	229.60	76.50
T77	2.45	0.355	0.610	0.199	235.90	79.50
T78	2.52	0.362	0.625	0.240	241.10	82.90
T79	2.52	0.360	0.630	0.241	241.40	82.05
T80	2.59	0.370	0.635	0.283	250.60	87.70
T81	2.66	0.385	0.655	0.300	256.60	92.40
CD	0.203	0.039	0.033	0.02	4.591	2.171
SEM	0.072	0.014	0.012	0.007	1.632	0.772

The Iron (Fe) content of Panchagavyaranged from 49.7 mg L^{-1}in T1 to 53.1 mg L^{-1}in T81.Manganese(Mn) content in Panchagavyawas 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 [18].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 [13,19].

Table 4. Micronutrientcontent of Panchagavya

Treatment	Fe (mg L^{-1})	Mn (mg L^{-1})	Zn (mg L^{-1})	Cu (mg L^{-1})
T1	49.7	2.60	4.10	12.50
T2	49.9	2.85	4.25	12.75
T3	50.1	3.00	4.45	12.90
T4	50.3	3.15	4.60	13.05
T5	50.6	3.35	4.75	13.25
T6	50.8	3.50	4.80	13.40
T7	51.0	3.65	4.95	13.55
T8	51.2	3.80	5.05	13.70

T9	51.5	3.90	5.15	13.80
T10	49.9	2.85	4.25	12.75
T11	50.1	3.00	4.45	12.90
T12	50.3	3.15	4.60	13.05
T13	50.6	3.35	4.75	13.25
T14	50.8	3.50	4.80	13.40
T15	51.0	3.65	4.95	13.55
T16	51.2	3.80	5.05	13.70
T17	51.5	3.90	5.15	13.80
T18	51.9	4.05	5.30	13.95
T19	50.1	3.00	4.45	12.90
T20	50.3	3.15	4.60	13.05
T21	50.6	3.35	4.75	13.25
T22	50.8	3.50	4.80	13.40
T23	51.0	3.65	4.95	13.55
T24	51.2	3.80	5.05	13.70
T25	51.5	3.90	5.15	13.80
T26	51.9	4.05	5.30	13.95
T27	52.1	4.20	5.45	14.10
T28	50.3	3.15	4.60	13.05
T29	50.6	3.35	4.75	13.25
T30	50.8	3.50	4.80	13.40
T31	51.0	3.65	4.95	13.55
T32	51.2	3.80	5.05	13.70
T33	51.5	3.90	5.15	13.80
T34	51.9	4.05	5.30	13.95
T35	52.1	4.20	5.45	14.10
T36	52.2	4.35	5.55	14.25
T37	50.6	3.35	4.75	13.25
T38	50.8	3.50	4.80	13.40
T39	51.0	3.65	4.95	13.55
T40	51.2	3.80	5.05	13.70
T41	51.5	3.90	5.15	13.80
T42	51.9	4.05	5.30	13.95
T43	52.1	4.20	5.45	14.10
T44	52.2	4.35	5.55	14.25
T45	52.4	4.50	5.70	14.40
T46	50.8	3.35	4.80	13.25
T47	51.0	3.50	4.95	13.40
T48	51.2	3.65	5.05	13.55

T49	51.5	3.80	5.15	13.70
T50	51.9	3.90	5.30	13.80
T51	52.1	4.05	5.45	13.95
T52	52.2	4.20	5.55	14.10
T53	52.4	4.35	5.70	14.25
T54	52.5	4.50	5.85	14.40
T55	51.0	3.50	4.95	13.40
T56	51.2	3.65	5.05	13.55
T57	51.5	3.80	5.15	13.70
T58	51.9	3.90	5.30	13.80
T59	52.1	4.05	5.45	13.95
T60	52.2	4.20	5.55	14.10
T61	52.4	4.35	5.70	14.25
T62	52.5	4.50	5.85	14.40
T63	52.7	4.70	6.05	14.60
T64	51.2	3.65	5.05	13.55
T65	51.5	3.80	5.15	13.70
T66	51.9	3.90	5.30	13.80
T67	52.1	4.05	5.45	13.95
T68	52.2	4.20	5.55	14.10
T69	52.4	4.35	5.70	14.25
T70	52.5	4.50	5.85	14.40
T71	52.7	4.70	6.05	14.60
T72	52.9	4.85	6.20	14.75
T73	51.5	3.80	5.15	13.70
T74	51.9	3.90	5.30	13.80
T75	52.1	4.05	5.45	13.95
T76	52.2	4.20	5.55	14.10
T77	52.4	4.35	5.70	14.25
T78	52.5	4.50	5.85	14.40
T79	52.7	4.70	6.05	14.60
T80	52.9	4.85	6.20	14.75
T81	53.1	5.05	6.35	14.95
CD	0.207	0.095	0.116	0.095
SEM	0.074	0.034	0.041	0.034

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). Thepercentage 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 [20]. Similar result was found by [21] and [22].

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

Table 8. Seed germination of Okra after treatment withPanchagavya

Treatment	Germination %	Root length (cm)	% increase of root length from control
T1	100.0	2.400	3.450
T2	95.0	2.430	4.740
T3	100.0	2.520	8.620
T4	95.0	2.520	8.620
T5	100.0	2.680	15.520
T6	100.0	3.090	33.190
T7	100.0	3.040	31.030
T8	100.0	3.280	41.380
T9	100.0	3.610	55.600
T10	100.0	2.400	3.450
T11	100.0	2.430	4.740
T12	100.0	2.570	10.775
T13	100.0	2.540	9.480
T14	100.0	2.700	16.380
T15	95.0	3.130	34.910
T16	100.0	3.090	33.190
T17	100.0	3.330	43.535
T18	100.0	3.710	59.910
T19	95.0	2.420	4.310
T20	100.0	2.470	6.465
T21	100.0	2.590	11.640
T22	100.0	2.580	11.210

T23	100.0	2.740	18.100
T24	100.0	3.160	36.210
T25	100.0	3.130	34.910
T26	100.0	3.380	45.690
T27	100.0	3.750	61.640
T28	100.0	2.990	28.880
T29	100.0	3.200	37.930
T30	99.5	3.470	49.570
T31	100.0	3.440	48.275
T32	100.0	3.800	63.790
T33	100.0	3.950	70.260
T34	100.0	3.900	68.100
T35	100.0	4.210	81.470
T36	95.0	4.320	86.210
T37	100.0	3.010	29.740
T38	100.0	3.240	39.655
T39	100.0	3.550	53.020
T40	95.0	3.500	50.860
T41	100.0	3.820	64.660
T42	100.0	3.990	71.980
T43	100.0	3.950	70.260
T44	95.0	4.250	83.190
T45	100.0	4.330	86.640
T46	100.0	3.060	31.900
T47	100.0	3.300	42.240
T48	100.0	3.670	58.190
T49	100.0	3.580	54.310
T50	100.0	3.840	65.520
T51	100.0	4.055	74.785
T52	100.0	4.010	72.840
T53	100.0	4.280	84.480
T54	95.0	4.400	89.660
T55	100.0	3.840	65.520
T56	100.0	4.060	75.000
T57	100.0	4.310	85.775
T58	100.0	4.300	85.345
T59	95.0	4.400	89.660
T60	100.0	4.600	98.275
T61	100.0	4.570	96.980
T62	95.0	4.715	103.235

T63	100.0	4.870	109.910
T64	100.0	3.880	67.240
T65	100.0	4.110	77.155
T66	100.0	4.390	89.225
T67	95.0	4.360	87.930
T68	100.0	4.430	90.950
T69	100.0	4.650	100.430
T70	95.0	4.600	98.275
T71	100.0	4.785	106.250
T72	100.0	4.915	111.855
T73	95.0	4.930	112.500
T74	100.0	4.150	78.880
T75	100.0	4.310	85.775
T76	95.0	4.370	88.360
T77	100.0	4.450	91.810
T78	100.0	4.680	101.720
T79	95.0	4.650	100.430
T80	100.0	4.810	107.330
T81	100.0	4.980	114.655
CD	2.152	0.027	1.144
SEM	NS	0.009	0.407

3.3 IAA and GAcontent 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 inT54. 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 [23]. The variation in hormonal contents among the treatments could be due to difference in the microbial activity[14,24]. 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 [25]

Table 9. IAA and GA content of Panchagavya

TRT	IAA (µgmL^{-1})	GA (µgmL^{-1})
T54	56.596	138.340
T59	71.331	143.607

T60	77.022	153.760
T61	84.853	159.100
T62	88.537	163.820
T63	93.154	176.133
T66	65.015	143.020
T67	71.706	149.420
T68	77.522	153.773
T69	84.912	159.093
T70	90.801	163.840
T71	93.824	169.493
T72	100.294	176.867
T73	71.912	148.573
T76	77.169	153.827
T77	84.926	159.093
T78	88.971	163.833
T79	93.904	169.673
T80	100.441	176.820
T81	104.191	185.233
CD	3.403	4.493
SEM	1.153	1.523

3.1.2 Principal Component Analysis

The results of laboratory analysis of Panchagavya combinations were subjected to principal component analysis (PCA) (Table 5, 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.

Table 5. 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

From the biplot (Fig.1) entire subset denoted with rectangle 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 within the rectangle 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 6) 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.

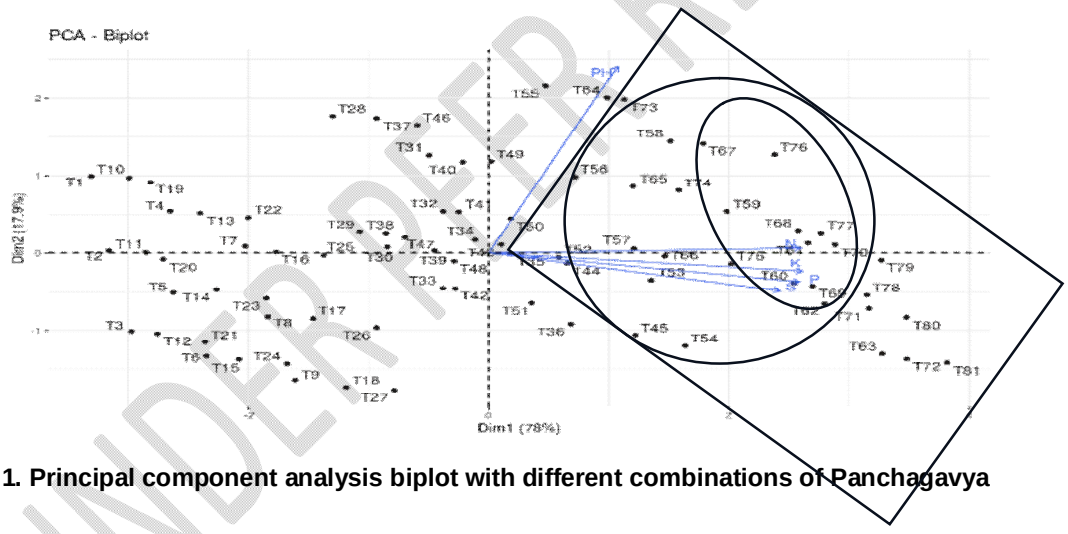

Fig. 1. Principal component analysis biplot with different combinations of Panchagavya

Table 6. 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

3.1.3 Biological properties of liquid organic manure

Microbial population present in selected best 10 combination of Panchagavya are given in Table 7. 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 [26]. 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 [27]. Among various organic farming inputs, Panchagavya showed the highest microbial population, including bacteria, fungi, and actinomycetes, thus promoting soil fertility and microbial activity [28]. Additionally, metagenomic analyses highlight Panchagavya's diverse microbial community, which further supports its capacity to enrich soil health through microbial diversity [29].

Table 7. 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

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 supportingorganic farming methods.

Disclaimer (Artificial intelligence)

Option 1:

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.

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