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RESEARCH PAPER

Impact of vrikshayurveda-based liquid organic manures on soybean yield, economics and soil health under organic and natural farming practices

KALMESH B. PUJARI[1*], C. P. CHANDRASHEKHAR[1], R. B. NEGALUR[1] AND G. R. RAJAKUMAR[2]

[1]Department of Agronomy, [2] Department of Soil Science, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, India
*E-mail: kalmeshpujari3003@gmail.com

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Abstract: A permanent plot experiment was carried out to study the influence of different farming practices on productivity, soil health and economics of soybean during 2024-25 at MARS, UAS, Dharwad. The experiment was laid out in strip plot design with three farming practices in strip-I [M_1: Natural Farming (NF), M_2: Integrated Natural Farming (INF), M_3: Organic Farming (OF)] and five liquid organic manures (LOM's) in strip-II [S_1: Fish amino acid @ 5%, S_2: Fish *Kunapajala* @ 5%, S_3: Cow womb *Kunapajala* @ 5%, S_4: Herbal *Kunapajala* @ 5% and S_5: *Panchagavya* (3%) + Cow urine (10%)] at vegetative, flowering, Pod formation, and Pod filling stages with two uneven controls Recommended Package of Practices (RPP) and Chemical Farming (CF)]. The results shows that, the OF recorded higher soybean seed yield, haulm yield (3202, 4504 kg ha^{-1}), gross returns (₹ 2,11,085 ha^{-1} and ₹ 1,77,781 ha^{-1} with and without premium price, respectively) and SOC (5.71 g kg^{-1} of soil) over NF. However, Harvest index, net returns, B:C ratio in both with and without premium price and SOC of NF were higher than OF. Foliar and soil application of *panchagavya* @ 3% + cow urine @ 10% recorded higher seed yield, haulm yield, gross returns, net returns and B:C ratio in both with and without premium price than all other liquid organic manures. Similarly, the strip-I and strip-II interaction shows that M_3S_5 produced higher seed yield, haulm yield and gross returns than other treatments. Whereas, the net returns, B:C ratio (with and without premium price) and harvest index were higher in M_1S_5 than other treatment combinations. The SOC was higher in OF with all LOM's and INF with S_1 and S_5. RPP recorded higher seed yield and haulm yield, gross and net returns as well as B:C ratio. However, the net returns and B:C ratio of NF and INF with S_5 were higher than RPP. However, higher net returns were obtained in natural farming in both with and without premium price (₹ 99,325 ha^{-1} and ₹ 70,695 ha^{-1}, respectively) due to lower cost of cultivation. But, the net returns of M_1S_5 were lesser by 23.22% without premium price. However, it was higher by 3.45% with premium price as compared to RPP. Similarly, the net return of M_1S_5 was lesser by 20.95% without premium price, but, it was 6.6% higher with premium price as compared to CF.

Key words: Integrated natural farming, Kunapajala, Natural farming, Organic farming, Vrikshayurveda

Introduction

Soybean (*Glycine max* L. Merrill), is a commercially exploited crop and is also called as "Golden Bean" or "Miracle crop" of the 21st century on account of its multiple uses. It contains 40 per cent good quality protein, 20 per cent oil with 85 per cent unsaturated fatty acids. In India, it occupies an area of 13 m.ha with a production of 12.04 m t and productivity of 930 kg ha (Anon., 2023). In Karnataka, soybean is cultivated in an area of 3.81 lakh ha^{-1} with a production of 4.37 lakh tons and productivity of 1147 kg ha^{-1} (Anon., 2023). Natural farming is an eco-friendly, low-cost way of growing healthy food using natural inputs instead of chemicals, while improving soil health and supporting the environment. Soybean is mostly grown using chemical farming, which harms soil, plants and human health (Khadse *et al*., 2018). However, cultivation of soybean particularly under natural farming and organic farming reduces the yield to the extent of 17% alone in natural farming (Chandrashekara *et al*., 2023). To address this issue, Vrikshayurveda practices rooted in ancient texts like Vrikshayurveda by Surapala are being adopted in organic and natural farming. These methods use natural, cow-based inputs like Fish *Kunapajala*, Herbal *kunapajala*, *Panchagavya*, Cow urine and *Jeevamrutha* to improve soil fertility, seed vigor, and plant health. In order to bridge the yield gap caused by natural farming through integration of organic farming, natural farming practices along with liquid organic manures (LOM'S) as foliar spray as well as soil application was tested in soybean during 2024-25 at MARS, UAS, Dharwad for better management to study their impact on soybean production, economics and soil health.

Material and methods

A field experiment was conducted in natural farming permanent block, maintained from 2018-19 in plot number E-131 at Main Agricultural Research Station, UAS, Dharwad, during 2024-25 under rainfed conditions in medium black soil. The study area belongs to Northern Transition Zone of Karnataka (Zone VIII) and is situated at 15° 49' North latitude, 74° 97' East longitude and at an altitude of 678 m above mean sea level (MSL). The experiment consist of three farming practices in strip-I [Main plots, M_1- Natural farming, M_2- Integrated natural farming and M_3- Organic farming] and five liquid organic manures in strip-II [S_1- Fish amino acid (5%), S_2- Fish *kunapajala* (5%), S_3- Cow womb *kunapajala* (5%), S_4- Herbal *kunapajala* (5%), S_5- *Panchagavya* (3%) + Cow urine (10%)] and two uneven control plots include C_1- Recommended Package of Practices (RPP) (Boifertilizers with 40:80:25 kg N: P_2O_5: K_2O ha^{-1} + FYM 6 t ha^{-1}) and C_2 - Chemical farming (CF) (Seed treatment with vitawax, 40: 80: 25 kg N:P_2O_5:K_2O ha^{-1} without FYM). In natural farming, Seeds were treated with *beejamrutha* on the day of sowing @ 25 l 100 kg^{-1} of seed. *Jeevamrutha* sprinkled over soil and crops at 21 days interval @ 500 l ha^{-1} from 21 DAS to 75 DAS (4 times application). 1000 kg ha^{-1} of *ghanajeevamrutha* was applied to soil in two equal splits at the time of sowing and at 30 DAS @ 500 kg ha^{-1} at each time. Exsitu green manuring of *Gliricidia* was grown on bunds and used as mulch at 30 DAS, after inter cultivation and manual weeding. Foliar applications of liquid organic manures were done as per the treatments. The pests were controlled by using *Neemastra*, *Agniastra* (3%), *Brahmastra* (3%) and *Dashaparni* (3%) as profilactic measures. Diseases were controlled by using sour butter milk @ 3% and Ginger astra were reported by Palekar, 2016. In integrated natural farming, Seeds were treated with *beejamrutha* before sowing then treated with bio fertilizers as per Organic farming practices. *Jeevamrutha* sprinkled over soil and crops at 21 days interval @ 500 l ha^{-1} from 21 DAS to 75 DAS (4 times application). 1000 kg ha^{-1} of g*hanajeevamrutha* was applied to soil in two equal splits at sowing and at 30 DAS @ 500 kg ha^{-1} at each time. Exsitu green manuring of *Gliricidia* was grown on bunds and used as mulch at 30 DAS. Application of Farmyard Manure (FYM) @ 3.0 t ha^{-1} (50% of the FYM recommended in organic farming) + application of FYM (4.35 t ha^{-1}) and vermicompost (2.8 t ha^{-1}) equivalent to 50% RDP *i.e* 7.35 t ha^{-1} FYM at 10 days before sowing and 2.8 t ha^{-1} of vermicompost at 30 DAS. Foliar application of liquid organic manures was done as per the treatments. Diseases and pests were controlled as per the natural farming formulations. In organic farming, FYM @ 6.0 t ha^{-1} (as per recommended dose of FYM in RPP) applied 10 days before sowing. Neem Cake @ 500 kg ha^{-1} applied to soil at 30 DAS. The organic manures were applied equivalent to 100% recommended dose of phosphorus (RDP) through FYM (equivalent to 40 kg P_2O_5) (FYM contains 0.2% P or 0.48% P_2O_5) and vermicompost (equivalent to 40 kg P_2O_5) (vermicompost contains 0.31% P or P_2O_5 0.71%) @ 50 per cent each in addition to recommended dose of FYM (6 t ha^{-1}). *Trichoderma* seed treatment was done @ 10 g kg^{-1} seed before sowing then treated with bio fertilizers, *Rhizobium* SB-120 strain and *PSB* @ 1250 g each ha^{-1} as per the recommended organic package of practices of UAS, Dharwad. Foliar applications of liquid organic manures were done as per the treatments. Pests were controlled by using Neem oil (5ml/l), *Nomuraea rileyi* and *Beauveria basssiana* @ 5 g/l. Diseases were controlled by using *Pseudomonas fluorescence* and *Bacillius subtillis*. The pH of the soil was determined using 1:2.5 soil:water suspension after stirring intermittently for half an hour. pH was recorded by using a Systronics direct digital-331 pH meter and Electrical conductivity (EC) was determined in a saturation soil extract or in using 1:2.5 soil-water solutions. EC was recorded by using a Systronics direct digital conductivity meter-304 as described (Sparks, 1996). The soil organic carbon content was determined by wet digestion method (Walkley and Black, 1934) and expressed in percentage. The economics *viz.,* Gross returns and net returns (₹ ha^{-1}) were calculated by considering the price of the product that was prevailing in the market after harvest. Separate gross returns, net returns and B:C ratio were worked out with and without premium price by considering 20 per cent premium price for soybean produced under organic, integrated natural farming and natural farming practices.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

Statistical analysis: The data collected on various parameters from the experiment at different growth stages of soybean was analyzed statistically for test of significance following the procedure described by Gomez and Gomez (1984) for strip-plot design. The results were discussed at the probability level of five per cent. The level of significance used in "F" and "T" test was p=0.05. The analysed data was arranged parameter-wise in Tables with S.Em± and CD at 5%.

Results and discussion

Seed yield, haulm yield and Harvest Index.

Among the farming practices, organic farming recorded significantly higher seed yield and haulm yield (3202 and 4504 kg ha^{-1}, respectively), which was superior to integrated natural farming (INF) (2949 and 4082 kg ha^{-1}, respectively) and natural farming (2752 and 3466 kg ha^{-1}, respectively) (Table 1). The higher productivity under organic farming can be attributed to the balanced and adequate supply of nutrients through well decomposed organic manures, like Farm yard manure and vermicompost equivalent to 50% of recommended dose of phosphorus (80 kg P_2O_5 ha^{-1}) along with seed treatment with of biofertilizers (*Trichoderma, PSB* and *Rhizobium*) which improved soil fertility, microbial activity and nutrient cycling. These favorable conditions likely enhanced vegetative growth and reproductive efficiency, resulting in significantly higher yields (Chandrashekara *et al*., 2023).

Among the soil and foliar application of liquid organic manure treatments, *panchagavya* @ 3% with cow urine @ 10% produced higher seed and haulm yields (3356 and 4574 kg ha^{-1}, respectively) than fish *kunapajala* @ 5% (3087 and 3326 kg ha^{-1}, respectively) and fish amino acid @ 5% (3027 and 4285 kg ha^{-1}, respectively) (Table 1). This was because *panchagavya* and cow urine supplies readily available nutrients, plant growth hormones and beneficial microbes that improve nutrient uptake and crop growth, In contrast, fish *kunapajala* and fish amino acid showed comparatively lower yields due to slower nutrient release, while herbal *kunapajala* @ 5% recorded the lowest yield (2550 kg ha^{-1}) because of its relatively poor nutrient composition. Similar positive effects of cow-based formulations on crop yield and soil fertility have been reported earlier by Yadav *et al*., (2020) in soybean, seed yield (3.45 t ha^{-1}) and haulm yield (4.72 t ha^{-1}) was significantly enhanced with *panchagavya* + cow urine. Similarly, Sandrakirana *et al*. (2021) observed yield improvement in groundnut (2.82 t ha^{-1} pod and 4.21 t ha^{-1} haulm) with cow urine spray.

The interaction between farming practices and liquid organic manures revealed that organic farming with *panchagavya* @ 3% + cow urine @ 10% recorded the higher seed and haulm yields (3526 and 5565 kg ha^{-1}, respectively), which were significantly superior to all other treatment combinations. This can be attributed to the synergistic effect of organic manures with cow-based liquid organic formulations

Table 1. Seed yield (kg ha^{-1}), Haulm yield (kg ha^{-1}) and harvest index of soybean as influenced by different farming practices and liquid organic manures

Treatment ®M: Farming practices ¯S: Liquid organic manures (LOM's)	Seed yield (kg ha^{-1})				Haulm yield (kg ha^{-1})				Harvest index			
	M_1: NF	M_2: INF	M_3:OF	Mean	M_1: NF	M_2: INF	M_3:OF	Mean	M_1: NF	M_2: INF	M_3:OF	Mean
S_1: Fish Amino Acid @ 5%	2752	3098	3230	3027	3593	3926	5336	4285	43.38	44.11	37.71	41.73
S_2: Fish *kunapajala* @ 5%	2938	3032	3292	3087	3569	4085	2324	3326	45.15	42.61	48.62	45.46
S_3: Cow womb *Kunapajala* @ 5%	2576	2798	3086	2820	3302	4268	4838	4136	43.82	39.60	38.95	40.79
S_4: Herbal *kunapajala* @ 5%	2428	2345	2876	2550	3078	3761	4457	3765	44.10	38.41	39.22	40.58
S_5: *Panchagavya* (3%) with Cow urine (10%)	3069	3473	3526	3356	3788	4371	5565	4574	44.76	44.28	38.79	42.61
Mean	2752	2949	3202		3466	4082	4504		44.24	41.80	40.66	
Sources of variation		S.Em. +	C.D at 5%		S.Em. +	C.D at 5%			S.Em. +	C.D at 5%		
M : Farming practices		36	143		130	362			0.07	0.22		
S : Liquid organic manures (LOM's)			62	205		87	201			0.08	0.19	
M x S : Interaction		55	184		68	405			0.12	0.28		
Control:												
C_1:Recommended Package of Practices		3732				5589				40.89		
C_2:Chemical farming		3321				5243				39.60		
To compare		S.Em. +	C.D at 5%		S.Em. +	C.D at 5%			S.Em. +	C.D at 5%		
Control Vs Treatment combinations		79	228		126	364			0.09	0.27		

M_1: Natural Farming, M_2: Integrated natural farming, M_3: Organic Farming

that supply readily available nutrients, growth-promoting substances and beneficial microbes, thereby enhancing nutrient uptake, photosynthetic efficiency and biomass accumulation. With respect to haulm yield, organic farming with fish amino acid @ 5% (5336 kg ha^{-1}) performed on par with *panchagavya* @ 3% + cow urine @ 10%, was due to the higher nitrogen and amino acid content in fish-based formulations that promote vegetative growth. Similar beneficial effects of cow-based liquid organic formulations were reported by Shekh *et al*., (2018) in groundnut, Arunkumar and Balakrishnan (2019) in blackgram and Srinivasan and Singh (2021) in kodo millet, where *panchagavya* and cow urine combinations significantly enhanced seed and haulm yields. Likewise, Behera *et al.,* (2025) demonstrated that fish amino acid-based liquid manures markedly increased vegetative biomass and haulm yields in maize, owing to their high nitrogen and amino acid content.

The comparison between treatment combinations with controls, shows that the recommended package of practices (RPP) recorded higher seed and haulm yield (3732, 5589 kg ha^{-1}), than other treatment combinations. However, the seed and haulm yield of OF with *panchagavya* @ 3% + Cow urine @ 10% (M_3S_5) (3526 and 5565 kg ha^{-1}, respectively) and with respect to haulm yield OF with fish amino acid @ 5% (5336 kg ha^{-1}) were on par with RPP. However, with respect to seed yield M_3S_5 was on par with chemical farming (3321 kg ha^{-1}) and with respect to haulm yield M_3S_5 and M_3S_1 were on par with CF. Similar findings have been reported earlier: *panchagavya* and cow-urine foliar sprays (3% *panchagavya*; 10% cow urine) significantly increased seed and haulm/stover yields and in several trials produced haulm in the 4-6 t·ha^{-1} range and grain yields close to recommended packages (Divya and Babalad, 2012; Bhargavi *et al*., 2018; Das *et al*., 2023). Fish amino acid (FAA) treatments also produced large vegetative biomass, supporting the observation that FAA was on-par with cow-based formulations for haulm

Among the farming practices, natural farming recorded a higher harvest index (44.24%) as compared to INF (41.80%) and OF (40.66%). This higher harvest index under natural farming was attributed to the relatively lower vegetative growth and dry matter accumulation due to limited external nutrient inputs, which restrict excessive vegetative growth while favoring a greater partitioning of assimilates towards the economic yield (seeds). In contrast, organic and integrated natural farming practices enhance nutrient availability, leading to higher total biomass production, which proportionally reduces the harvest index despite higher absolute yields. Similar observations have been reported earlier, where reduced nutrient supply under natural farming conditions improved assimilate partitioning efficiency and resulted in a relatively higher harvest index (Yadav *et al*., 2020 and Chandrashekara *et al*., (2023).

Among the liquid organic manure treatments, fish *kunapajala* @ 5% recorded the higher harvest index (45.46%) than cow womb *kunapajala* @ 5% (40.79%) and *Panchagavya* @ 3% with cow urine @ 10% (42.61%). Whereas, herbal *kunapajala* @ 5% recorded the lower harvest index (40.58%) (Table 1). The relatively higher harvest index under fish *kunapajala* was attributed to its rich nitrogen, amino acids and micronutrient content, which promote more reproductive organs without excessive vegetative biomass accumulation, thereby enhancing assimilate partitioning towards seed yield. In contrast, cow womb *kunapajala*, herbal *kunapajala* and *panchagavya* + cow urine stimulate greater vegetative growth due to their hormonal and microbial activity, resulting in more haulm biomass and a proportionally lower harvest index. Similar findings have been reported earlier, where nutrient-rich fish-based formulations improved reproductive efficiency and increased harvest index as compared to other organic liquid manures (Yadav *et al*., 2020) and (Sandrakirana *et al*., 2021).

The interaction between farming practices with LOM's, the combination of organic farming with fish *kunapajala* @ 5% recorded the higher harvest index (48.62%), which was significantly higher than other interactions (Table 1). This improvement in harvest index can be attributed to the balanced supply of macro and micro-nutrients, amino acids and organic carbon from fish *kunapajala* under the organic farming practices, which enhances nutrient uptake, photosynthetic efficiency and reproductive growth. The presence of readily available nitrogen and bioactive compounds in fish-based formulations likely favored assimilate partitioning towards seed formation rather than excessive vegetative growth, thereby increasing harvest index. Similar results have been reported earlier, where the application of nutrient-rich liquid organic manures such as fish-based preparations under organic systems improved reproductive efficiency and harvest index in soybean (Yadav *et al*., 2020 and Sandrakirana *et al*., 2021).

The comparison between treatment combinations with controls, RPP recorded higher harvest index (40.89%) than chemical farming (CF) (39.60%). The harvest index of organic farming with fish *kunapajala* @ 5% (48.62 %) was superior to both controls and all other treatment combinations (Table 1). which can be attributed to the balanced supply of nutrients in RPP that ensures efficient partitioning of assimilates towards grain. Among the treatment combinations, organic farming with fish *kunapajala* @ 5% (48.62%) was superior to both controls and all other interactions. This higher harvest index may be due to the rich nutrient composition, amino acids, and bioactive compounds present in fish *kunapajala*, which under organic farming conditions enhance nutrient uptake, reproductive efficiency and assimilate partitioning towards seed yield rather than vegetative biomass. Such findings are in line with earlier studies, where fish-based organic formulations were shown to improve reproductive growth and harvest index in soybean and other crops compared to cow-based or herbal formulations (Yadav *et al*., 2020) and (Sandrakirana *et al*., 2021).

Economics

Gross returns, net returns (₹ ha^{-1}) and B:C ratio (without premium price)

Among the farming practices, organic farming recorded higher gross returns (₹ 1,77,781 ha^{-1}), than integrated natural farming (₹ 1,63,592 ha^{-1}) and natural farming (₹ 1,51,818 ha^{-1}). However, in terms of net returns, natural farming recorded the higher net returns (₹ 70,695 ha^{-1}), than integrated natural farming (₹ 53,942 ha^{-1}), while the least was observed in organic farming (₹ 33,657 ha^{-1}). Similarly, with respect to the B:C ratio, natural farming recorded significantly higher B:C ratio (1.90), followed by integrated natural farming (1.50) and lowest in organic farming (1.24) (Table 2). The higher gross returns under organic farming can be attributed to the higher seed and haulm yield, which were influenced by application of organic inputs, such as farmyard manure, vermicompost along with biofertilizers, which improve soil fertility and crop productivity (Chandrashekara *et al*., 2023). However, the organic manures were applied equivalent to RDP along with bio pesticides and bio fungicides, which increases the input and labor cost as compared to NF and INF, results in reduced net returns and B:C ratio than NF and INF. In contrast, natural farming involves the use of locally available natural resources with minimal external inputs, resulting in lower production costs, which enhanced economic efficiency and given higher net returns despite slightly lower gross returns and lower yield (Khadse *et al*., 2018) and (Yadav *et al*., 2020). This indicates that cost-effectiveness, rather than absolute yield, is the primary factor determining profitability in low-input natural farming practices.

Among the liquid organic manure treatments, significant results were noticed with respect to gross returns without premium price, where *panchagavya* (3%) + cow urine (10%) registered the higher gross returns (₹ 1,85,972 ha^{-1}), which was significantly superior to all other LOMs, followed by fish *kunapajala* @ 5% (₹ 1,68,874 ha^{-1}). Similarly, in terms of net returns, *panchagavya* (3%) + cow urine (10%) recorded the higher net return (₹ 77,703 ha^{-1}), which was significantly superior to all other treatments, followed by fish *kunapajala* @ 5% (₹ 62,069 ha^{-1}), cow womb *kunapajala* @ 5% (₹ 53,909 ha^{-1}) and herbal *kunapajala* @ 5% (₹ 39,246 ha^{-1}), while the lowest net returns were observed with fish amino acid @ 5% (₹ 30,895 ha^{-1}). With respect to the B:C ratio without premium price, *panchagavya* (3%) + cow urine (10%) (1.79) again recorded the higher B:C ratio, followed by fish *kunapajala* @ 5% (1.66), cow womb *kunapajala* @ 5% (1.59) and herbal *kunapajala* @ 5% (1.45), while the lowest B:C ratio was recorded with fish amino acid @ 5% (1.25) (Table 2). The superior performance of *panchagavya* @ 3% + cow urine @ 10% can be attributed to its rich nutrient composition, beneficial microbes, and growth-promoting substances, which enhance plant growth, pod formation, and seed filling, resulting in higher productivity and gross returns (Chandrashekara *et al*., 2023). Furthermore, the reduced dependence on external chemical fertilizers in this treatment lowers production costs, thereby improving net returns and B:C ratio. Other LOMs, such as fish amino acid or herbal *kunapajala*, provide comparatively limited nutrient availability or slower nutrient release, leading to reduced economic performance (Yadav *et al*., 2020). This indicates that combining multiple bioactive components in LOMs, like *panchagavya* @ 3% + cow urine @ 10%, enhances both productivity and profitability in soybean cultivation.

The interaction effect between farming practices and liquid organic manures (LOMs) showed significant results with respect to gross returns, net returns and the B:C ratio. Among the treatment combinations, organic farming with *panchagavya* (3%) + cow urine (10%) recorded the highest gross returns (₹ 1,97,282 ha^{-1}), which were *significantly* superior to all other combinations due to higher seed and haulm yield. But, In terms of net returns, natural farming with *panchagavya* (3%) + cow urine (3%) (₹ 91,431 ha^{-1}) recorded the higher net returns, which was on par with natural farming + fish *kunapajala* (5%) (₹ 85,347 ha^{-1}) and integrated natural farming with *panchagavya* (3%) + cow urine (10%) (₹ 85,082 ha^{-1}). Similarly, the B:C ratio was significantly higher in natural farming with *panchagavya*

(3%) + cow urine (10%) (2.18) as compared to all other treatment combinations, while natural farming with fish *kunapajala* @ 5% (2.12) was statistically on par with M_1S_5 (Table 2). These results indicate that the combination of nutrient-rich liquid organic manures with appropriate farming practices enhances both economic returns and profitability by improving yield and reducing cultivation costs. The superior performance of these combinations can be attributed to several factors. *Panchagavya* and cow urine are rich in macro and micronutrients, beneficial microbes and plant growth-promoting substances, which enhance vegetative growth, pod formation and seed filling, leading to higher yields (Chandrashekara *et al.*, 2023). Furthermore, natural farming practices reduce dependence on external inputs, lowering cultivation costs and thereby improving net returns and B:C ratios (Khadse *et al.*, 2018) and (Yadav *et al.*, 2020). The synergistic effect of nutrient-rich LOM's with low-input farming systems enhances soil microbial activity and nutrient cycling, which further improves crop performance and profitability. These results indicate that combining nutrient-rich liquid organic manures with appropriate farming practices optimizes both economic returns and sustainability.

When treatment combinations were compared with the control treatments, the recommended package of practices (RPP) recorded significantly higher gross returns (₹ 2,08,037 ha^{-1}) than most of the treatment combinations, while organic farming with *panchagavya* @ 3% + cow urine @ 10% (₹ 1,97,282 ha^{-1}) was on par with RPP. Similarly, chemical farming (CF) registered lower (₹ 1,85,800 ha^{-1}) gross returns than OF with *panchagavya* (3%) + cow urine (10%) (₹ 1,97,282 ha^{-1}) and integrated natural farming (INF) with *panchagavya* (3%) + cow urine (10%) (₹ 1,91,541 ha^{-1}), where as M_3S_1, M_3S_2, M_3S_5 and M_2S_5 were on par with CF, But, the net returns and B:C ratio of RPP (₹ 1,19,093 ha^{-1} and 2.34, respectively) and CF (₹ 1,15,716 ha^{-1} and 2.65, respectively) were significantly higher than all other treatment combinations (Table 2). The higher gross returns under RPP are attributed to the optimum use of chemical fertilizers along with FYM and biofertilizers, pest and disease management and improved crop practices, which maximize yield resulted in higher economical returns. The comparable performance of OF with *panchagavya* @ 3%+ cow urine @ 10% was due to the nutrient-rich composition of liquid organic manures, including macro and micronutrients and beneficial microbes, which enhance plant growth, pod formation and seed filling leads to higher and on par seed yield with RPP. (Chandrashekara *et al.*, 2023). CF recorded slightly lower gross returns compared to OF treatments and INF treatment combinations because synthetic fertilizers, while efficient, may not always match the growth-promoting and soil-enhancing effects of organic inputs under specific soil and environmental conditions. Higher net returns and B:C ratio in RPP and CF were mainly due to the efficient yield per unit cost achieved under conventional chemical-based management. The cost of cultivation reduced due to no organic manure and application costs. Although organic and integrated natural farming treatments reduce external inputs, the higher labor and preparation costs for organic manures can reduce profitability despite good yields. These results are consistent with previous findings, indicating that economic efficiency depends on both yield and cost-effectiveness, highlighting the importance of balanced nutrient management for maximizing profitability (Yadav *et al.*, 2020) and (Khadse *et al.*, 2018).

Gross returns, net returns (₹ ha^{-1}) and B:C ratio (with premium price)

Among the farming practices, organic farming recorded higher gross returns (₹ 2,11,085 ha^{-1}), followed by integrated natural farming (₹ 1,94,268 ha^{-1}) and natural farming (₹ 1,80,448 ha{₹), whereas, natural farming registered higher net returns (₹ 99,325 ha^{-1}) and B:C ratio (2.27), followed by integrated natural farming (₹ 84,619 ha^{-1} and 1.78, respectively) and least was in organic farming (₹ 66,961 ha^{-1} and 1.47, respectively) (Table 3). Organic farming recorded higher gross returns because of higher seed yield produced due to use of nutrient-rich inputs like farmyard manure and vermicompost along with biofertilizers which improve soil fertility, plant growth and yield (Chandrashekara *et al.*, 2023). In contrast, natural farming had

Table 2. Gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and B:C ratio of soybean cultivation (without premium price) as influenced by different farming practices and liquid organic manures

Treatment												
→M: Farming practices	Gross returns (₹ ha^{-1})				Net returns (₹ ha^{-1})				B:C ratio			
↓S: Liquid organic manures (LOM's)	M_1: NF	M_2: INF	M_3:OF	Mean	M_1: NF	M_2: INF	M_3:OF	Mean	M_1: NF	M_2: INF	M_3:OF	Mean
S_1: Fish Amino Acid @ 5%	152121	170946	181335168	13445474	35573	11638	30895	1.43	1.26	1.07	1.25	
S_2: Fish *kunapajala* @ 5%	161716	167911	176994	168874	85347	63131	37731	62069	2.12	1.60	1.27	1.66
S_3: Cow womb *Kunapajala* @ 5%	142207	156183	172584	156992	69678	55083	36966	53909	1.96	1.54	1.27	1.59
S_4: Herbal *kunapajala* @ 5%	133951	131377	160712	142013	61544	30840	25355	39246	1.85	1.31	1.19	1.45
S_5: *Panchagavya* (3%) with Cow urine (10%)	169093	191541	197282	185972	91431	85082	56597	77703	2.18	1.80	1.40	1.79
Mean	151818	163592	177781		70695	53942	33657		1.91	1.50	1.24	
Sources of variation	S.Em. +	C.D at 5%			S.Em. +	C.D at 5%			S.Em. +	C.D at 5%		
M : Farming practices	2773	7701			2773	7701			0.02	0.07		
S : Liquid organic manures (LOM's)	4775	11013			4775	11013			0.04	0.10		
M x S : Interaction	3993	9440			3993	9440			0.04	0.09		
Control:												
C_1:Recommended Package of Practices		208037				119093				2.34		
C_2:Chemical farming		185800				115716				2.65		
To compare	S.Em. +		C.D at 5%		S.Em. +		C.D at 5%		S.Em. +		C.D at 5%	
Control Vs Treatment combinations	4227		12178		4227		12178		0.04		0.12	

M_1: Natural Farming, M_2: Integrated natural farming, M_3: Organic Farming

higher net returns and B:C ratio, because of lower cost of cultivation, it relied on locally available resources and required fewer external inputs and reducing costs (Khadse *et al*., 2018). Integrated natural farming, which combines part of the organic manures and lower amounts of external inputs, gave intermediate gross and net returns, balancing yield and cost. These results show that while organic farming increases income through higher yield, but, the natural farming practices are more profitable due to lower input costs and lesser cost of cultivation (Yadav *et al*., 2020)

Among the liquid organic manure treatments, significant differences were observed in terms of economic returns with premium price. *Panchagavya* (3%) + Cow urine (10%) registered higher gross returns (₹ 2,20,878 ha^{-1}), followed by Fish *kunapajala* (5%) (₹ 2,00,985 ha^{-1}), Fish amino acid (₹ 1,99,618 ha^{-1}) and Cow womb *kunapajala* (5%) (₹ 1,86,321ha^{-1}) (Table 3). Similarly, the net returns were higher with *panchagavya* (3%) + Cow urine (10%) (₹ 1,12,610 ha^{-1}), than Fish *kunapajala* (5%) (₹ 94,181 ha^{-1}) and Cow womb *kunapajala* (5%) (₹ 83,239 ha^{-1}) (Table 3). The B:C ratio was also higher with *panchagavya* (3%) + Cow urine (10%) which proved superior (2.13), than Fish *kunapajala* (5%) (1.98) and Cow womb *kunapajala* (5%) (1.89) (Table 3). Foliar application of *panchagavya* + Cow urine performed best because it is rich in nutrients and beneficial microbes, which enhance soil fertility, plant growth, pod development and seed filling, leading to higher yields and economical returns (Chandrashekara *et al*., 2023). Other LOMs, like Fish *kunapajala* and Cow womb *kunapajala*, release nutrients slowly or in smaller amounts, resulting in moderate returns. The higher B:C ratio with *Panchagavya* + Cow urine was due to its combination of high yield and relatively low input costs, leads to increasing profitability (Yadav *et al*., 2020).

The interaction effect between farming practices and liquid organic manures (LOMs) showed significant differences, among the treatments. Organic farming combined with *panchagavya* @ 3% + cow urine @ 10% (M_3S_5) recorded higher gross returns (₹ 2,33,955 ha^{-1}), followed by INF with *Panchagavya* (3%) + Cow urine (10%) (₹ 2,27,663 ha^{-1}) and OF with Fish *kunapajala* (5%) (₹ 2,11,230 ha^{-1}), while INF with *Panchagavya* @ 3% + Cow urine @ 10% was on par with M_3S_5. Whereas, natural farming with *panchagavya* @ 3% + cow urine @ 10% registered higher net returns (₹ 1,23,355 ha^{-1}), followed by INF with *Panchagavya* (3%) + Cow urine (10%) (₹ 1,21,205 ha^{-1}) and NF with Fish *kunapajala* (5%) (₹ 1,15,905 ha^{-1}), with INF and NF with Fish *kunapajala* being on par with M_1S_5, and in terms of B:C ratio, NF with *Panchagavya* @ 3% + Cow urine @ 10% had the higher B:C ratio (2.59), followed by M_2S_5 (2.14) and M_3S_5 (1.66), while NF with Fish *kunapajala* @ 5% was on par with M_1S_5, all these combinations being significantly superior to the other treatments (Table 3). The superior performance of *Panchagavya* + Cow urine was due to its rich nutrients and beneficial microbes, which improve soil fertility, plant growth, pod formation, and seed filling, leading to higher yields and economical returns (Chandrashekara *et al*., 2023). The LOM's, like Fish *kunapajala*, supply nutrients more slowly or in smaller amounts, resulting in moderate returns. Natural farming achieved higher net returns and B:C ratio because of lower input costs, while INF provided intermediate performance by balancing yield and cost-effectiveness (Khadse *et al*., 2018).

The comparison of treatment combinations with controls showed that RPP (₹ 2,08,037 ha^{-1}) and CF (₹ 1,85,800 ha^{-1}) recorded significantly lower gross returns than OF with *Panchagavya* @ 3% + Cow urine @ 10% and INF with *Panchagavya* @ 3% + Cow urine @ 10%, although RPP was on par with OF with Fish amino acid @ 5%, Fish *kunapajala* @ 5%, Cow womb *kunapajala* @ 5%, INF with Fish amino acid @ 5%, Fish *kunapajala* @ 5% and NF with *Panchagavya* @ 3% + Cow urine @ 10%, while most of the OF with LOM's combinations out performed CF except M_1S_1, M_1S_3, M_1S_4 and M_2S_4 which were lower than OF. Whereas, the net returns with premium price were significantly higher in NF with *Panchagavya* @ 3% + Cow urine @ 10% (₹ 1,23,355 ha^{-1}), RPP (₹ 1,19,093 ha^{-1}) and CF (₹ 1,15,716 ha^{-1}) than all other treatment combinations except M_1S_2, M_2S_5, RPP and CF. The later treatment were on par with M_1S_5. INF with *Panchagavya* @ 3% + Cow urine @ 10%

Table 3: Gross returns (₹ ha^{-1}), net returns (₹ ha^{-1}) and B:C ratio of soybean cultivation (with premium price) as influenced by different farming practices and liquid organic manures

Treatment												
→M: Farming practices	Gross returns (₹ ha^{-1})				Net returns (₹ ha^{-1})				B:C ratio			
↓S: Liquid organic manures (LOM's)	M_1: NF	M_2: INF	M_3:OF	Mean	M_1: NF	M_2: INF	M_3:OF	Mean	M_1: NF	M_2: INF	M_3:OF	Mean
S_1: Fish Amino Acid @ 5%	180748	203171	214933	199618	74101	67798	45236	62379	1.69	1.50	1.27	1.49
S_2: Fish *kunapajala* @ 5%	192274	199450	211230	200985	115905	94670	71967	94181	2.52	1.90	1.52	1.98
S_3: Cow womb *Kunapajala* @ 5%	168997	185286	204682	186321	96468	84186	69064	83239	2.33	1.83	1.51	1.89
S_4: Herbal *kunapajala* @ 5%	159202	155772	190625	168533	86795	55234	55268	65766	2.20	1.55	1.41	1.72
S_5: *Panchagavya* (3%) with Cow urine (10%)	201017	227663	233955	220878	123355	121205	93270	112610	2.59	2.14	1.66	2.13
Mean	180448	194268	211085		99325	84619	66961		2.27	1.78	1.47	
Sources of variation	S.Em. +		C.D at 5%		S.Em. +		C.D at 5%		S.Em. +		C.D at 5%	
M : Farming practices	3307		9183		3307		9183		0.03		0.08	
S : Liquid organic manures (LOM's)	5700		13146		5700		13146		0.05		0.12	
M x S : Interaction	4807		11347		4807		11347		0.04		0.11	
Control:												
C_1:Recommended Package of Practices		208037				119093				2.34		
C_2:Chemical farming		185800				115716				2.65		
To compare	S.Em. +		C.D at 5%		S.Em. +		C.D at 5%		S.Em. +		C.D at 5%	
Control Vs Treatment combinations	4932		14207		4932		14207		0.05		0.14	

M_1: Natural Farming, M_2: Integrated natural farming, M_3: Organic Farming

(₹ 1,21,205 ha^{-1}) and NF with Fish *kunapajala* @ 5% (₹ 1,15,905 ha^{-1}) were on par with M_1S_5. M_1S_2, M_1S_5 and M_2S_5 gave better net returns than CF and M_1S_5 and M_2S_5 were on par with RPP, as also reported by Patil *et al*. (2021) and Kumar *et al*. (2022). The CF recorded the higher B:C ratio (2.65), than RPP (2.34), while NF with *Panchagavya* @ 3% + Cow urine @ 10% (2.59) and NF with Fish *kunapajala* @ 5% (2.52) were on par with RPP and CF and RPP recorded lower B:C ratio than NF with *Panchagavya* @ 3% + Cow urine @ 10%, NF with Fish *kunapajala* @ 5%, and NF with Cow womb *kunapajala* @ 5%, consistent with the findings of Aher *et al*. (2022) (Table 3). The superior performance of OF and INF with *Panchagavya* + Cow urine was due to its rich nutrient content and beneficial microbes, which enhance soil fertility, plant growth, pod formation and pod filling, resulting in higher yields and gross returns (Chandrashekara *et al*., 2023). NF treatment combinations achieved higher net returns and B:C ratios because of lower input costs, while CF and RPP showed high B:C ratios due to optimized yield per unit cost. NF and INF + LOM's treatments were on par with CF and RPP. Similarly, (Khadse *et al*., 2018), (Yadav *et al*., 2020), (Patil *et al*., 2021), (Kumar *et al*., 2022) and (Aher *et al*., 2022), indicate that careful combination of organic inputs with LOM's can match conventional practices in productivity and profitability

Soil chemical properties (Soil pH, Electrical Conductivity (EC) and Soil Organic Carbon (SOC))

At harvesting stage of soybean, the soil pH and electrical conductivity (EC) showed non significant differences due to different farming practices, liquid organic manures (LOMs), or their interactions and all treatment combinations when compared with the control (Table 4). Similar results have been reported by Yadav *et al*. (2020) and Kumar *et al*. (2022), where soil pH and EC remained largely unaffected by organic, natural and integrated natural farming practices after soybean cultivation, despite improvements in yield and soil biological activity. However, Soil organic carbon showed significant results. Among the farming practices, organic farming recorded the higher organic carbon content (5.71 g kg^{-1} of soil), which was significantly superior to natural farming (5.24 g kg^{-1} of soil) and on par with integrated natural farming (5.41 g kg^{-1} of soil) (Table 4). This was due to application of nutrient-rich organic inputs like farmyard manure and vermicompost equivalent to RDP along with biofertilizers, which increase the soil organic matter, enhance microbial activity and improve carbon accumulation. Natural farming had lower SOC due to reliance on locally available inputs with less added organic manures, while integrated natural farming showed intermediate values (Chandrashekara *et al*., 2023)

Among the liquid organic manure treatments, fish amino acid @ 5% recorded the higher organic carbon (5.53 g kg^{-1} of soil), which was statistically on par with fish *kunapajala* @ 5% (5.49 g kg^{-1}), cow womb *kunapajala* @ 5% (5.40 g kg^{-1} of soil), herbal *kunapajala* @ 5% (5.41 g kg^{-1} of soil) and *Panchagavya* @ 3% + cow urine @ 10% (5.42 g kg^{-1} of soil), showing non significant differences among all LOM's treatments (Table 4). The on par SOC values among treatments were due to the organic carbon, amino acids and beneficial microbes present in all LOMs, which enhance soil organic matter and microbial activity, leading to comparable increases in SOC (Chandrashekara *et al*., 2023)

The interaction between farming practices with LOM's, the higher organic carbon was observed in organic farming with fish *kunapajala* @ 5% (5.97 g kg^{-1} of soil), followed closely by organic farming with fish amino acid @ 5% (5.87 g kg^{-1} of soil), herbal *kunapajala* @ 5% (5.67 g kg^{-1} of soil), *Panchagavya* @ 3% + cow urine @ 10% (5.56 g kg^{-1} of soil) and integrated natural farming with *Panchagavya* @ 3% + cow urine @ 10% (5.56 g kg^{-1} of soil) than with M_2S_1 (5.51 g kg^{-1} of soil), than M_2S_3 and M_2S_4 and all NF combinations. These treatments were statistically on par, indicating their similar effectiveness in improving soil organic carbon (Table 4). The on par SOC values among these treatments indicate that all combinations of

Table 4: Chemical properties of soil after harvest of soybean as influenced by different farming practices and liquid organic manures

Treatment	Chemical properties											
→M: Farming practices		Soil pH				EC (dSm^{-1})				Soil OC (g kg^{-1} of soil)		
↓S: Liquid organic manures (LOM's)	M_1: NF	M_2: INF	M_3: OF	Mean	M_1: NF	M_2: INF	M_3: OF	Mean	M_1: NF	M_2: INF	M_3: OF	Mean
S_1: Fish Amino Acid @ 5%	7.31	7.22	7.62	7.38	0.35	0.35	0.32	0.34	5.21	5.51	5.87	5.53
S_2: Fish *kunapajala* @ 5%	7.18	7.48	8.06	7.57	0.34	0.34	0.36	0.35	5.26	5.24	5.97	5.49
S_3: Cow womb *Kunapajala* @ 5%	7.31	7.60	7.82	7.58	0.33	0.33	0.34	0.33	5.38	5.36	5.46	5.40
S_4: Herbal *kunapajala* @ 5%	7.42	7.68	7.80	7.63	0.35	0.36	0.32	0.34	5.18	5.38	5.67	5.41
S_5: *Panchagavya* (3%) with Cow urine (10%)	7.28	7.19	7.53	7.33	0.36	0.34	0.35	0.35	5.15	5.56	5.56	5.42
Mean	7.30	7.43	7.77		0.35	0.34	0.34		5.24	5.41	5.71	
Initial values for main plots	7.23	7.13	7.08		0.08	0.07	0.09		5.99	6.55	6.09	
Sources of variation		S.Em. +	CD at 5%		S.Em. +		CD at 5%		S.Em. +		CD at 5%	
M : Farming practices		0.22	NS		0.010		NS		0.16		0.45	
S : Liquid organic manures (LOM's)		0.19	NS		0.009		NS		0.13		NS	
M X S : Interaction		0.31	NS		0.015		NS		0.23		0.54	
Control:												
C_1:Recommended Package of Practices		7.26 (7.17)*				0.35 (0.08)*				5.11 (6.28)*		
C_2:Chemical farming		7.13 (7.42)*				0.37 (0.07)*				4.33 (5.90)*		
To compare		S.Em. +	CD at 5%		S.Em. +		CD at 5%		S.Em. +		CD at 5%	
Control Vs Treatment combinations		0.23	NS		0.01		NS		0.17		0.50	

*: Initial values

M_1: Natural Farming, M_2: Integrated natural farming, M_3: Organic Farming

organic and liquid organic inputs effectively improve soil organic carbon by adding organic matter and stimulating microbial activity, regardless of the source of LOM, which enhances carbon accumulation in the soil (Chandrashekara *et al*., 2023)

The comparison between treatment combinations with controls, all organic, natural and integrated natural farming practices combination recorded significantly higher soil organic carbon than chemical farming (4.33 g kg^{-1} of soil). Recommended package of practices (RPP) showed 5.11 g kg^{-1} of soil organic carbon and was on par with natural farming treatments but lower than most organic farming combinations *viz.,* M_3S_1, M_3S_2, M_3S_4, M_3S_5 and M_2S_5). This was because organic farming practices, supply nutrient-rich organic inputs, such as farmyard manure, vermicompost, *panchagavya* and cow urine, which enhance soil organic matter, microbial activity and carbon sequestration, whereas chemical farming relies primarily on inorganic fertilizers that do not contribute to SOC accumulation. Similar trends have been reported by Savalagi *et al*. (2017) , Chakraborty and Hazari (2016) , Manu *et al* (2020) and Rashmi *et al* (2018) showing higher SOC under organic and integrated nutrient management systems compared to conventional chemical practices.

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