SUPPLEMENTARY MATERIAL AVAILABLE ONLINE

Indian Journal of Agricultural Sciences **96** (3): 319–327, March 2026/Article
https://doi.org/10.56093/ijas.v96i3.167651

Assessment of the influence of different doses of liquid organic formulations on growth, flowering and yield attributes of strawberry (*Fragaria* × *ananassa*) cv. Camarosa under black polyethylene mulch

GAURAV CHAMOLI[1], KH CHANDRAKUMAR SINGH[1]*, MANJU[1], DEEPAK MEWAR[1], SHIKHAR SEMWAL[1], PANKAJ BAHUGUNA[1], HAOBIJAM JAMES WATT[2], GARGI GOSWAMI[1], TEJAS ASHOK BHOSALE[1] and DEVINA SERAM[2]

College of Horticulture, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Bharsar, Uttarakhand 246 123, India

Received: 07 June 2025; Accepted: 26 February 2026

ABSTRACT

The experiment was conducted for two consecutive seasons from 2022–2023 at College of Horticulture, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Bharsar, Uttarakhand in a naturally ventilated polyhouse by using five different liquid organic formulations (*Jeevamrut*, *Amritpani*, Seaweed extract, Vermiwash, Humic acid) with three different doses, taking strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa as the test crop. The experiment was laid out on a randomised complete block design (RCBD) in triplicate. Certain plant growth parameters, yield and economic parameters were taken into consideration for drawing conclusions in the study. In the majority of the traits, humic acid (HA) @3% outperformed and proved significantly higher yield over the rest of the treatments, 256.67% higher yield over the control. Even though the profitability of a production system largely depends on yield, there is a necessity for considering the input cost incurred in the production as well. HA @1%, even though it produced a lesser yield as compared to HA @3%, proved the most profitable input (C:B, 1:4.38) due to the lesser input cost, though there shall be a 9% compromise in yield as compared to HA @3%. Yet, HA @1% scored 198.4% higher yield over the control. Thereby, farmers can derive a promising return of 4.38 fold profit from their investments.

Keywords: Black polyethylene mulch, Humic acid, Organic formulations, Soil properties

Strawberry (*Fragaria* × *ananassa* Duch.), a soft fruit species, is one of the world's most preferred fruits because of the presence of certain health-promoting substances and considerably higher antioxidative properties (Fijol-Adach *et al.* 2016), in addition to their taste. Further, this berry has L-ascorbic acid, certain polyphenolic compounds and other easily absorbable organic compounds (Muthukumaran *et al.* 2017).

With especial context to India, as a matter of fact, inorganic fertilisers are one of the prime reasons behind soil degradation leading to the severe soil acidity and finally compromising the long-term sustainability in agriculture, which in fact is a wake-up call to human health and to environment (Rathore *et al.* 2023). To cope-up the ill effects of surplus use of these inorganic fertilisers, the application of organic manures is witnessed for being an excellent alternative which fulfils the nutrient requirements of crops, along with the add-on benefits of improvement in physico-chemical and biological properties of soil, ensuring upscaled crop productivity (Patel *et al.* 2015).

The inclusions of traditional organic formulations, a type of organic manure, have been practiced by multiple researchers and proven to enhance the fertility and productivity of soil. The application of such fermented liquid bio-formulations (vermiwash, seaweed, humic acid, *amritpani*, *jeevamrut, panchagavya*, etc.) encourages soil microbial activities, which eventually results in the increase in soil fertility as well as availability of nutrients (Chatterjee *et al.* 2014, Sharma *et al.* 2021*,* Rathore *et al.* 2023). A diverse range of microorganisms and their corresponding populations, such as bacteria, actinomycetes, fungi, phosphobacteria, methylotrophs, *Azotobacter*, *Pseudomonas* and *Azospirillum* are found to be there in these bio-stimulants (Sreenivasa *et al.* 2009). The mechanisms for the beneficial effects of these organic formulations are attributed to higher microbial populations and activity

[1]College of Horticulture, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Bharsar, Uttarakhand; [2]School of Agriculture, Lovely Professional University, Phagwara, Punjab. *Corresponding author email: chandrakumarkh@gmail.com

(Murphy *et al.* 2007), higher soil enzymatic activities such as dehydrogenases and proteases (Meena and Rao 2021), which are responsible for the catalysing and breaking down of organic matter, nutrient transformation and cycling. It is worth to note that drastic improvements in crop production are associated with the use of synthetic fertilisers and pesticides, however, indiscriminate and intensive use shall lead to severe depletion in soil health and crop productivity (Khandare *et al.* 2020). Nevertheless, the growth, yield and quality of crops are greatly influenced by types of fertilisation (Kouam *et al.* 2024).

In our experiment, it was hypothesised that the enactment of different doses of liquid organic formulations will have different degrees of improvement in soil properties and growth and production of strawberries. Hence, a field trial in naturally ventilated polyhouse conditions was conducted with the primary objective to discover the effect of different doses of liquid organic formulations, viz. *jeevamrut, amritpani*, sea-weed extract, vermiwash and humic acid on the growth and production of strawberry cv. Camarosa as a function of improved soil properties.

MATERIALS AND METHODS

The experiment was conducted for two consecutive seasons from 2022–2023 at College of Horticulture, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Bharsar (30.0574 °N, 78.9924 °E; at an elevation of 1900 m amsl), Uttarakhand under naturally ventilated polyhouse conditions. One-year-old Camarosa runners were separated from their mother block at College of Horticulture, Bharsar. Liquid organic formulations *jeevamrut* and *amritpani* were freshly prepared in the experimental site, adopting standard protocols, Indian Farmers Fertiliser Cooperative Limited (IFFCO) manufactured seaweed extract and humic acid and vermiwash was collected from the Fruit Nursery orchard of the institute.

The land was brought to a fine tilth with the help of a power tiller and repeated crushing of soil clods and subsequent plots were made. Well-decomposed farmyard manure (FYM) @15 t/ha was applied and mixed thoroughly. The basic soil properties of the experimental site were tested before and after transplanting in second season (Supplementary Table 1). Prior to transplanting, black polyethylene mulch (25 μ) was laid over beds (90 cm × 90 cm) and holes were then made at recommended spacing (30 cm × 30 cm) with the help of sharp glass. Uniform healthy runners were then transplanted on raised beds in the month of September 2022, ensuring the whole operation was carried out in evening hours to facilitate the establishment of runners. Sufficient irrigation was given soon after the transplanting of runners. Regular hand-weeding was done at 60, 120, 180 and 240 DAT (days after transplanting). 2/3 of the mature fruits of Camarosa, having a considerable amount of firmness and fruit colour were plucked manually along with pedicel.

The analysis of soil hydro-physico-chemical properties was made following standard protocols as given by Jackson (1973) and Singh (1980). The physiological parameters, relative leaf water content (RWC, %) by Barrs and Weatherley (1962), specific leaf weight (SLW, g/cm^2) and chlorophyll content (mg/g) by Arnon (1949) methods were also investigated. The details of the treatment formulations in the experiment are depicted in Table 1. The experiment was laid in a randomised complete block design (RCBD) in triplicate for both the seasons. Total number of foliar sprays applied in each treatments were 6 (3 sprays in each season) i.e. @30, 60 and 90 days after transplanting (DAT) in season 1 and @150, 180 and 210 DAT in season 2.

The recorded data (SEM±) were subjected to analysis by ANOVA procedures with the help of Microsoft Excel. Differences in means among treatments were compared (LSD test) and considered significant at $p \leq 0.05$. Correlation studies were based on the Pearson correlation matrix and Euclidean distances.

RESULTS AND DISCUSSION

Hydro-physico-chemical properties of soil of the experimental site: Bulk density (BD) and saturated hydraulic conductivity (HC) were estimated at three different stages (before transplanting, after harvesting in first season and after harvesting in second season) (Fig. 1 and 2). Five random samples from the entire field were observed and the mean value was considered as the initial value of BD (1.25 Mg/m^3) and HC (0.56 cm/min) in all the treatments. Hikes in BD values were seen in all the treatments with time, though the degrees of hikes were variable. The highest BD (1.45 Mg/m^3) was seen in AP @4% at the end of the experiment, however, a BD (1.40 Mg/m^3) was observed in *amritpani* (AP) @12%, at par with the control (1.401 Mg/m^3), indicating a greater dose of AP shall be required for further improvement in soil health. The rest of the treatments showed superior performance over control, the least BD (1.32 Mg/m^3), being under humic acid (HA) @3%, indicating the greater buffering on hike, indicating soils were comparatively less compacted, which would in turn encourage better root proliferation, nutrient and water extraction. The HC of a soil is closely associated with the structure, texture, organic matter content, etc. A decrease in HC values with time in all the treatments was seen, indicating gradually increasing compaction, resulting in fewer macropores for water transmission within the soil mass. At the end of the experiment, the highest HC (0.8 cm/min) was noticed in vermiwash (VW) @10% followed by VW @6% (0.7 cm/min). The worse HC (0.4 cm/min) was recorded in the control, indicating a higher degree of soil compaction, which might be because the treatment had only FYM @20 t/ha as the source of organic matter, unlike the rest of the treatments. Thereby, the least improvement in soil structure could be claimed in control.

Considerable changes in soil chemical properties were seen from the initial stage to the end of the experiment. Rise in *p*H were seen in all the treatments. The initial *p*H value of 5.49 got hiked to 5.50–6.11, perhaps owing to the addition of organic matter through different organic formulations along

Table 1 Treatment details implemented in the experiment

Sl. no.	@	Treatment annotations	Total quantity of LOF applied during the experiment	Quantity of LOF applied in each spray	Frequency of foliar applications
1	NIL	Control	NIL	NIL	NIL
2	*Jeevamrut* @2 %	JM @2%	200 L/ha	≈ 33.33 L/ha	Thrice in both seasons: Season 1: at 30, 60 and 90 DAT Season 2: at 150, 180 and 120 DAT
3	*Jeevamrut* @4%	JM @4%	400 L/ha	≈ 66.66 L/ha	
4	*Jeevamrut* @6 %	JM @6%	600 L/ha	100 L/ha	
5	*Amritpani* @4 %	AP @4%	200 L/ha	≈ 33.33 L/ha	
6	*Amritpani* @8 %	AP @8%	400 L/ha	≈ 66.66 L/ha	
7	*Amritpani* @12 %	AP @12%	600 L/ha	100 L/ha	
8	Seaweed extract @1%	SWE @1%	60 L/ha	10 L/ha	
9	Seaweed extract @2%	SWE @2%	120 L/ha	20 L/ha	
10	Seaweed extract @3%	SWE @3%	180 L/ha	30 L/ha	
11	Vermiwash @6%	VW @6%	300 L/ha	50 L/ha	
12	Vermiwash @9%	VW @9%	450 L/ha	75 L/ha	
13	Vermiwash @12%	VW @12%	600 L/ha	100 L/ha	
14	Humic acid @1%	HA @1%	60 L/ha	10 L/ha	
15	Humic acid @2%	HA @2%	120 L/ha	20 L/ha	
16	Humic acid @3%	HA @3%	180 L/ha	30 L/ha	

LOF, Liquid organic formulations; DAT, Days after transplanting.

with FYM @20 t/ha. Control had a negligible hike in *p*H, which might be due to the least amount of received organic matter. Zydlik and Zydlik (2023) reported an increase in soil *p*H with HA-Quadruple (4 times foliar applications of HA @20 L/ha) in strawberry. Akinci *et al.* (2009), Katkat *et al.* (2009) and Zydlik and Zydlik (2020) also claimed the decline in soil acidity due to the application of HA. An increase in electrical conductivity values was also seen in

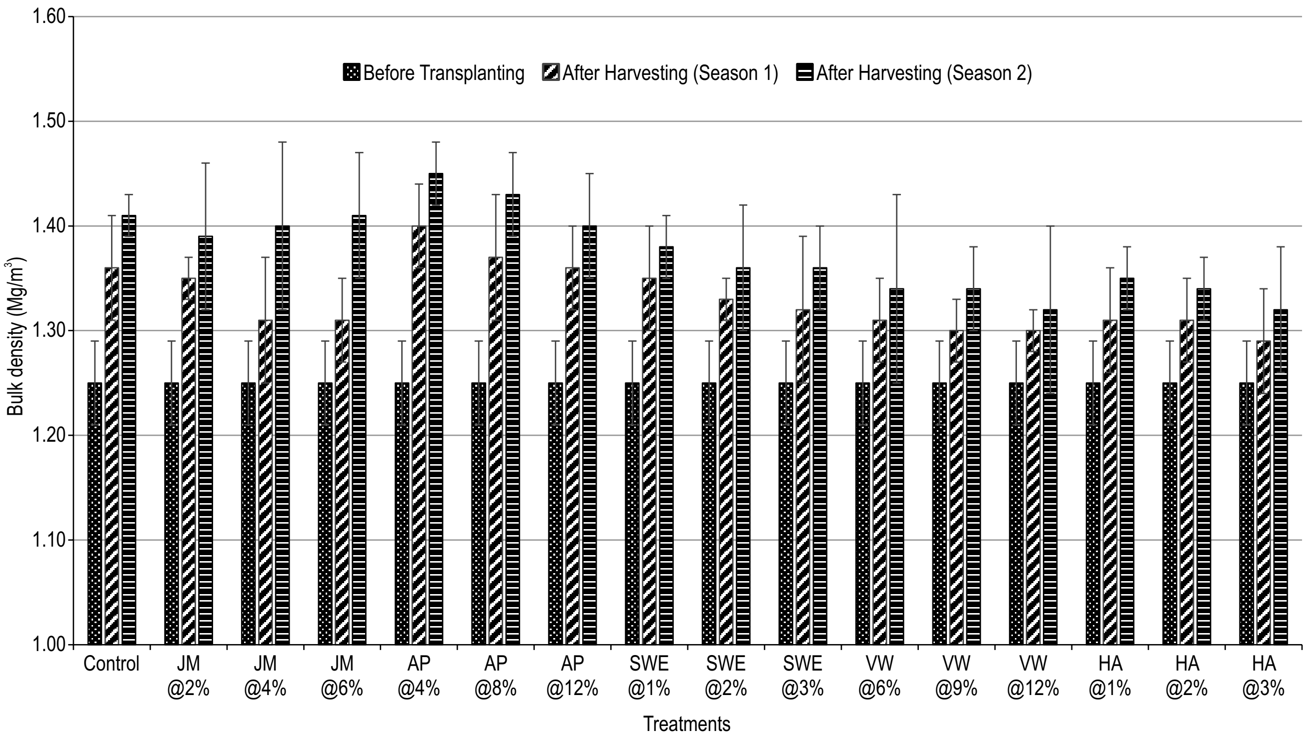

Fig. 1 Bulk density observed in different treatments at different periods.
JM, *Jeevamrut*; AP, *Amritpani*; SWE, Seaweed extract; VW, Vermiwash; HA, Humic acid.

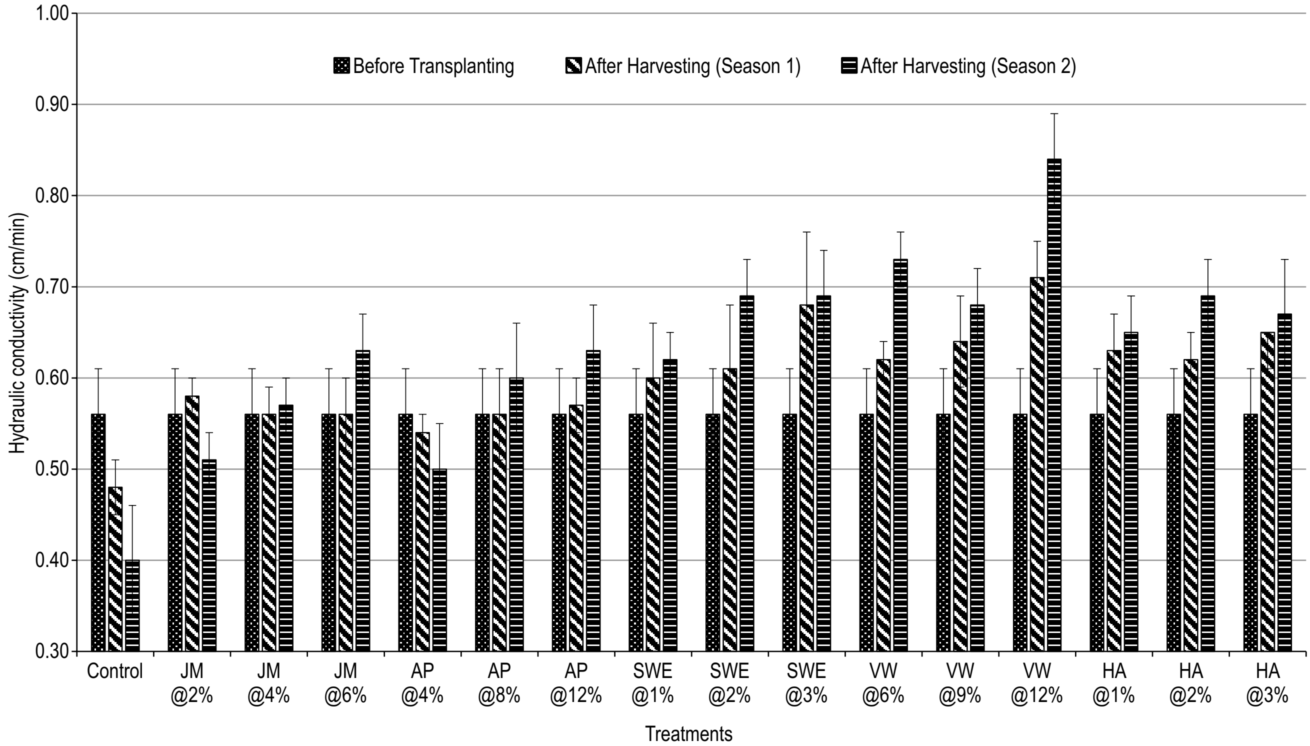

Fig. 2 Saturated hydraulic conductivity observed in different treatments at different periods. JM, *Jeevamrut*; AP, *Amritpani*; SWE, Seaweed extract; VW, Vermiwash; HA, Humic acid.

all the treatments (0.49–0.68 dS/m). The oxidisable organic carbon content was also seen to increase from 1.71% to 1.74–1.79%. This increment could result from the added FYM and different organic formulations rich in essential nutrients, though no distinct variations in the increment was seen among the treatments. Antil and Singh (2007) also reported increased soil organic carbon content as a result of the amendment of organic manure. Similar finding was also reported by Ewulo and Ojeniyi (2008) in tomato. There had been a decrease of OC (%) in control and an unchanged value in SE @2%. The highest available N (566.46 kg/ha) was noticed in HA @3%. There had been a decrease in available N in the control from 544.97 kg/ha to 408.19 kg/ha at the end of the experiment in the control. Thus, the experimental site had high available N in all the treatments except in control. HA-Double (twice foliar applications of HA @20 L/ha) in strawberry assured a significant increase in available nitrogen in soil (Zydlik and Zydlik 2023). An increase in available P_2O_5 content in all the treatments except in control and SWE treatments, the highest being 30.95 kg/ha in VW @6% was seen. Increase in N and P content at the end of the experiment could be a result of the release of nutrients from added organic formulations, owing to greater mineralisation from applied organic formulations and release from the soil due to richer organic matter. Higher N mineralisation as a result of the addition of *panchagavya* was reported by Aher *et al.* (2021) and Chen *et al.* (2017). The K_2O contents of the soils were found to be decreased at the end of the experiment in all the treatments; however, the degree of decrement was least in HA treatments (81.76–83.44 kg/ha) and highest in the control (60.25 kg/ha) from the initial value of 85.00 kg/ha. We, in our experiment, could see an overall improvement in hydro-physico-chemical soil properties, owing to the imposition of varying doses of different organic formulations, though the degree of improvement is variable. HA is a natural bio-stimulant derived from dead and decay tissues of plants and animals, commonly found in organic wastes, which plays a key role in improving soil health and plant productivity, leading to sustainable agriculture (Antu *et al.* 2025). They have a unique ability in soil for augmenting aggregate stability, aeration, water holding capacity and root proliferation, which in turn boosts the growth of plants and tolerance to stressors, including heavy metal toxicity, drought and salinity (Antu *et al.* 2025).

Schoebitz *et al.* (2016) emphasised that HAs encourage activities of beneficial soil microorganisms and increase available nutrients in soil (Zanin *et al.* 2018*,* Zydlik and Zydlik 2020), which could easily be taken up by plant roots (Nazli *et al.* 2014*,* Ennab *et al.* 2016). HAs are also claimed to be effective in increasing plant resistance to different types of stresses (Nunes *et al.* 2019*,* Saidimoradi *et al.* 2019) and pests and fungal attacks (Olivares *et al.* 2015).

Physiological parameters of strawberry: The findings of our study revealed a statistically significant influence of varying doses of different organic formulations on the physiological attributes of strawberry (Table 2) against the untreated control. To be more specific, the pooled data of both seasons clearly showed the highest leaf area (88.63 cm^2), leaf area index (1.48), specific leaf weight (SLW,

Table 2 Effect of different organic formulations on certain physiology in strawberry (pooled value of season 1 and season 2)

Treatments	Days taken to first flower opening ± SE(m)	Number of flowers/plant ± SE(m)	Duration of flowering (days) ± SE(m)	Number of fruits/ plant ± SE(m)	Fruit set (%) ± SE(m)	Duration of fruiting (days) ± SE(m)
Control	116.77 ± 1.33	13.13 ± 0.29	50.73 ± 1.65	9.30 ± 0.17	70.37 ± 0.17	38.93 ± 0.49
JM @2%	98.30* ± 1.99	14.63 ± 0.48	57.17* ± 0.84	10.87 ± 0.61	74.03* ± 2.13	44.17* ± 0.15
JM @4%	95.93* ± 1.12	15.10* ± 0.70	58.93* ± 1.68	11.43* ± 0.77	75.37* ± 1.70	45.20* ± 1.35
JM @6%	101.43* ± 2.10	13.97 ± 0.47	56.20* ± 1.59	10.33 ± 0.22	73.80* ± 0.99	42.27* ± 0.32
AP @4%	105.73* ± 0.73	13.37 ± 0.81	53.60 ± 1.21	9.70 ± 0.61	72.23 ± 0.12	40.67 ± 1.120
AP @8%	102.30* ± 1.75	13.57 ± 0.50	54.37* ± 1.03	9.87 ± 0.37	72.67 ± 0.93	41.97* ± 1.33
AP @12%	107.80* ± 2.22	13.27 ± 0.69	52.67 ± 1.48	9.57 ± 0.60	71.83 ± 0.90	40.30 ± 0.20
SWE @1%	86.27* ± 1.49	18.17* ± 0.87	65.77* ± 1.73	15.10* ± 0.80	83.07* ± 1.47	51.63* ± 0.90
SWE @2%	84.47* ± 2.27	20.40* ± 0.56	69.47* ± 1.33	17.13* ± 0.47	83.93* ± 0.24	52.87* ± 0.81
SWE @3%	82.43* ± 2.08	20.90* ± 0.66	71.93* ± 1.43	17.73* ± 0.69	84.73* ± 1.29	55.10* ± 1.19
VW @6%	92.73* ± 0.97	15.57* ± 0.55	59.50* ± 0.17	11.83* ± 0.69	75.80* ± 1.96	46.87* ± 1.67
VW @9%	88.43* ± 0.82	16.80* ± 0.38	60.87* ± 1.63	13.10* ± 0.46	77.70* ± 1.07	48.00* ± 1.18
VW @12%	87.43* ± 1.18	17.87* ± 0.82	63.27* ± 1.42	14.23* ± 0.67	79.63* ± 1.22	50.57* ± 0.97
HA @1%	80.73* ± 0.96	21.93* ± 0.76	73.13* ± 0.22	18.67* ± 0.64	85.03* ± 1.68	56.80* ± 0.80
HA @2%	75.43* ± 1.59	23.00* ± 0.97	76.23* ± 0.19	19.83* ± 0.84	86.30* ± 0.21	59.07* ± 0.34
HA @3%	72.57* ± 1.56	24.07* ± 0.29	77.50* ± 1.35	20.90* ± 0.06	86.90* ± 0.85	61.00* ± 1.02
SE(d)	2.17	0.89	1.54	0.78	1.57	1.37
CD (p=0.05)	4.45	1.83	3.16	1.60	3.23	2.81

*Significant at 5% level of significance as compared to control. Values given are means of triplicates. JM, *Jeevamrut*; AP, *Amritpani*; SWE, Seaweed extract; VW, Vermiwash; HA, Humic acid.

22.00 mg/cm^2), relative water content (RWC, 83.90%) and chlorophyll content (2.34 mg/g) in HA @3%, followed by HA @2% and HA @1%, however, the lowest values were seen in untreated control (Table 3).

The increase in leaf area could be attributed to enhance cell division, elongation and expansion of cell walls and higher plant nitrogen as a result of HA treatment. An increase in the area of the leaf blade of strawberry upon application of HA-Double was proven most effective (Zydlik and Zydlik 2023). Rzepka-Plevnes *et al.* (2011) and Derkowska *et al.* (2015) also noticed the stimulating effect of HA on increasing leaf area.

The overall improvement in RWC and SLW could be the result of the low molecular weight component of HA reaching the plasma membrane and exerting its positive effects, boosting RWC and promoting nutrient uptake, resulting in an increase in SLW. Similar results were also obtained by Saidimoradi *et al.* (2019) in strawberry. Application of HA-Double resulted in the highest SLW (Zydlik and Zydlik 2023). According to Zydlik and Zydlik (2023), RWC didn't have a significant influence from the application of HA.

The increase in chlorophyll content in leaves could be associated with quicker nitrogen and nitrate absorption, increased nitrogen metabolism and protein formation via HA as confirmed by Haghighi *et al.* (2012). Similar findings were also reported by Ameri and Tehranifar (2012) and Karakas and Dikilitas (2021) in strawberry.

Flowering and fruiting parameters: As a matter of fact, the degree of flowering of a particular crop shall be the function of certain parameters like the number and area of leaves and other parameters like SLW, RWC and chlorophyll content. RWC is an index for water stress experienced by plant leaves and is closely related to chlorophyll content, influencing the rate of photosynthesis, which in turn will affect the fruit yield.

Statistically significant effect of different organic formulations, especially HA @3%, as compared to the control was observed on certain flowering and fruiting attributes (Table 3). Data witnessed the earliest first flower opening (72.57 days) in HA @3% against control (116.78 days). The number of flowers/plant (24.07), duration of flowering (77.50 days), number of fruits/plant (20.90) and the %fruit set (86.90%) were all found to be statistically higher in HA @3% followed by HA @2% and HA @1%, respectively. The plants grown under HA (irrespective of doses) seemed to have certain perks for developing their metabolic activities for a longer period, which could result in the earliness in flowering, like quicker photosynthate translocation, which increased flower bud initiation, resulting in flower initiation being earlier. The possible reason behind more flowers/plants could be the enhanced plant spread and number of crowns by the application of HA. Similar results were also recorded by Kazemi (2014) and Rostami and Shokouhian (2018) in strawberry.

HA @3% provided the longest flowering duration

Table 3 Effect of different organic formulations on certain flowering and fruiting attributes (pooled value of season 1 and season 2)

Treatments	Leaf area (cm^2) ± SE(m)	Leaf area index (LAI) ± SE(m)	Specific leaf weight (g/cm^2) ± SE(m)	Relative leaf water content (%) ± SE(m)	Chlorophyll content (mg/g) ± SE(m)
Control	52.78 ± 1.75	0.88 ± 0.03	15.20 ± 0.40	67.17 ± 1.44	1.41 ± 0.03
JM @2%	65.17* ± 1.10	1.09* ± 0.02	16.97* ± 0.44	73.47* ± 0.20	1.62* ± 0.06
JM @4%	67.30* ± 2.08	1.12* ± 0.04	17.43* ± 0.10	74.30* ± 1.59	1.66* ± 0.04
JM @6%	59.07* ± 1.44	0.98* ± 0.02	16.30 ± 0.27	71.83* ± 0.27	1.58* ± 0.06
AP @4%	56.63* ± 0.95	0.94* ± 0.02	15.93 ± 0.80	71.10 ± 1.77	1.60 ± 0.04
AP @8%	58.03* ± 1.23	0.97* ± 0.02	16.23 ± 0.82	71.27 ± 1.79	1.54 ± 0.01
AP @12%	55.47 ± 0.72	0.92 ± 0.01	15.73 ± 0.43	70.73 ± 1.91	1.47 ± 0.06
SWE @1%	74.20* ± 1.88	1.24* ± 0.03	19.80* ± 0.52	76.70* ± 1.94	2.03* ± 0.03
SWE @2%	77.27* ± 1.42	1.29* ± 0.03	20.27* ± 0.56	77.63* ± 0.84	2.07* ± 0.08
SWE @3%	80.43* ± 0.23	1.34* ± 0.00	21.07* ± 0.09	78.33* ± 1.54	2.13* ± 0.05
VW @6%	70.17* ± 1.09	1.17* ± 0.02	17.87* ± 0.65	74.77* ± 1.30	1.80* ± 0.08
VW @9%	72.57* ± 0.67	1.21* ± 0.01	18.90* ± 0.67	75.47* ± 0.17	1.86* ± 0.03
VW @12%	73.40* ± 0.60	1.22* ± 0.01	19.20* ± 0.60	76.40* ± 0.74	1.90* ± 0.05
HA @1%	81.23* ± 1.16	1.36* ± 0.02	21.50* ± 0.47	81.07* ± 1.85	2.21* ± 0.07
HA @2%	86.20* ± 1.60	1.43* ± 0.03	21.80* ± 0.32	82.93* ± 1.68	2.27* ± 0.07
HA @3%	88.63* ± 0.64	1.48* ± 0.01	22.00* ± 0.32	83.90* ± 1.59	2.34* ± 0.06
SE(d)	1.80	0.03	0.83	2.01	0.08
CD (p=0.05)	3.69	0.06	1.70	4.12	0.16

*Significant at 5 % level of significance as compared to control. Values given are means of triplicates. JM, *Jeevamrut*; AP, *Amritpani*; SWE, Seaweed extract; VW, Vermiwash; HA, Humic acid.

(77.50 days) and the shortest (50.73 days) in the control. This could be due to the HA application boosted soil organic matter, resulting in improved soil properties and hence an increased blooming period. Similar findings were also reported by Kazemi (2014) and Rafeii and Pakkish (2014) in strawberry. A significant positive influence of HA-Triple (three foliar applications of HA @20 L/ha) on flowering intensity and the number of flowers/plant (50% more than control, i.e. only mineral fertilisers) of strawberry was reported by (Zydlik and Zydlik 2023).

Data clarified the highest number of fruits/plant (20.90) in HA @3% and the least (9.30) in the control. The boost in the number of fruits/plant might be attributed to HA, which raised the number of flowers/plant and the highest flower bud differentiation rate. More than twice the average number of fruits/plant of strawberry was observed in HA-Triple as compared to the control (Zydlik and Zydlik 2023). Similar results were also obtained by Saidimoradi *et al.* (2019) in strawberry.

The highest fruit set (86.90%) was seen in HA @3% and the least (70.37%) in the control. This could be related to higher absorption of macro and micro elements and improved plant performance for floral parts. Similar findings were also reported by Aldulaimy and Alsinbol (2012) in strawberry. Zydlik and Zydlik (2023) found a 79.00% higher fruit set percentage over control in strawberry when applied with HA-Quadruple.

Yield and weed-biomass: A tally of 12 pickings was made in the entire experiment (combined count of pickings/harvesting during both fruiting season 1 and fruiting season 2). The longest fruiting duration (61.00 days), fruit yield/plant (487.23 g) and estimated fruit yield (16.92 t/ha) were associated with HA @3%, followed by HA @2% and HA @1%, respectively (pooled values) and the least in the control (Tables 3 and 4). HA @3% had 256.67%, 9.00% and 8.00% higher yield over control, HA @1% and HA @2%, respectively (Table 4). The yield improvement in strawberries upon application of HA could probably be due to higher availability and better ease of uptake of those essential macro- and micronutrients in soil (Nazli *et al.* 2014), which could have been facilitated by better root proliferation under HA application (Bryla and Strik 2015). Higher water absorption and retention in plants (RWC) treated with HA could also be a responsible factor for higher yield of strawberries (Khaled and Fawy 2011). Zydlik and Zydlik (2023) reported a yield increment of strawberry, around 60.00% in HA-Triple and HA-Quadruple, over control (only mineral fertilisers). Higher yielding potentials of strawberries are witnessed when treated with HAs (Shehata *et al.* 2011).

Comparatively less weed biomass (24.58 g/m^2) was seen in HA @3% over the control (85.35 g/m^2). HA also seemed to have weed-suppressing properties; however, our experiment does not have solid evidence on the matter.

Correlation analysis: A correlation study is an important statistical tool that explains the correlation between two variables. In our experiment, the number of days taken to first flowering had a statistically significant (R^2=0.9247 and

Table 4 Effect of organic formulations on yield parameters and economics in strawberry

Treatments	Fruit yield per plant (g/plant) ± SE(m)	Estimated fruit yield (t/ha) ± SE(m)			Total estimated fruit yield (t/ha) (Season-1 + Season-2)	Increase in fruit yield over control (%)	Dry weed biomass (g/m^2) ± SE(m)	C:B ratio
		Season 1	Season 2	Pooled				
Control	136.60 ± 1.35	4.39 ± 0.18	5.09 ± 0.28	4.743 ± 0.05	9.49	-	85.35 ± 3.12	1:1.44
JM @2%	175.58* ± 5.82	5.99* ± 0.23	6.21* ± 0.23	6.10* ± 0.20	12.19	28.55	71.60* ± 1.86	1:1.98
JM @4%	186.21* ± 5.73	6.40* ± 0.21	6.54* ± 0.25	6.47* ± 0.20	12.93	36.35	76.62* ± 4.43	1:2.05
JM @6%	162.07* ± 2.87	5.28* ± 0.24	5.97* ± 0.21	5.63* ± 0.10	11.26	18.70	83.58 ± 2.81	1:1.57
AP @4%	144.96 ± 3.35	4.69 ± 0.21	5.37 ± 0.25	5.03 ± 0.12	10.07	6.11	87.03 ± 2.43	1:1.47
AP @8%	150.53 ± 5.47	4.90 ± 0.21	5.55 ± 0.23	5.23 ± 0.19	10.45	10.27	92.01* ± 1.83	1:1.50
AP @12%	143.05 ± 3.61	4.62 ± 0.24	5.31 ± 0.25	4.97 ± 0.13	9.934	4.72	100.19* ± 3.52	1:1.31
SWE @1%	283.72* ± 0.89	9.58* ± 0.27	10.12* ± 0.21	9.85* ± 0.03	19.70	107.67	47.09* ± 0.47	1:2.51
SWE @2%	331.93* ± 6.91	10.71* ± 0.27	12.34* ± 0.21	11.52* ± 0.24	23.05	142.95	42.55* ± 1.23	1:2.38
SWE @3%	375.63* ± 6.87	12.27* ± 0.27	13.81* ± 0.21	13.04* ± 0.24	26.09	174.99	36.48* ± 1.36	1:2.16
VW @6%	204.07* ± 7.04	6.79* ± 0.25	7.38* ± 0.23	7.09* ± 0.25	14.17	49.42	59.76* ± 0.94	1:1.96
VW @9%	236.92* ± 6.74	7.79* ± 0.25	8.66* ± 0.22	8.22* ± 0.23	16.45	73.37	69.57* ± 2.56	1:2.24
VW @12%	266.49* ± 3.56	8.87* ± 0.25	9.63* ± 0.24	9.25* ± 0.12	18.51	95.02	72.74* ± 1.13	1:2.45
HA @1%	407.66* ± 6.79	13.89* ± 0.22	14.42* ± 0.25	14.15* ± 0.24	28.31	198.40	35.37* ± 1.46	1:4.38
HA @2%	447.20* ± 3.50	15.26* ± 0.21	15.79* ± 0.22	15.53* ± 0.12	31.06	227.37	28.55* ± 2.42	1:3.72
HA @3%	487.23* ± 6.64	16.50* ± 0.27	17.34* ± 0.25	16.92* ± 0.23	33.84	256.67	24.58* ± 1.31	1:3.28
SE(d)	6.93	0.29	0.33	0.24	-	-	2.90	-
CD (p=0.05)	14.22	0.60	0.67	0.50	-	-	5.95	-

*Significant at 5 % level of significance as compared to control. Values given are means of triplicates. JM, *Jeevamrut*; AP, *Amritpani*; SWE, Seaweed extract; VW, Vermiwash; HA, Humic acid.

R^2=0.8881; $p \leq 0.001$) negative correlation with the number of fruits/plant and flowering duration (Supplementary Fig. 1). The correlation explains that delayed flowering had a negative impact on duration of flowering and number of fruits bearing/plant, which means earlier flowering ensured the plants provide longer duration for flowering and, thereby, an increase in number of fruits bearing/plant.

In another correlation study, the RWC had a statistically significant (R^2=0.9268 and R^2=0.9453; $p \leq 0.001$) positive correlation with chlorophyll content and fruit yield. The correlation visualised that the increase in RWC significantly increases chlorophyll content and fruit yield (Supplementary Fig. 2). Therefore, these independent variables shall be taken care of so that their effect on the dependent variable yield, etc. is also taken care of.

Economics of the experiment: The data (Table 4) depicted that HA @3% provided the highest total estimated fruit yield of 33.84 t/ha (combined in both seasons), while the least (9.4 t/ha) was seen in the control. The highest cost of cultivation was incurred in SWE @3%, however, the highest gross and net returns were calculated in HA @3%. In contrast, the most profitable cost-benefit ratio (1:4.38) was seen in HA @1% and the least (1:1.31) in AP @12%. It was further interesting to learn that HA @1%, even though recorded as the 3rd highest yielder, stood the most profitable variant of organic formulation dose because the treatment incurred a lesser cost of cultivation as compared to HA @2% and HA @3%. More profits are being assured with the use of bio-stimulants by reducing the inputs of production (du Jardin 2015).

The results obtained from the present investigation clarified that all organic formulations, at their different concentrations, proved themselves superior to the control in all the traits under investigation (viz. physiological, floral and fruit yield parameters). Among the different treatments applied, HA @3% outperformed in all attributes of growth, flowering and yield. However, considering the economic point of view, HA @1% was found to be the most profitable because of the lower input cost, though there shall be a compromise of 9.00% yield, yet still acquiring 198.44% higher yield over control. Cultivators of mid-hill regions can derive benefits of profitable production of strawberry (*Fragaria × ananassa* Duch.) cv. Camarosa by adopting simple technique of mulching with Black Polyethylene Mulch and providing foliar application of humic acid @1% @10 L/ha thrice for every season (i.e. 6 times for both season 1 and season 2). With such little efforts, farmers can derive a 4.38 fold profit from their investments (i.e. C:B of 1:4.38) to be more specific.

REFERENCES

Aher S B, Lakaria B L, Kaleshananda S and Singh A B. 2021. Yield, nutrient uptake and economics of soybean–wheat cropping system under organic nutrient management in central India.

Journal of Plant Nutrition **45**: 904–19. https://doi.org/10.1080/01904167.2021.1994600

Akinci S, Buyukkeskin T, Eroglu A and Erdogan B E. 2009. The effect of humic acid on nutrient composition in broad bean (*Vicia faba* L.). *Notulae Scientia Biologicae* **1**(1): 81–7. https://doi.org/10.15835/nsb113489

Aldulaimy R M H and Alsinbol O K I. 2012. Effect of foliar humic acid application and mulching of soil on character of growth and yield of strawberry (*Fragaria ananassa* Duch.). *Anbar Journal of Agricultural Sciences* **10**(1): 82–96.

Ameri A and Tehranifar A. 2012. Effect of humic acid on nutrient uptake and physiological characteristics of *Fragaria ananassa* var. Camarosa. *Journal of Biological and Environmental Sciences* **6**(16): 77–79. https://doi.org/10.17660/ActaHortic.2014.1049.54

Antil R S and Singh M. 2007. Effects of organic manures and fertilisers on organic matter and nutrients status of the soil. *Archives of Agronomy and Soil Science* **53**: 519–28. https://doi.org/10.1080/03650340701571033

Antu U B, Roy T K, Kulsum T I, Mitu P R, Ismail Z, Arifin M, Datta M, Hossain Sk A, Islam Md S, Mahiddin N A, Bakky A Al, Hossin Sh, Islam S and Idris A M. 2025. Role of humic acid for climate change adaptation measures to boost up sustainable agriculture and soil health: A potential review. *International Journal of Biological Macromolecules* **313**: 144043. https://doi.org/10.1016/j.ijbiomac.2025.144043

Arnon D I. 1949. Copper enzymes isolated chloroplasts, polyphenol oxidase in *Beta vulgaris*. *Plant Physiology* **24**: 1–15. https://doi.org/10.1104/pp.24.1.1

Barrs H D and Weatherley P E. 1962. A research examination of the relative turgidity techniques for estimating water deficits in leaves. *Australian Journal of Biological Sciences* **15**: 413–28.

Bryla D R and Strik B C. 2015. Nutrient requirements, leaf tissue standards and new options for fertigation of northern highbush blueberry. *HortTechnology* **25**: 464–47. https://doi.org/10.21273/HORTTECH.25.4.464

Chatterjee R and Bandyopadhyay S. 2014. Effects of organic, inorganic and biofertilizers on plant nutrient status and availability of major nutrients in tomato. *International Journal of Bio-resource and Stress Management* **5**: 93–97. https://ojs.pphouse.org/index.php/IJBSM/article/view/482

Chen D, Yuan L, Liu Y, Ji J and Hou H. 2017. Long-term application of manures plus chemical fertilisers sustained high rice yield and improved soil chemical and bacterial properties. *European Journal of Agronomy* **90**: 34–42. https://doi.org/10.1016/j.eja.2017.07.007

Derkowska E, Paszt L S, Trzciński P, Przybył M and Weszczak K. 2015. Influence of biofertilisers on plant growth and rhizosphere microbiology of greenhouse-grown strawberry cultivars. *Acta Scintiarum Polonarum Hortorum Cultus* **14**: 83–96. https://czasopisma.up.lublin.pl/asphc/article/view/2643

du Jardin P. 2015. Plant Biostimulants: Definition, concept, main categories and regulation. *Scientia Horticultura* **196**: 3–14. https://doi.org/10.1016/j.scienta.2015.09.021

Ennab H. 2016. Effect of humic acid on growth and productivity of Egyptian Lime trees (*Citrus aurantifolia* Swingle) under salt stress conditions. *Journal of Sustainable Agricultural Sciences* **42**(4): 494–505. https://doi.org/10.21608/jsas.2016.3057

Ewulo B and Ojeniyi S O. 2008. Effect of poultry manure on selected soil physical and chemical properties, growth, yield and nutrient status of tomato. *African Journal of Agricultural Research* **3**: 612–16.

Fijoł-Adach E, Feldyn-Szewczyk B, Kazimierczak and Stalenga J. 2016. Effect of an agricultural production system on the presence of bioactive substances in strawberry fruits. *Postępy Techniki Przetwórstwa Spożywczego* **1**: 78–86.

Haghighi M, Kafi M and Fang P. 2012. Photosynthetic activity and N metabolism of lettuce as affected by humic acid. *International Journal of Vegetable Science* **18**: 182–89. https://doi.org/10.1080/19315260.2011.605826

Jackson M L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Karakas S D and Dikilitas M. 2021. Determination of the physiological and biochemical effects of humic acid application in strawberry plant grown under salt stress. *Harran Tarım ve Gıda Bilimleri Dergisi* **25**(3): 326–35. https://doi.org/10.29050/harranziraat.905113

Katkat A V, Çelik H, Turan M A and Asık B B. 2009. Effects of soil and foliar applications of humic substances on dry weight and mineral nutrients uptake of wheat under calcareous soil conditions. *Australian Journal of Basic and Applied Science* **3**(2): 1266–73.

Kazemi M. 2014. The impact of foliar humic acid sprays on reproductive biology and fruit quality of strawberry. *Thai Journal of Agricultural Science* **47**(4): 221–25.

Khaled H and Fawy H A. 2011. Effect of different levels of humic acids on the nutrient content, plant growth and soil properties under conditions of salinity. *Soil and Water Research* **6**(1): 21–29.

Khandare R N, Chandra R, Pareek N and Raverkar K P. 2020. Carrier-based and liquid bioinoculants of Azotobacter and PSB saved chemical fertilisers in wheat (*Triticum aestivum* L.) and enhanced soil biological properties in Mollisols. *Journal of Plant Nutrition* **43**: 36–50. https://doi.org/10.1080/01904167.2019.1659333

Kouam I D, Moungang S, Koulagna H I, Ntsoli G P, Titti R W and Yaouba A. 2024. Influence of organic and mineral fertilisers and a foliar biostimulant on the yield and nutritional quality of strawberries (*Fragaria* × *ananassa* Duch.) under field conditions. *Biochemical Systematics and Ecology* **117**: 104917. https://doi.org/10.1016/j.bse.2024.104917

Meena A and Rao K S. 2021. Assessment of soil microbial and enzyme activity in the rhizosphere zone under different land use/cover of a semiarid region, India. *Ecological Process* **10**: 16. https://doi.org/10.1186/s13717-021-00288-3

Murphy D V, Stockdale E A, Brookes P C and Goulding K W. 2007. Impact of microorganisms on chemical transformations in soil. *(In) Soil Biological Fertility*, pp. 37–59. Abbott L K and Murphy D V (Eds). Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6619-1_3

Muthukumaran S, Tranchant C, Shi J, Ye X and Xue S J. 2017. Ellagic acid in strawberry (*Fragaria* spp.): Biological, technological, stability and human health aspects. *Food Quality and Safety* **1**: 227–52. https://doi.org/10.1093/fqsafe/fyx023

Nazli R I, Kuşvuran A, Inal I, Demirbaş A and Tansi V. 2014. Effects of different organic materials on forage yield and quality of silage maize (*Zea mays* L.). *Turkish Journal of Agriculture and Forestry* **38**: 23–31. https://doi.org/10.3906/tar-1302-62

Nunes R O, Domiciano G A, Alves W S, Melo A C A, Nogueira F C S, Canellas L P, Olivares F L, Zingali R B and Soares M R. 2019. Evaluation of the effects of humic acids on maize root architecture by label-free proteomics analysis. *Scientific Reports* **9**(1): 12019. https://doi.org/10.1038/s41598-019-48509-2

Olivares F L, Aguiar N O, Rosa R C C and Calellas L P. 2015. Substrate biofortification in combination with foliar sprays of plant growth promoting bacteria and humic substances boosts production of organic tomatoes. *Scientia Horticulturae* **183**: 100–08. http://dx.doi.org/10.1016/j.scienta.2014.11.012

Patel D P, Das A, Kumar M, Munda G C, Ngachan S V, Ramkrushna I, Jayanta L, Pongla N, Buragohain J and Somireddy U. 2015. Continuous application of organic amendments enhances soil health, produce quality and system productivity of vegetable-based cropping systems in subtropical eastern Himalayas. *Experimental Agriculture* **51**(1): 85–106.

Rafeii S and Pakkish Z. 2014. Improvement of vegetative and reproductive growth of 'Camarosa' strawberry: Role of humic acid, Zn and B. *Agriculturae Conspectus Scientificus* **79**(4): 239–44.

Rathore G, Kaushal R, Sharma V, Sharma G, Chaudhary S, Dhaliwal S S, Alsuhaibani A M, Gaber A and Hossain A. 2023. Evaluation of the usefulness of fermented liquid organic formulations and manures for improving the soil fertility and productivity of brinjal (*Solanum melongena* L.). *Agriculture* **13**(2): 417. https://doi.org/10.3390/agriculture13020417

Rostami M and Shokouhian A A. 2018. Evaluation of humic acid application methods and ratios of nitrogen on characteristics of morphological and yield of strawberry (*Fragaria ananassa* Duch.) cv. Paros. *Journal of Horticultural Science* **32**(2): 251–61.

Rzepka-Plevnes D, Kulpa D, Gołębiowska D and Porwolik D. 2011. Effects of auxins and humic acids on in vitro rooting of strawberry (*Fragaria* × *ananassa* Duch.). *Journal of Food, Agriculture and Environment* **9**: 592–95.

Saidimoradi D, Ghaderi N and Javadi T. 2019. Salinity stress mitigation by humic acid application in strawberry (*Fragaria* × *ananassa* Duch.). *Scientia Horticulturae* **256**: 1–13. https://doi.org/10.1016/j.scienta.2019.108594

Schoebitz M, L'opez M D, Serri H, Martínez O and Zagal E. 2016. Combined application of microbial consortium and humic substances to improve the growth performance of blueberry seedlings. *Journal of Soil Science and Plant Nutrition* **16**: 1010–23. http://dx.doi.org/10.4067/S0718-95162016005000074

Sharma S K, Jain D, Choudharya R, Jata G, Jain P, Bhojiya A A, Jain R and Yadav S K. 2021. Microbiological and enzymatic properties of diverse Jaivik krishi inputs used in organic farming. *Indian Journal of Traditional Knowledge* **20**: 237–43.

Shehata S A, Gharib A A, Mohamed M El-Mogy, Abdel Gawad E A and Shalaby E A. 2011. Influence of compost, amino and humic acids on the growth, yield and chemical parameters of strawberries. *Journal of Medicinal Plants Research* **5**(1): 2304–08.

Singh R A. 1980. *Soil Physical Analysis*. Kalyani Publishers, New Delhi.

Sreenivasa M N, Nagaraj M, Naik N and Bhat S N. 2009. Beneficial traits of microbial isolates of organic liquid manures. *(In) Proceedings of the First Asian PGPR Congress for Sustainable Agriculture*, ANGRAU Hyderabad, June 21–24.

Zanin L, Tomasi N, Zamboni A, Sega D, Varanini Z and Pinton R. 2018. Water extractable humic substances speed up transcriptional response of maize roots to nitrate. *Environmental and Experimental Botany* **147**: 167–78. https://doi.org/10.1016/j.envexpbot.2017.12.014

Zydlik Z and Zydlik P. 2020. Effect of a preparation containing humic acids on selected physico-chemical and biological properties of replanted soil. *Journal of Elementology* **25**: 993–1004. http://dx.doi.org/10.5601/jelem.2020.25.2.2002

Zydlik Z and Zydlik P. 2023. The effect of a preparation containing humic acids on the growth, yield and quality of strawberry fruits [*Fragaria* × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier]. *Agronomy* **13**: 1872. https://doi.org/10.3390/agronomy13071872