Ann. Agric. Res. New Series Vol. 43 (4) : 375-381 (2022)

Effect of organic formulations on growth and yield of wheat in South-Eastern Rajasthan

Gajendra Nagar[1], D. S. Meena[2], B. S. Meena[3], M. K. Sharma[4], B. K. Patidar[5], Rajendra Kumar Yadav[6], D. L. Yadav[7] and Baldev Ram[8]

Department of Agronomy, College of Agriculture, Ummedganj- Kota, Agriculture University, Kota [1]

Received: June 2022; Revised Accepted: November 2022

Abstract

A field experiment was conducted at Research Farm of Agricultural Research Station Ummedganj, Kota during *rabi* season 2020-21 on clay loam soils. The experiment comprised of ten treatments consisted of farmyard manure, vermicompost, ghanjeevamrut and liquid organic manures *viz*., liquid consortia of biofertilizers, cow urine, vermiwash sasyagavya which were calculated on the basis of 120 kg/ha nitrogen equivalency, which were designed with three replications using randomized block design. A critical examination of data revealed that application of 50% organic manure + 50% vermicompost + vermiwash spray 10% recorded significantly higher plant height (60.22 cm), number of tillers/plant (6.9), chlorophyll content (2.91 mg/g), plant dry weight (75.0 g/mrl) and crop growth rate (7.83 g/m^2/day) of wheat over control. Likewise, application of 50% organic manure + 50% vermicompost + 10% vermiwash spray plots exhibited significantly higher number of effective tillers (78.0), ear length (8.63 cm), number of seeds/ear (41.0), test weight (41.50 g), seed yield (4220 kg/ha), straw yield (6383 kg/ha), biological yield (10603 kg/ha), gross return (₹145857), net return (₹95792) and wheat production efficiency (31.26 kg/ha/day) as compared to rest of treatments. Therefore, application of organic manures combined with vermicompost and vermiwash spray proved better to obtain higher wheat yields under South-Eastern Rajasthan conditions.

Keywords: Wheat, Organic manure, Vermicompost, Liquid consortia of biofertilizer

Introduction

Wheat (*Triticum aestivum* L.) is a native of South West Asia and stood one of the most important staple food crop. Wheat is a good supplement for nutritional requirement of human body as it contains 8.0-15.0 per cent protein, 60-68 per cent starch, 1.5-2.0 per cent fat, 2.0-2.5 per cent cellulose and 1.5-2.0 per cent minerals. India is the second largest wheat producer country in the world. It is the second most important crop in India after rice, both in terms of area and production. In India it is cultivated in almost all part of the country and occupied 31.12 million ha with the production of 109.58 million tonnes and with an average productivity of 3551 kg/ha (Anonymous, 2020-21). In Rajasthan production of wheat is about 11.04 million tonnes from an area around 3.00 million ha and average productivity of 3676

Ph.D. Research Scholar, Department of Agronomy, College of Agriculture, Ummedganj- Kota, Agriculture University, Kota [1]
Associate professor, Department of Agronomy, ARS, Ummedganj Kota, Agriculture University, Kota [2, 3, 8]
Associate professor, Department of Soil Science and Agriculture Chemistry, ARS, Ummedganj Kota, Agriculture University, Kota [4]
Associate Professor, Department of Entomology, ARS, Ummedganj Kota, Agriculture University, Kota [5]
Assistant Professor, Department of Plant Pathology, ARS, Ummedganj Kota, Agriculture University, Kota [7]
Assistant professor, Department of Soil Science and Agriculture Chemistry, ARS, Ummedganj Kota, Agriculture[6] Ummedganj, Kota,

kg/ha (Anonymous, 2020-21).

Organic farming as a sustainable production management system provides long-term benefits to people and the environment (Basavalingaiah *et al*., 2022). Organic farming is a unique production management system which promotes and enhances agro-ecosystem health including biodiversity, biological cycles and soil biological activity. This is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs (viz. fertilizers, pesticides, hormones and feed additives) and to the maximum extent feasible rely upon crop rotations, crop residues, animal manures, off-farm organic waste, mineral grade rock additives and biological system of nutrient mobilization and plant protection (Gopakkali *et al*., 2012; Rajanna *et al*., 2012).

Continuous cropping without adequate restorative practices may endanger the sustainability of agriculture (Gopinath *et al*., 2022; Rajanna *et al*., 2022) and proper management of soil fertility demands, careful identification of constraints of current nutrient status with monitoring the changes in soil fertility so as to sustain food production at a reasonable level to ensure continued high productivity in future (Patil *et al*., 2014). The increased content of leaf chlorophyll in critical growth and reproductive phase seems to be due to increased supply of balance nutrition especially nitrogen with micro nutrient (Harish *et al*., 2022). This may lead to greater synthesis of photosynthetic pigments in the active assimilatory zones. It is explained by nitrogen, which is a structural element of chlorophyll and protein molecules and has an impact on the formation of chloroplasts and chlorophyll accumulation in them. Hence, application of organic manures enhances crop yields through exhibiting better physiological basis in the crop plants. The adequate availability of organic manures in bulk, selection of suitable improved variety with solid and liquid organic manures that adapts itself under the peculiar climatic condition of humid south eastern plain zone V for sustainable organic production of wheat. Therefore, keeping the above facts in view, the objective of present study was therefore to evaluate, effect of different organic formulation on growth and yield of wheat in South-Eastern Rajasthan.

Material and Methods

A field experiment was conducted at Research Farm of Agricultural Research Station Ummedganj, Kota during *rabi* season 2020-21. The soil of the experimental field was clay loam, having bulk bensity (1.39), particle density (2.57), porosity (45.91), maximum water holding capacity (40.05%), organic carbon (0.45%), pH (7.85), EC (0.38 dS/m), available N (348 kg/ha) available P_2O_5 (44.0 kg/ha) available K_2O (429 kg/ha), available Zn (0.79 mg/kg), available Fe (3.45 mg/kg), available Cu (0.50 mg/kg) and available Mn (3.05 mg/kg). The experiment was laid out in randomized block design with three replications and comprised of ten treatments *viz*. T_1 (Control), T_2 (100% OM + 10% CU), T_3 (100% OM + 5% *Panchgavya*), T_4 (75% OM + 25% VC + 10% VW), T_5 (50 % OM + 50 % VC + 10% VW), T_6 (75% OM + JA 500 L/ha), T_7 (75% OM + GJA 500 kg/ha), T_8 (100% OM + LCB 1250 ml/ha), T_9 (75 % OM + LCB 1250 ml/ha), T_{10} (75% OM + LCB 1250 ml/ha + 10% SG). Different organic formulation, solid organic manures *viz*., farmyard manure, vermicompost and ghanjeevamrut and liquid organic manures *viz*., liquid consortia of biofertilizers, cow urine, vermiwash, sasyagavya which were calculated on the basis of 120 kg/ha nitrogen equivalency. *Panchgavya* was prepared with a mixture of five components in the ratio of 5:4:3:2:1, *viz*., cow dung, cow urine, milk, curd, ghee, tender coconut water and six ripe bananas. *Jeevamrut* was prepared with a mixture of fresh cow dung 25 kg, 5-10 lit. cow urine, 2 kg jiggery, 2 kg chickpea flour and 1 kg sajiv soil (Soil below baniyan tree) for one acre use one time added in 200 lit. water. It was applied along with irrigation water in wheat crop. *Ghanjeevamrut* was prepared using fresh cow dung 200 kg, 10 lit. cow urine, 1 kg jiggery, 2 kg chickpea Flour and 1 kg sajiv soil (Soil below baniyan tree). The rate of application is 500 kg/ha at a time, applied on soil when it is weted as per treatment. Sasaygavya was prepared with a mixture of six components in the ratio of 1:1:1:2:0.2:0.2 (fresh cow dung 5 kg, 5 lit. cow urine, 5 kg cutting of herbs (rich nutrient weed, vegetable, fruits) 10 lit. water and added 1 kg (Leaves or Chatani of

dhatura, deshi Tobacco, neem, and calotropis) as activator and 1 kg sajiv soil (Soil below baniyan tree). *Vermiwash* is a liquid extract obtained from vermicomposting process and used as an organic fertilizer for crop plant. To maintain the moisture level of cow dung kept in plastic tank, water is sprinkled to the vermicompost heap drop by drop. The earthworms eat up and digested the wet organic waste and thus some amount of water absorb by the earthworms. During vermicomposting process drained continues nutrient enriches solution from vermi-bed or heap in a pot generated wash which is an extract of not only earthworm-worked biomass but also the earthworm body fluids. This yellowish liquid released by the earthworms is known as vermiwash. *Beejamrut* was prepared with a mixture of five components in the ratio of 1:5:5:0.5:0.1:0.025, *viz.*, water, cow dung, cow urine, milk, lime and sajiv soil respectively, (for treating 100 kg seeds) which was fermented for 12 hours, then the seeds of Wheat were treated with filtered beejamrut @ 50 to 100 ml/kg for 5-7 minutes.

Farm yard manure (FYM) was applied at 15 days before sowing, while vermicompost incorporated at the time of sowing. Jeevamrut was applied and ghanjeevamrut was applied at first irrigation in wheat. Liquid organic manure sprayed on wheat crop at 40 and 60 days. Wheat variety 'RAJ 4037' was sown in 22.5 cm apart at a seed rate of 100 kg seed/ha on the third fourth night of Nov. The recommended cultural practices and plant protection measures were followed to raise the healthy crop. The crop was generally manually harvested in the third week of March. In order to test the significance of variation in experimental data obtained for various treatment effects, the data were statistically analysed by RBD as described by Panse and Sukhatme (1985).

Results and Discussion

A critical examination of data revealed that application of different organic sources significantly enhanced growth parameters at 60 DAS successive growth stages (Table 1). Data referred that organic sources significantly influenced the plant height (60.22 cm), number of tillers/plant (6.9), chlorophyll content (2.91 mg/g), plant dry weight (75.0 g/mrl) and crop growth rate (7.83 g/m^2/day) of wheat crop over control. Significantly higher plant height, chlorophyll content and crop growth rate were recorded in application of 50% OM + 50% VC + 10% VW remained statistically on par with application of 75% OM + 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + 10% SG and 75% OM + LCB 1250 ml/ha. Further data indicate that significantly higher number of tillers/plant was observed in application of 50% OM + 50% VC + 10% VW which was statistically on par with application of 75% OM + 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha and 75% OM + LCB 1250 ml/ha + 10% SG at 60 DAS. However significantly higher plant dry

Table 1. Effect of different organic formulations on growth parameters of wheat

Treatment		Plant height (cm) At 60 DAS	Total no. tillers/plant At 60 DAS	Chlorophyll mg/g) (At 60 DAS	Plant dry weight (g/mrl) At 60 DAS DAS	CGR (g/m^2/ day) At 30- 45	RGR (g/g/day) At 30- 45 DAS
T_1	Control	44.67	3.8	2.50	53.0	4.95	0.073
T_2	100 % OM + 10% CU	52.00	5.6	2.71	62.3	6.30	0.075
T_3	100 % OM + 5% *Panchgavya*	54.11	5.8	2.75	64.7	6.60	0.075
T_4	75 % OM + 25 % VC + 10% VW	59.33	6.4	2.88	73.0	7.68	0.077
T_5	50 % OM + 50 % VC + 10% VW	60.22	6.9	2.91	75.0	7.83	0.077
T_6	75 % OM + JA 500 L/ha	51.11	5.2	2.67	61.0	6.18	0.075
T_7	75 % OM + GJA 500 kg/ha	50.00	4.6	2.65	59.0	5.85	0.073
T_8	100 % OM + LCB 1250 ml/ha	59.00	6.3	2.85	70.7	7.47	0.077
T_9	75 % OM + LCB 1250 ml/ha	55.78	6.0	2.81	67.0	6.86	0.074
T_{10}	75 % OM + LCB 1250 ml/ha + 10% SG	58.00	6.2	2.83	68.7	7.15	0.075
SEm ±		1.70	0.24	0.04	1.97	0.34	0.003
CD (P=0.05)		5.05	0.70	0.11	5.86	1.02	NS

weight per meter row length was observed in application of 50% OM + 50% VC + 10% VW and followed by application of 75% OM + 25% VC + 10% VW and 100% OM + LCB 1250 ml/ha at 60 DAS. Maximum relative growth rate (RGR) (0.077 g/g/day) was recorded with application of 50% OM + 50% VC + 10% VW followed by application of 75% OM + 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + 10% SG. Increments in growth values might be due to the increased availability of all essential nutrients due to application of organic manures such as farmyard manure, vermicompost along with two spray of vermiwash. Balanced crop nutrition plays a significant part in rapid cell division and elongation in meristematic plant tissues, growth and photosynthesis, which are accountable for the quantitative upsurge in the plant growth (Gopakkali *et al*., 2012; Rajanna *et al*., 2018). On the other hand, the enhancing effect of using organic sources on plant growth may be due to that such organic manures play a role as a soil amendment which improves water holding capacity and increase macro and micro elements availability in the rhizosphere around roots system which in turns increased plant growth (Rajanna *et al*., 2012; Upadhyay *et al*., 2022). This promoting effect could be related to the N supplementary effect of N fixing bacteria (used as bio N-fertilizer) to plants due to their ability to fix free molecular atmospheric nitrogen (Gopinath *et al*., 2022; Harish *et al*., 2022). Additionally the significantly increased number of tillers/plant might have been due to the ready availability of nutrients like nitrogen, phosphorus, through liquid organic formulations, *i.e*., vermiwash as foliar spray at critical stages, which would have triggered tillers/plant, similar findings was reported by Meena *et al*. (2021).

A perusal of data revealed that application of different organic sources significantly influenced yield attributes and yield (Table 2). Application of 50% OM + 50 %VC + 10% VW was recorded significantly higher number of effective tillers per metre row length (78.0) and ear length (8.63 cm), number of seed/ear (41.0), test weight (41.50 g), seed yield (4220 kg/ha), straw yield (6383 kg/ha) and biological yield (10603 kg/ha) as compared to rest of treatments. Further data indicate that significantly higher ear length, number of seed/ear, test weight and straw yield were observed in application of 50% OM + 50% VC + 10% VW remained statistically on par with application of 75% OM+ 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + 10% SG and 75% OM + LCB 1250 ml/ha. Significantly higher number of effective tillers per meter row length, seed yield and biological yield were recorded in application of 50% OM + 50% VC + 10% VW which was statistically on par with application of 75% OM+ 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha and 75% OM + LCB 1250 ml/ha + 10% SG. Moreover, the positive effect of liquid organic

Table 2. Effect of different organic formulations on yield attributes and yields of wheat

Treatment		Effective tillers/m row length	Ear length (cm)	Number of seeds/ ear	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ ha)
T_1	Control	53.00	6.77	35.00	32.67	2253	3576	5830
T_2	100 % OM + 10% CU	63.00	7.80	38.22	37.83	3520	5530	9050
T_3	100 % OM + 5% *Panchgavya*	65.00	7.87	38.67	38.00	3620	5683	9303
T_4	75 % OM + 25 % VC + 10% VW	76.22	8.59	40.75	41.00	4000	6145	10145
T_5	50 % OM + 50 % VC + 10% VW	78.00	8.63	41.00	41.50	4220	6383	10603
T_6	75 % OM + JA 500 L/ha	62.33	7.60	38.11	37.00	3386	5333	8720
T_7	75 % OM + GJA 500 kg/ha	60.00	7.53	37.33	36.50	3310	5223	8533
T_8	100 % OM + LCB 1250 ml/ha	75.00	8.50	40.33	40.67	3760	5843	9603
T_9	75 % OM + LCB 1250 ml/ha	71.33	8.17	39.11	40.00	3640	5716	9356
T_{10}	75 % OM + LCB 1250 ml/ha + 10% SG	74.44	8.43	39.22	40.33	3710	5788	9498.3
SEm ±		2.09	0.23	0.64	1.16	189.6	228.1	408.6
CD (P=0.05)		6.21	0.69	1.91	3.46	563.6	677.7	1214.1

Note: OM= Organic manure, VC= Vermicompost, JA = Jeevamrut, GJA = Ghanjeevamrut, LCB= Liquid consortia of biofertilizers, CU= Cow Urine, VW= Vermiwash, SG= sasyagavya

manure on growth parameters may be due to that, liquid organic manure has a stimulatory effect of many physiological processes, such as respiration activities, cell division and many enzymes activities (Gopakkali *et al*., 2012; Patil *et al*., 2014). The positive effect of liquid organic manure treatments on chlorophyll may be attributed to their N-fixing activity and the production of plant growth-promoting substances such as IAA, gibberellins, and which regulates and protect photosynthetic processes and in turn probably led to more synthesis of pigments including total chlorophylls content (Rana *et al*., 2018). As most of these growth and yield attributes showed significantly positive correlation with grain yield of wheat evidently resulted in higher yield in 50% OM + 50% VC + 10% VW which get timely nitrogen appears to be on account of their influence on dry matter production and indirectly via increase in plant height, number of total tillers, number of effective tillers and possibly a result of higher uptake of nutrients (Rajanna *et al*., 2011; Upadhyay *et al*., 2022). The overall growth and development of crop is reflected in the development of yield contributing characters which affect the final yield of the crop as these parameters are positively correlated to seed yield.

It can be inferred from the economic assessment of data that all the different organic formulation treatments recorded significantly higher gross return (₹145857), net return (₹95792) and wheat production efficiency (31.26 kg/ha/day) were recorded in application of 50% OM + 50% VC + 10% VW as compared to over rest of treatments (Table 3). Further data indicate that application of 50% OM + 50% VC + 10% VW was registered significantly higher gross return and it was found on par with the application of 75% OM + 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + 10% SG. Significantly higher net return was registered in application of 50% OM + 50% VC + 10% VW followed by 75% OM+ 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + SG spray 10%, 75% OM + LCB 1250 ml/ha, 100% OM + 5% *Panchgavya*, 100% OM + 10% CU and 75 % OM + JA 500 L/ha. Significantly higher wheat production efficiency was recorded in application of 50% OM + 50% VC + 10% VW remained statistically on par with application of 75% OM+ 25% VC + 10% VW, 100% OM + LCB 1250 ml/ha, 75% OM + LCB 1250 ml/ha + 10% SG and 75% OM + LCB 1250 ml/ha. Maximum B:C ratio (2.16) was recorded with application of 75% OM + LCB 1250 ml/ha due to low cost of cultivation followed by application of 75% OM + LCB 1250 ml/ha + 10% SG, 100% OM + LCB 1250 ml/ha and 75% OM + 25% VC + 10% VW. It could be able to increase the yield level of wheat in addition to the increased cost of production. The cost of integration of organic manure (farmyard manure + vermicompost + vermiwash) was compensated

Table 3. Effect of different organic formulation on economics and production efficiency (kg/ha/day) of wheat

Treatment		Gross return (₹/ha)	Net return (₹/ha)	B:C ratio	Wheat production efficiency (kg/ha/day)
T_1	Control	78723	49058	1.65	16.69
T_2	100 % OM + 10% CU	122690	78925	1.80	26.07
T_3	100 % OM + 5% *Panchgavya*	126157	79992	1.73	26.81
T_4	75 % OM + 25 % VC + 10% VW	138728	91663	1.95	29.63
T_5	50 % OM + 50 % VC + 10% VW	145857	95792	1.91	31.26
T_6	75 % OM + JA 500 L/ha	118107	77842	1.93	25.09
T_7	75 % OM + GJA 500 kg/ha	115487	74322	1.81	24.52
T_8	100 % OM + LCB 1250 ml/ha	130737	87562	2.03	27.85
T_9	75 % OM + LCB 1250 ml/ha	126863	86688	2.16	26.96
T_{10}	75 % OM + LCB 1250 ml/ha + 10% SG	129112	86937	2.06	27.48
SEm ±		6180	6180	0.15	1.41
CD (P=0.05)		18362	18362	NS	4.17

Note: OM= Organic manure, VC= Vermicompost, JA = Jeevamrut, GJA = Ghanjeevamrut, LCB= Liquid consortia of biofertilizers, CU= Cow Urine, VW= Vermiwash, SG= sasyagavya

with the higher yield of wheat. This trend in economic return is mainly due to the higher cost and treatment effect on the seed and straw yield of wheat.

Conclusion

Based on the findings, it can be inferred that, application of 50% organic manure + 50% vermicompost + 10% vermiwash spray exhibited significantly higher growth and yield parameters of wheat over other organic manures. However, application of beejamuruth, *Panchgavya*, biodigester liquid and *Ghanjeevamrut* showed positive effects on yields and therefore need to be validated in long term trials.

References

Anonymous (2020-21). Agricultural Statistics at a Glance. The Directorate of Economics & Statistics of the Department of Agriculture & Cooperation.

Basavalingaiah, K., Paramesh, V., Parajuli, R., H.C. Girisha, M. Shivaprasad, G.V. Vidyashree, Thoma, G., M. Hanumanthappa, G.S. Yogesh, Misra, S.D., Bhat, S., M.M. Irfan and Rajanna, G.A. (2022). Energy flow and life cycle impact assessment of coffee-pepper production systems: An evaluation of conventional, integrated and organic farms in India. *Environmental Impact Assessment Review* **92**: 106687.

Gopakkali, P., Channanaik, D., Rajanna, G. A., Sannathimmappa, Ramesha, Y. M. and Veeresha, 2012. Economics and nutrient uptake of rice (*Oryza sativa* L.) as influenced by various levels of FYM and cattle urine application in Bhadra command area of Karnataka. *Crop Research*, **43** (1,2&3): 10–14.

Gopinath, K.A., Rajanna, G.A., Venkatesh, G., Jayalakshmi, M., Kumari, V.V., Prabhakar, M., Rajkumar, B., Chary, G.R., Singh, V.K. (2022). Influence of crops and different production systems on soil carbon fractions and carbon sequestration in rainfed areas of semi-arid tropics in India. *Sustainability* 2022, 14, 4207.

Harish, M.N., Choudhary, A.K., Bhupenchandra, I., Dass, A., Rajanna, G.A., Singh, V.K., Bana, R.S., Varatharajan, T., Verma, P., George, S., Kashinath, G.T., Bhavya, M., Chongtham, S.K., Devi, E.L., Kumar, S., Devi, S.H. and Bhutia, T.L. (2022). Double zero-tillage and foliar-P nutrition coupled with bio-inoculants enhance physiological photosynthetic characteristics and resilience to nutritional and environmental stresses in maize–wheat rotation. *Frontiers in Plant Science* **13**:959541.

Meena, A.M., Karwal, M., Raghavendra, K.J. and Kumari, P. (2021). Vermiwash: A potential tool for sustainable organic farming. *Food and Scientific Reports*, **2**(5) 43–45.

Panse, V.G. and Sukhatme, P.V. (1985). *Statistical Methods for Agricultural Workers*, Indian Council of Agricultural Research, New Delhi.

Patil, M.D., Dhindwal, A.S. and Rajanna, G.A. (2014). Integrated moisture stress management in wheat (*Triticum aestivum*). *Indian Journal of Agronomy* **59** (4): 629–633

Rajanna, G. A., Murali, K., Gopakkali, P., Nayak, P., Sudakara, T. M. and Lakshmipathy, R. N., 2012. Effect of different sources and time of application of organic manures on residual fertility and nutrient balance in Aerobic Rice (*Oryza sativa* L.). *Crop Research*, 43(1,2&3):5–9.

Rajanna, G. A., Murali, K., Nayak, P., R. N. Lakshmipathy, Gopakkali P. and Paramesh, V. (2011). Effect of different sources and time of application of organic manures on yield attributes, yield and economics of Aerobic Rice (*Oryza sativa* L.). *International Journal of Agricultural Sciences*, **7**(1):193–196.

Rajanna, G.A., Dass, A., Suman, A., Babu, S., Paramesh, V., Singh, V.K., Upadhyay, P.K., Sudhishri, S., 2022. Co-implementation of tillage, irrigation, and fertilizers in soybean: Impact on crop productivity, soil moisture, and soil microbial dynamics. *Field Crops Research* **288** :108672.

Rajanna, G.A., Dhindwal, A.S., Narender, Patil, M. D. and Shivakumar, L. (2018). Alleviating moisture stress under irrigation scheduling and crop establishment techniques on productivity and profitability of wheat (*Triticum aestivum*) under semi-arid conditions of western India. *Indian Journal of Agricultural Sciences*, 88 (3): 372–378.

Rana, D.S., Dass, A., Rajanna, G.A. and Choudhary, A.K. (2018). Fertilizer phosphorus solubility effects on Indian mustard–maize and wheat–soybean cropping systems productivity. *Agronomy Journal*, **110** (6): 2608–2618.

Upadhyay, P.K., Sen, A., Singh, Y., Singh, R.K., Prasad, S.K., Sankar, A., Singh, V.K., S.K. Dutta, Kumar, R., Rathore, S.S., Shekhawat, K., Babu, S., Singh, R.K., Kumar, B., Dey, A., Rajanna, G. A. and Kulshekaran, R. (2022). Soil health, energy budget, and rice productivity as influenced by cow products application with fertilizers under South Asian Eastern Indo-Gangetic Plains Zone. *Frontiers in Agronomy*, **3**:1–13, 758572.