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WHEAT PRODUCTIVITY OPTIMIZATION THROUGH ORGANIC NUTRIENT SOURCES UNDER SYSTEM OF WHEAT INTENSIFICATION IN EASTERN UTTAR PRADESH INDIA

Anu Nawhal[1*], Shikha Singh[1], Naveena[2], Shalini B. Masih[3], Abhilash S.[1], Roshan Hrangkhwal[1], Kancharla Cris John Sanjeev[1] and Judy K. Lalrinsangi[4]
[1]Department of Agronomy, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh, India.
[2]Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, Jammu & Kashmir, India.
[3]Department of Mathematics and Statistics, Sam Higginbottom University of Agriculture, Technology and Science, Prayagraj, Uttar Pradesh, India.
[4]Krishi Vigyan Kendra, Central Agricultural University, Aizawl, Mizoram, India.
*Corresponding author E-mail: 21phagrn103@gmail.com
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ABSTRACT

The Indian Green Revolution increased reliance on synthetic agro-inputs for higher crop production, gradually deteriorated soil health and food ecosystems, and is worsening in eastern Uttar Pradesh. Alternative sustainable techniques, such as organic manures, are being explored for improved crop productivity, profitability, and environmental sustainability. We hypothesized that the application of solid organic manures and liquid organic formulations to wheat crop cultivated under the system of wheat intensification would improves the productivity of crop. A two-year (2022-2024) field experiment was designed in a split plot to study the impact of solid organic manures and liquid organic formulations on wheat growth, yield attributes and yield under system of wheat intensification. The pooled analysis of both years of investigation revealed that the application of neem cake manure produced taller plants with a greater number of total and productive tillers, grains per spike and increased grain yield by 16.23-38.36% compared to other solid organic manures. In addition to this, fortnightly foliar spray of 10% Jeevamrutha comparably improved the growth and yield contributing characters and enhanced the grain yield by 47.88%. However, higher straw yield was obtained with foliar spray of 2% cow urine due to more availability of nitrogen during vegetative development. The present investigation suggested that the among different organic nutrient sources basal application of 5 t/ha neem cake manure and fortnightly spray of 10% jeevamrutha up to 90 days after sowing performs significantly in optimizing the productivity of wheat under the crop intensification system.
***Keywords* :** Cow urine Neem cake manure, Jeevamrutha, Wheat, Yield.

Introduction

Wheat (*Triticum aestivum*), a crucial cereal crop globally, is known for its climate adaptability and nutritional value. It has been cultivated in temperate regions, including China, India, the United States, and Russia. However, challenges such as changing climates, soil health degradation, and pest epidemics continue to affect wheat production. Sustainable farming techniques, such as the System of Wheat Intensification (SWI), aim to enhance yield through efficient resource utilization. SWI involves root development and intensive care, maintaining plant density, wider spacing, and sowing 1-2 seeds per hill (Raghavendra *et al*., 2019). This system improves productivity and resilience by reducing plant competition and increasing soil fertility (Debbarama *et al*., 2020). Organic manures, such as cow dung, cow urine, and plant-based formulations, are decomposed animal or plant products that increase soil organic matter and soil structure (Shakywal *et al*., 2023). Farmyard manure, a composite organic material produced from cow dung, urine, bedding materials, and crop residue, significantly increases soil microbial activity and supports better plant nutrient uptake (Saidia and Mrema, 2016). Since ancient times, farmers have used non-edible seed cakes like neem, karanj, and castor as admixtures in manure. Large-scale cultivation of bioenergy crops for biofuel production may lead to the production of by-products like oilcakes, which can be used as manure, motivating farmers to reduce chemical fertilizer use. Neem cake is an organic botanical product containing essential nutrients for plant growth, including nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. It also contains micronutrients like zinc, copper, iron, and manganese (Gupta, 2022). Neem cake decomposes organic acids, reducing soil alkalinity and improving soil structure. Permanent soil cover is another important component of organic farming, which has additional benefits for soil and water conservation. Mulching reduces weed infestation, lowers cultivation costs, and maintains soil temperature, aiding in the growth of beneficial insects and microorganisms in the soil. Liquid organic formulations (LOF) are produced by fermenting cow products, such as dung, urine, milk, curd, and ghee, with locally available resources like jaggery, gram flour, coconut water, and bananas. Panchagavya is a traditional, economical, and eco-friendly LOF made by combining cow dung, urine, milk, curd, and ghee (Upadhyay *et al*., 2018). Jeevamrutha is another efficient LOF prepared from the fermentation of diluted cow dung, urine, gram flour, jaggery, and field soil that has a higher bacterial count (14×10^5 cfu/ml) (Chakraborty and Sarkar, 2019), which leads to increased nutrient mineralization in the rhizosphere. Cow urine is rich in macro- and micronutrients, providing preventive and disinfecting qualities, and is used in biofertilizers and biopesticides in agriculture (Ramani *et al*., 2012). It is an effective tool to address multi-nutrient deficiencies in soils. Hence, this research has been designed with the aim of optimizing wheat productivity with organic nutrient sources under the system of wheat intensification.

Materials and Methods

Experimental site

The field trials were conducted during *the rabi* season of 2022-23 and 2023-24 at the SHUATS Model of Organic Farm (SMOF), Department of Agronomy, Sam Higginbottom of University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, situated at 25.40º N latitude, 81.85º E longitude, and at an altitude of about 112 m above the mean sea level within the agro-climatic zone V (Mid plain zone) of Uttar Pradesh and zone IV (Middle Gangetic plains) of India. The experimental location is characterized by a humid subtropical climate, hot dry summers, warm humid monsoons, and cool dry winters. Uttar Pradesh experiences hot summers (March to July) and harsh winters (December-January). During the experimental period, the temperature ranged between 7.2-34.5℃ and 6.7-38.3℃ with mean rainfall of 36 and 32 mm in the 1st and 2nd years, respectively. The experimental soil (*Inceptisol*) was sandy loam with good drainage capability. The pre-experimental analysis of soil samples (1:2 soil:water ratio) from 0 to 15 cm depth indicated a neutral reaction (pH of 7.7 and 7.4) (Jackson, 1973), medium organic carbon (0.56 and 0.50%) (Walkley and Black, 1934), available phosphorus (21 and 18 kg/ha) (Olsen *et al*., 1954), exchangeable potassium (202 and 213 kg/ha) (Jackson, 1973), and low available nitrogen (250 and 238 kg/ha) (Subbiah and Asija, 1956) in the 1st and 2nd years, respectively.

Experimental design and management

The study aimed to optimize the wheat productivity under a crop intensification system through solid organic manure and liquid organic formulation application. The experiment was designed in split plot with 2 factors and 4 levels of each *viz*., Solid organic manures (S_1: Farmyard manure; S_2: Farmyard manure followed by straw mulching; S_3: Neem cake manure; S_4: Neem cake manure followed by straw mulching) and Liquid organic formulations (L_1: No spray; L_2: 3% Panchagavya; L_3: 10% Jeevamrutha; L_4: 2% Cow urine) forming 16 treatments, namely, Farmyard manure + no spray (S_1L_1); Farmyard manure + 3% Panchagavya (S_1L_2); Farmyard manure + 10% Jeevamrutha (S_1L_3); Farmyard manure + 2% Cow urine (S_1L_4); Farmyard manure followed by straw mulching + no spray (S_2L_1); Farmyard manure followed by straw mulching + 3% Panchagavya (S_2L_2); Farmyard manure followed by straw mulching + 10% Jeevamrutha (S_2L_3); Farmyard manure followed by straw mulching + 2% Cow urine (S_2L_4); Neem cake manure + no spray (S_3L_1); Neem cake manure + 3% Panchagavya (S_3L_2); Neem cake manure + 10% Jeevamrutha (S_3L_3); Neem cake manure + 2% Cow urine (S_3L_4); Neem cake manure followed by straw mulching + no spray (S_4L_1); Neem cake manure followed by straw mulching + 3% Panchagavya (S_4L_2); Neem cake manure followed by straw mulching + 10% Jeevamrutha (S_3L_3); Neem cake manure followed by straw mulching + 2% Cow urine (S_4L_4). The solid organic manures (SOM) *i.e.*, Farmyard manure (0.55% N, 0.24% P, and 0.61% K) and Neem cake manure (5.0% N, 1% P, and 2% K) were applied as per the recommended dose of nitrogen (150 N kg/ha) ten days before sowing at the time of layout preparation, while in SOM and mulching treatments, additionally sterilized organic paddy straw at the rate of 4 t/ha were applied 10 days after sowing in between crop rows. The liquid organic formulations were applied at 2-week intervals starting from 15 DAS to 90 DAS. Before the LOF foliar spray, they were filtered through a clean muslin cloth and diluted with water based on the treatment percentage. For example, 3 ml of Panchagavya was mixed with 97 ml of water to make a 3% solution. This was then adjusted for a 4 m x 4 m plot by changing the dilution rate to 550 l/ha. Similarly, other liquid organic formulations were diluted to make the required percentage. A seed rate of 30 kg/ha of DBW 187 (Karan Vandana) wheat variety was used during both years and treated before sowing as per the seed treatment method under the System of Wheat Intensification (Khadka and Raut, 2012) and sown in 20 cm x 20 cm planting geometry in all plots.

Statistical analysis

The plant observations were collected on different growth and yield attributing characters were subjected to statistical analysis using Fisher's analysis of variance (ANOVA) for split plot design as per the procedure described by Gomez and Gomez, (1984). The standard deviation (SD) and standard error (SE) were used to measure the degree of variability between the individual data values.

Results and Discussion

Impact of solid organic manures on wheat growth, yield attributes, and yield under system of wheat intensification. The wheat growth, yield attributes, and yield were significantly (p<0.05) influenced by the application of solid organic manures (SOM) (Fig. 1 & 2 and Table 1). The statistical analysis of the SOM application indicated that 5 t/ha of neem cake manure produced significantly 12.2, 14.1, 17.2, 11.9, 38.4, 14.5, 11.0% higher plant height (64.4 cm), number of total tillers (239.38/m²), productive tillers (158.96/m²), grains per spike (48.38), grain yield (29.50 q/ha), straw yield (36.51 q/ha), and harvest index (44.31%), respectively, than the farmyard manure application (control) in the pooled data of both years. Irrespective of solid organic manures, yield attributes except productive tillers and yield improved in the 2nd year compared to the 1st year of investigation. The application of neem cake manure not only provides vital nutrients such as nitrogen (1.65%), phosphorus (1.59%), and potassium (0.14%) (Salma and Hoassain, 2021), but its gradual nutrient release capability aligns with the crop's uptake and promotes sustainable growth and productivity. Azadirachtin in neem cake affects the metabolic activity of *Nitrosomonas* and disrupts energy production in *Nitrobacter* (Nawarathna *et al.* 2021), thereby reducing its population and activity, while other bioactive compounds such as nimbin and salannin are antibacterial and cytotoxic and damage the cell membrane and enzymatic function of nitrifying bacteria and slow down the nitrification process (Abeka *et al.* 2022). This reduced the nitrogen losses, ensured a steady and prolonged nitrogen supply to the crop, and improved the initial crop growth in terms of increasing plant height and total tillers (Figs. 1 and 2).

Impact of liquid organic formulations on wheat growth, yield attributes and yield under system of intensification. The foliar spray of liquid organic formulations significantly (p<0.05) affected growth, yield attributes, and yield of wheat (Figs. 3 & 4 and Table 2). The critical study of LOF application on wheat revealed that foliar spray of 10% Jeevamrutha produced taller plants (62.1 cm), more total (242.71/m²) and effective tillers (157.71/m²), grains/spike (48.43), grain yield (29.62 q/ha), and harvest index (44.91%), while 2% cow urine spray produced more straw yield (36.04 q/ha), which were significantly 5.0, 18.0, 22.9, 12.8, 47.9, 16.0, and 14.9% higher, respectively, compared to control (no spray) in the pooled analysis. Across all liquid organic formulations, yield attributes (except for productive tillers) and yield (except for straw yield) got better in the second year of research. These findings are in accordance with Bharadwaj (2021), who reported improved soil nutrient status due to jeevamrutha application, which led to significant increases of 16.4% in the number of grains/spikes, 32.4% in grain yield, 27.9% in straw yield, and 2.5% in the harvest index compared to the control. Frequent spraying of Jeevamrutha enriches the soil with essential nutrients (N, P, K, S, Fe, and Zn) and growth-promoting hormones, leading to enhanced grain and straw yield in wheat (Bhadu *et al.* 2021). Nutrients and helpful bacteria in Jeevamrutha enhance soil fertility, promoting bold seed development (Manisha and Singh, 2024). Auxins and cytokinins, two plant growth regulators in Jeevamrutha, may also boost grain production.

Interaction effect of liquid organic formulations at the different level of solid organic manures on growth, yield attributes and yield of

wheat under SWI. The interaction effect of liquid organic formulations with different solid organic manures has significantly influenced the growth parameters (Table 3), yield attributes (Table 4), and yield of wheat (Table 5). The interaction of 10% Jeevamrutha with all types of SOMs had a synergistic effect on wheat productivity in the first year, second year, and pooled analysis. The critical examination of yearly impact on crop growth irrespective of LOF and SOM interaction reported an increase in growth parameters, yield attributes, and yield except for total and productive tillers from the 1st to 2nd year.

Liquid organic formulations x Farmyard manure interaction. The pooled analysis revealed a significant interaction of liquid organic formulations with farmyard manures for growth, yield attributes, and yield. The interaction of 10% Jeevamrutha with FYM produced the tallest plants (61.3 cm), a higher number of total (224.17/m²) and productive tillers (155.0), grain yield (25.95 q/ha), and harvest index (43.76%), while the maximum number of grains per spike (45.53) and straw yield (33.70 q/ha) were obtained through the interaction of 2% cow urine with FYM. These were significantly 14.6, 20.1, 25.7, 46.6, 15.9, 12.1, and 15.5% higher, respectively, than the interaction of no spray with FYM (control). These results might be due to their synergistic impact of jeevamrutha and farmyard manure on soil health, nutrient availability, and microbial activity. Farmyard manures improved the organic matter, while jeevamrutha enhanced microbial activity, leading to increased nitrogen mineralization and better nutrient uptake and hence increased plant height and total tillers per m2. Also, nutrient solubilizing bacteria in Jeevamrutha improved the availability of magnesium, hence improved chlorophyll content, and enhanced photosynthesis, contributing to increased grain yield (Kaushal *et al.*, 2024). The enriched soil environment due to the combined application of cow urine and FYM promoted healthy flowering, grain formation, and uniform grain filling, hence producing higher grains/spike. The interaction between cow urine and farmyard manure creates a conducive environment for wheat plants by enhancing nutrient availability, stimulating beneficial microbial activity, providing natural growth stimulants, and improving soil moisture retention, hence contributing to increased straw yield (Chaudhari *et al.*, 2020).

Liquid organic formulations x Farmyard manure followed by straw mulching interaction. A significant interaction of liquid organic formulations with farmyard manure followed by straw mulching (M_2) on growth, yield attributes and yield observed in the pooled analysis of both years. The interaction of 10% Jeevamrutha with M_2 main-plot produced only higher number of total tillers (224.17/m2). However, the interaction of 2% cow urine with FYM fb straw mulching had a positive response on productive tillers (157.50), grains/spike (52.47), grain yield (33.08 q/ha), straw yield (38.53 q/ha), and harvest index (43.76%), which were significantly 16.9, 26.0, 27.7, 73.9, 26.6, and 20.8% higher, respectively, than the interaction of no spray and FYM fb straw mulching. Beneficial soil microorganisms from cow urine used FYM's organic matter as a food source. This increased the growth of microorganisms, sped up the breakdown of organic matter, released nutrients in forms that plants could use, and improved the efficiency of nutrient uptake (Pradhan *et al.*, 2018). Also, straw mulching not only conserved soil moisture but also prevented nitrogen losses through volatilization, which improved nutrient uptake and overall plant health, leading to better growth and higher yields (Peng *et al*. 2005).

Liquid organic formulations x Neem cake manure interaction. The pooled analysis revealed a significant interaction of liquid organic formulations with neem cake manure (M_3) on growth, yield attributes, and yield. The interaction of 10% Jeevamrutha with the M_3 main plot produced a higher number of total (224.17/m²) and productive tillers (175.00), grains/spike (53.87), grain yield (38.64 q/ha), straw yield (42.03 q/ha), and harvest index (47.94%), which were significantly 17.0, 10.5, 21.6, 69.4, 25.9, and 18.8% higher, respectively, than the interaction of no spray and neem cake manure. The combination of neem cake and jeevamrutha created a nutrient-rich soil environment with enhanced microbial activity and led to vigorous root growth, better uptake of nutrients, and an increase in the number of tillers that develop into productive, grain-bearing shoots (effective tillers). The systemic resistance induced by neem cake also helped to reduce stress-related tiller mortality, ensuring more tillers reach maturity. Cytokinin and auxin present in jeevamrutha promoted cell division in spikelets, leading to more grains per spike, while gibberellins stimulated panicle elongation and grain setting. These results are similar to those reported by Verma *et al.* (2018) and Kumar *et al.* (2018) in wheat. Grain yield is influenced by factors like tillering, spikelet fertility, grain filling, and seed weight as well as due to the improved soil fertility, microbial diversity, and plant growth by the combination of neem cake manure and jeevamrutha. Straw yield (biomass production) is directly influenced by factors such as tillering, plant height, vegetative growth, and nutrient uptake. Jeevamrutha contains essential plant growth regulators such as auxin that promote cell division and stem elongation, leading to increased plant height and biomass, and gibberellins enhance internode elongation, also neem cake provides essential nutrients for sustained vegetative growth that synergistically increased straw length and yield. These results are in line with those reported by Hameedi *et al.* (2017) and Boraiah *et al.* (2017) in bell pepper, Bharadwaj (2021), and Kaur *et al.* (2020) in wheat.

Liquid organic formulations x Neem cake manure followed by straw mulching interaction. The pooled analysis revealed a significant interaction of liquid organic formulations with neem cake manure followed by straw mulching (M_4) on growth, yield attributes, and yield. The interaction of 10% Jeevamrutha with M_4 main-plot produced a higher number of total (240/m²) and productive tillers (152.50), straw yield (35.42 q/ha), and harvest index (44.97%), while maximum grain yield was obtained in the interaction of 2% cow urine with NCM fb straw mulching, which was significantly 18.5, 15.1, 11.7, 12.9, and 34.0% higher, respectively, than the interaction of no spray and neem cake manure followed by straw mulching. The application of Jeevamrutha and neem cake manure has been associated with an increased number of effective tillers per meter row length (Vala *et al.* 2024). This improvement in tillering contributed to a more robust plant structure essential for higher straw yield. In addition, straw mulching conserved soil moisture and regulated soil temperature, creating a favorable environment for plant growth (Ram *et al.*, 2013). Adding straw mulch to Jeevamrutha and neem cake manure made the benefits of these organic inputs even better, which led to better growth and yield parameters. Whereas the application of cow urine along with NCM and straw mulch increased grain yield due to the essential nutrient provided by cow urine for the synthesis of chlorophyll (Deotale *et al.*, 2019).

Conclusion

The research findings proved the hypothesis that the application of organic nutrients to wheat under a crop intensification system improved the wheat's growth and productivity. The results of a two-year experiment suggested that the application of 5 t/ha neem cake manure significantly enhanced growth, yield attributes, and yield of wheat under SWI. Further, these findings also reported the positive response of 10% Jeevamrutha on crop growth and productivity when sprayed fortnightly up to 90 DAS. The interaction of liquid organic formulations with different solid organic manures also significantly influenced the wheat productivity in both years and the pooled analysis of both years.

Table 1 : Effect of solid organic manures (main-plot factor) on yield attributes and yield of wheat under SWI

Main-plot treatments	Yield Attributes and Yield																	
	Productive tillers/m²			Grains per spike			1000-seeds weight (g)			Grain yield (q/ha)			Straw yield (q/ha)			Harvest index (%)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
FYM (M_1)	137.92	133.33	135.63	42.07	44.40	43.23	44.38	45.67	45.15	19.74	22.90	21.32	31.34	32.41	31.88	38.69	41.13	39.91
FYM fb straw mulching (M_2)	152.50	138.33	145.42	44.58	48.77	46.68	46.38	46.35	46.37	23.50	27.26	25.38	34.34	33.02	33.68	40.23	44.93	42.58
NCM (M_3)	165.00	152.92	158.96	44.97	51.78	48.38	48.20	46.90	47.55	27.15	31.86	29.50	35.58	37.45	36.51	42.87	45.75	44.31
NCM fb straw mulching (M_4)	154.17	130.42	142.29	42.87	49.42	46.14	46.73	46.90	46.86	23.68	26.72	25.20	31.76	35.40	33.58	42.65	42.88	42.76
S.Em(±)	**0.94**	**3.48**	**1.97**	**0.56**	**0.68**	**0.36**	**1.43**	**0.42**	**0.72**	**0.52**	**0.89**	**0.40**	**1.22**	**1.05**	**0.76**	**0.91**	**0.54**	**0.34**
CD (P=0.05)	**3.25**	**12.03**	**6.82**	**1.94**	**2.36**	**1.25**	**N.S.**	**N.S.**	**N.S.**	**1.80**	**3.07**	**1.38**	**N.S.**	**3.62**	**2.61**	**3.14**	**1.87**	**1.18**

Table 2 : Effect of liquid organic formulations (sub-plot factor) on the yield attributes and yield of wheat under SWI

Sub-plot treatments	Yield Attributes and Yield																	
	Productive tillers/m^2			Grains per spike			1000-seeds weight (g)			Grain yield (q/ha)			Straw yield (q/ha)			Harvest index (%)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
No spray (S_1)	142.08	127.50	134.79	39.58	46.32	42.95	45.88	45.84	45.86	18.22	21.84	20.03	28.93	33.21	31.07	38.62	39.55	39.08
3% Panchagavya (S_2)	150.00	133.33	141.67	42.25	47.87	45.06	46.16	46.33	46.24	21.75	26.39	24.07	31.40	33.64	32.52	40.72	43.88	42.30
10% Jeevamrutha (S_3)	169.58	145.83	157.71	47.30	49.57	48.43	46.55	46.94	46.75	27.77	31.48	29.62	36.03	36.01	36.02	43.42	46.41	44.91
2% Cow urine (S_4)	147.92	148.33	148.13	45.35	50.62	47.98	47.36	46.80	47.08	26.34	29.04	27.69	36.65	35.42	36.04	41.68	44.84	43.26
S.Em(±)	**1.49**	**2.59**	**1.76**	**0.43**	**0.92**	**0.48**	**0.70**	**0.35**	**0.44**	**0.50**	**0.48**	**0.33**	**1.06**	**0.59**	**0.60**	**0.81**	**0.32**	**0.48**
CD (P=0.05)	**4.34**	**7.57**	**5.14**	**1.25**	**2.70**	**1.41**	**N.S.**	**N.S.**	**N.S.**	**1.47**	**1.39**	**0.96**	**3.09**	**1.73**	**1.76**	**2.37**	**0.95**	**1.40**

Table 3 : Interaction effect of liquid organic formulation at the same level of solid organic manures on growth parameters of wheat under SWI

Main-plot (M) / (S) Sub-plot	Plant height at 70 DAS											
	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	47.6	54.2	58.2	55.0	59.3	61.6	67.7	62.3	53.5	57.9	63.0	58.6
(S_2) 3% Panchagavya	53.6	56.4	61.4	54.2	59.4	63.3	67.4	63.4	56.5	59.8	64.4	58.8
(S_3) 10% Jeevamrutha	59.0	54.1	62.4	58.0	63.5	65.2	69.2	65.5	61.3	59.7	65.8	61.8
(S_4) 2% cow urine	53.9	55.6	61.6	59.6	62.5	65.6	66.9	63.0	58.2	60.6	64.2	61.3
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	1.49		4.34		1.59		N.S.		1.08		3.15	
S x M_4	1.49		N.S.		1.59		N.S.		1.08		N.S.	
S x M_3	1.49		4.34		1.59		N.S.		1.08		N.S.	
S x M_4	1.49		4.34		1.59		N.S.		1.08		N.S.	

Main-plot (M) / (S) Sub-plot	Total tillers/m^2 at 70 DAS											
	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	196.67	238.33	240.00	216.67	176.67	186.67	201.67	188.33	186.67	212.50	220.83	202.50
(S_2) 3% Panchagavya	230.00	243.33	275.00	223.33	205.00	190.00	208.33	201.67	217.50	216.67	241.67	212.50
(S_3) 10% Jeevamrutha	250.00	273.33	285.00	265.00	198.33	223.33	231.67	215.00	224.17	248.33	258.33	240.00
(S_4) 2% cow urine	223.33	235.00	248.33	251.67	198.33	196.67	225.00	200.00	210.83	215.83	236.67	225.83
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	15.11		44.09		10.05		N.S.		8.83		25.77	
S x M_4	15.11		N.S.		10.05		29.33		8.83		25.77	
S x M_3	15.11		44.09		10.05		29.33		8.83		25.77	
S x M_4	15.11		44.09		10.05		N.S.		8.83		25.77	

[**S x M_1:** Interaction of liquid organic formulations with Farmyard manure; **S x M_2:** Interaction of liquid organic formulations with Farmyard organic formulations fb straw mulching; **S x M_3:** Interaction of liquid organic formulations with Neem cake manure; **S x M_4:** Interaction of liquid organic formulations with Neem cake manure fb straw mulching]

Table 4 : Interaction effect of liquid organic formulation at the same level of solid organic manures on yield attributes of wheat under SWI

Productive tillers/m^2

Main-plot (M) / (S) Sub-plot	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	130.00	136.67	158.33	143.33	116.67	113.33	158.33	121.67	123.33	125.00	158.33	132.50
(S_2) 3% Panchagavya	131.67	155.00	160.00	153.33	131.67	146.67	123.33	131.67	131.67	150.83	141.67	142.50
(S_3) 10% Jeevamrutha	155.00	165.00	183.33	175.00	155.00	131.67	166.67	130.00	155.00	148.33	175.00	152.50
(S_4) 2% cow urine	135.00	153.33	158.33	145.00	130.00	161.67	163.33	138.33	132.50	157.50	160.83	141.67
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	2.98		8.69		5.19		15.14		3.52		10.28	
S x M_4	2.98		8.69		5.19		15.14		3.52		10.28	
S x M_3	2.98		8.69		5.19		15.14		3.52		10.28	
S x M_4	2.98		8.69		5.19		15.14		3.52		10.28	

Grains/spike

Main-plot (M) / (S) Sub-plot	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	39.67	37.60	39.20	41.87	41.60	44.60	49.40	49.67	40.63	41.10	44.30	45.77
(S_2) 3% Panchagavya	40.40	42.07	44.33	42.20	42.73	47.80	51.60	49.33	41.57	44.93	47.97	45.77
(S_3) 10% Jeevamrutha	44.47	48.33	54.33	42.07	45.93	48.07	53.40	50.87	45.20	48.20	53.87	46.47
(S_4) 2% cow urine	43.73	50.33	42.00	45.33	47.33	54.60	52.73	47.80	45.53	52.47	47.37	46.57
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	0.85		2.49		1.85		5.39		0.97		2.83	
S x M_4	0.85		2.49		1.85		5.39		0.97		2.83	
S x M_3	0.85		2.49		1.85		N.S.		0.97		2.83	
S x M_4	0.85		2.49		1.85		N.S.		0.97		N.S.	

1000-seeds weight (g)

Main-plot (M) / (S) Sub-plot	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	43.37	45.33	47.47	46.67	44.77	46.07	46.00	46.53	44.40	45.70	46.73	46.60
(S_2) 3% Panchagavya	44.80	45.97	47.27	46.27	46.00	46.03	46.70	46.57	45.57	46.00	46.98	46.42
(S_3) 10% Jeevamrutha	44.57	46.63	48.53	46.47	46.77	46.83	47.53	46.63	45.67	46.73	48.03	46.55
(S_4) 2% cow urine	44.77	47.60	49.53	47.53	45.13	46.47	47.73	47.87	44.95	47.03	48.63	47.70
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	1.41		N.S.		0.70		N.S.		0.87		N.S.	
S x M_4	1.41		N.S.		0.70		N.S.		0.87		N.S.	
S x M_3	1.41		N.S.		0.70		N.S.		0.87		N.S.	
S x M_4	1.41		N.S.		0.70		N.S.		0.87		N.S.	

[**S x M_1:** Interaction of liquid organic formulations with Farmyard manure; **S x M_2:** Interaction of liquid organic formulations with Farmyard organic formulations fb straw mulching; **S x M_3:** Interaction of liquid organic formulations with Neem cake manure; **S x M_4:** Interaction of liquid organic formulations with Neem cake manure fb straw mulching]

Table 5 : Interaction effect of liquid organic formulation at the same level of solid organic manures on yield of wheat under SWI

Grain yield (q/ha)

Main-plot (M) / (S) Sub-plot	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	16.79	17.01	18.95	20.11	18.62	21.02	26.67	21.06	17.70	19.02	22.81	20.59
(S_2) 3% Panchagavya	18.47	19.88	27.38	21.26	21.93	25.36	28.39	29.87	20.20	22.62	27.88	25.57
(S_3) 10% Jeevamrutha	23.25	24.49	36.59	26.74	28.66	29.17	40.69	27.39	25.95	26.83	38.64	27.06
(S_4) 2% cow urine	20.46	32.64	25.66	26.61	22.38	33.51	31.69	28.57	21.42	33.08	28.68	27.59
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	1.00		2.93		0.95		2.79		0.66		1.92	
S x M_4	1.00		2.93		0.95		2.79		0.66		1.92	
S x M_3	1.00		2.93		0.95		2.79		0.66		1.92	
S x M_4	1.00		2.93		0.95		2.79		0.66		1.92	

Straw yield (q/ha)

Main-plot (M) / (S) Sub-plot	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	27.16	29.50	29.82	29.25	31.25	31.35	36.94	33.31	29.20	30.43	33.38	31.28
(S_2) 3% Panchagavya	29.69	30.12	35.53	30.27	32.64	30.40	32.76	38.78	31.17	30.26	34.14	34.53
(S_3) 10% Jeevamrutha	33.22	35.75	42.44	32.71	33.67	35.27	41.62	33.49	33.44	35.51	42.03	33.10
(S_4) 2% cow urine	35.30	41.98	34.52	34.81	32.10	35.08	38.48	36.03	33.70	38.53	36.50	35.42
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	2.12		6.19		1.19		N.S.		1.20		3.52	
S x M_4	2.12		6.19		1.19		3.47		1.20		3.52	
S x M_3	2.12		6.19		1.19		3.47		1.20		3.52	
S x M_4	2.12		N.S.		1.19		3.47		1.20		3.52	

Harvest Index (%)

Main-plot (M) / (S) Sub-plot	2022-23				2023-24				Pooled			
	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)	FYM (M_1)	FYM fb straw mulching (M_2)	NCM (M_3)	NCM fb straw mulching (M_4)
(S_1) No spray	38.21	36.62	38.82	40.81	37.34	40.10	41.91	38.85	37.77	38.36	40.37	39.83
(S_2) 3% Panchagavya	38.12	39.75	43.60	41.43	40.15	45.48	46.43	43.45	39.13	42.61	45.02	42.44
(S_3) 10% Jeevamrutha	41.53	40.73	46.43	44.99	45.99	45.26	49.44	44.95	43.76	42.99	47.94	44.97
(S_4) 2% cow urine	36.90	43.84	42.64	43.35	41.03	48.86	45.21	44.25	38.97	46.35	43.93	43.80
Interactions	**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**		**S.Em(±)**		**CD (P=0.05)**	
S x M_1	1.63		N.S.		0.65		1.89		0.96		2.80	
S x M_4	1.63		4.75		0.65		1.89		0.96		2.80	
S x M_3	1.63		4.75		0.65		1.89		0.96		2.80	
S x M_4	1.63		N.S.		0.65		1.89		0.96		2.80	

[**S x M_1:** Interaction of liquid organic formulations with Farmyard manure; **S x M_2:** Interaction of liquid organic formulations with Farmyard organic formulations fb straw mulching; **S x M_3:** Interaction of liquid organic formulations with Neem cake manure; **S x M_4:** Interaction of liquid organic formulations with Neem cake manure fb straw mulching.

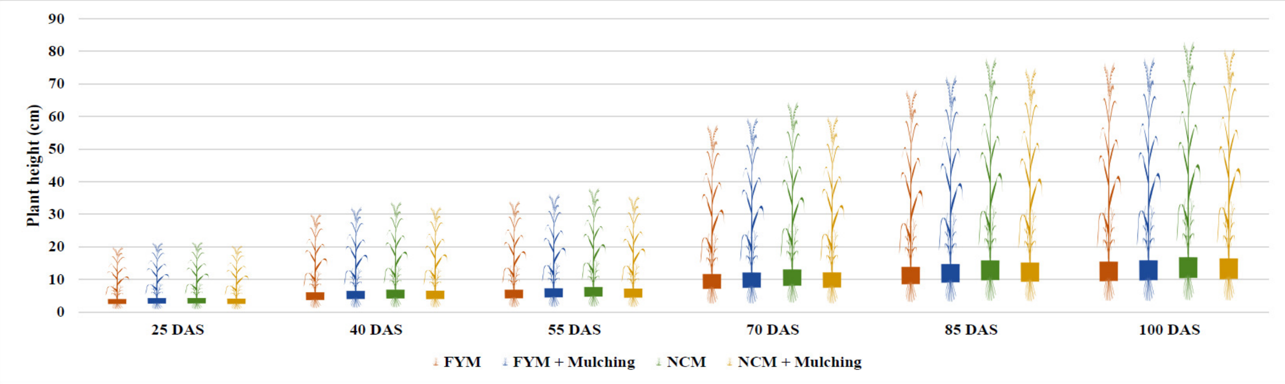

Fig. 1 : Graphical representation of periodic plant height of wheat under SWI as affected by solid organic manures

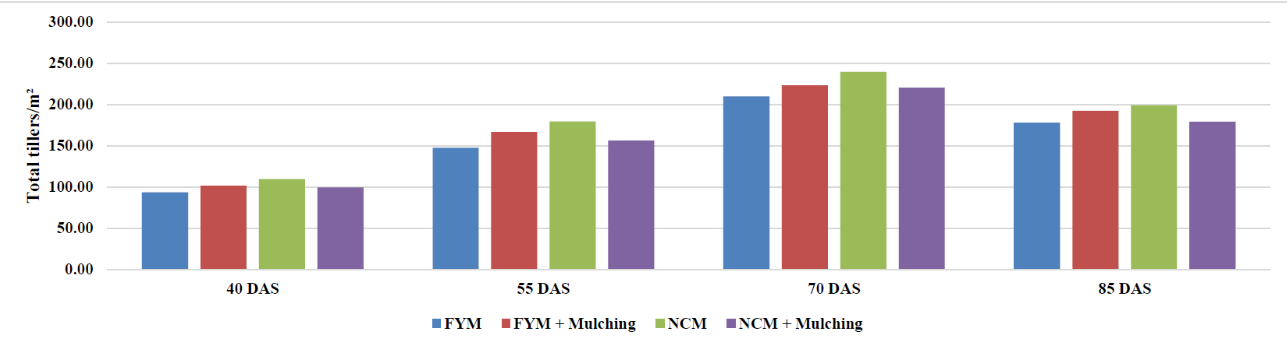

Fig. 2 : Graphical representation of periodic total tillers/m^2 of wheat under SWI as affected by solid organic manures

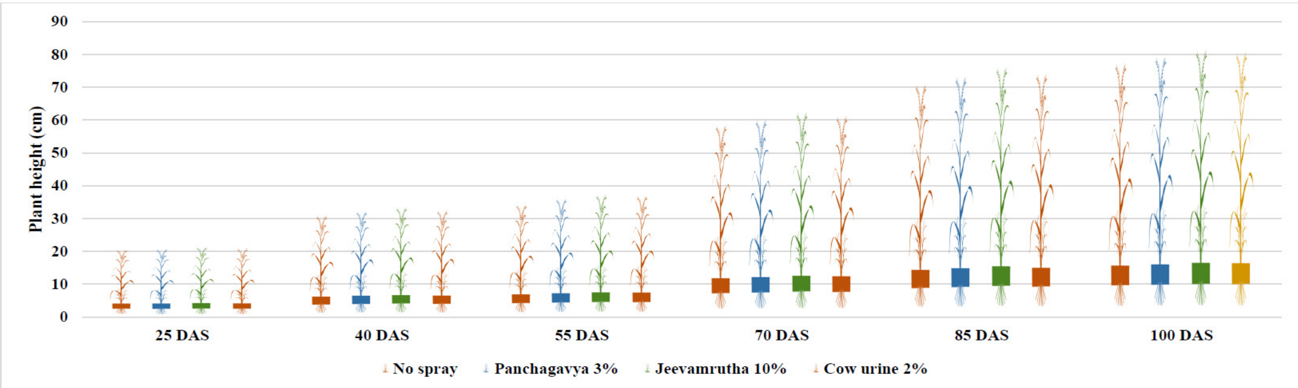

Fig. 3 : Graphical representation of periodic plant height of wheat under SWI as affected by liquid organic formulations

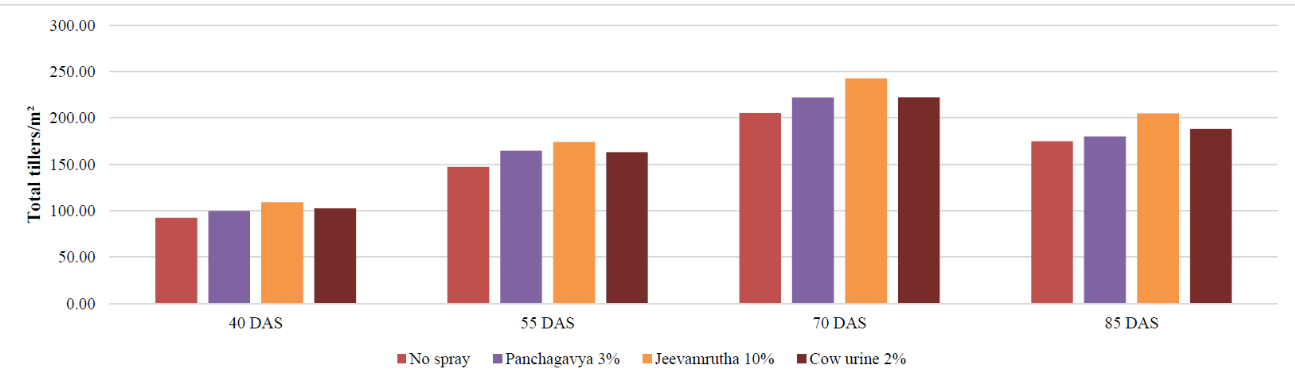

Fig. 4 : Graphical representation of periodic total tillers/m^2 of wheat under SWI as affected by liquid organic formulations

Conflict of Interest

We declare that there is no conflict of interest.

Author's Contribution

Study conceptualization and design: A.N. and S.S.; Investigation and methodology: A.N.; Data acquisition and analysis: A.N. A.S., R.H. and K.C.J.S.; Drafting of the manuscript: A.N.; Reviewing and editing of the draft: S.S., N. and J.K.L.; Study supervision and critical revision for important intellectual content: S.S.; Final approval of the submitted version: S.S. and A.N.

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Declaration of generative AI in scientific writing

During the preparation of this work the authors used Large Language Model (Quillbot) during writing of manuscript in order to refine the language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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