Range Management and Agroforestry 46 (2) : 311-317, 2025
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2025.v46.i2.17

Research article

Effect of integrated nutrient management on the productivity of oat-green gram cropping system in Inceptisols

Krishnendu Mondal[1], Kalyan Jana[2], Khurshid Alam[3], Bappa Paramanik[4]*, Subhash Chand[5], Priyanka Saha[6], Ramyajit Mondal[7] and Gopal Dutta[2]

[1]Dhaanyaganga Krishi Vigyan Kendra, Ramakrishna Mission Vivekananda Educational and Research Institute, Belur Math-711202, India
[2]Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, India
[3]Tilka Manjhi Agriculture College, Birsa Agricultural University, Ranchi-834006, India
[4]Dakshin Dinajpur Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Dakshin Dinajpur-733133, India
[5]ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India
[6]ICAR Krishi Vigyan Kendra, West Garo Hills, Tura-794005, India
[7]Seacom Skills University, Kendradangal-731236, India
*Corresponding author email: paramanikbappa@gmail.com

Received: 26th February, 2025 Accepted: 06th November, 2025

Abstract

The present field experiment was conducted during two consecutive rabi-summer seasons at the Instructional Farm, Jaguli, under the new alluvial zone of West Bengal to evaluate the effect of integrated nutrient management on the productivity of dual-purpose oats (*Avena sativa* L.) and its residual impact on succeeding green gram (*Vigna radiata* L.). Seven nutrient management treatments were tested in a randomized block design with three replications, combining different proportions of the recommended dose of nitrogen (RDN), vermicompost, phosphate-solubilizing bacteria (PSB), Azotobacter and zinc sulphate ($ZnSO_4 \cdot 7H_2O$). Among the treatments, T_6 (75% RDN + vermicompost 2 t ha^{-1} + PSB + Azotobacter + $ZnSO_4 \cdot 7H_2O$ @ 20 kg ha^{-1}) produced the best performance. Pooled over two years, T_6 increased oat grain yield to 17.2 q ha^{-1} compared with 7.0 q ha^{-1} under the control (≈146% higher), and stover yield to 66.2 q ha^{-1} versus 38.3 q ha^{-1} (≈73% higher). Plant height, leaf area index, and dry aerial biomass under T_6 (152.6 cm, 3.93, and 25.5 q ha^{-1}, respectively) were higher by ≈36%, ≈11.6%, and ≈82.9%, respectively, compared with the control. The residual seed yield of green gram under T_6 was 11.0 q ha^{-1}, ≈15.9% higher than the control. The results suggest that integrated application of inorganic, organic and biofertilizer inputs can enhance system productivity, improve soil fertility and support sustainable intensification of food-fodder cropping systems in the region.

Keywords: Biofertilizer, Dual-purpose oat, Nitrogen management, Residual green gram

Introduction

Oat (*Avena* spp.), belonging to the *Poaceae* family, is a widely grown low-input cereal crop that serves as a food source for humans and an essential feed for livestock. Historically, oats were primarily grown for animal feed, but their increasing recognition as a functional food has contributed to a rise in human consumption (Jing and Hu, 2012). Oat grains contain a diverse array of bioactive compounds, including β-glucan, polyunsaturated fatty acids, vitamin E, minerals, and phytochemicals, which have been linked to a lower risk of chronic diseases such as cardiovascular ailments, diabetes, obesity, and cancer (Redaelli *et al*., 2015; Sterna *et al*., 2016). Oats function as a dual-purpose crop, providing both grain and high-quality fodder. However, a major limiting factor in oat cultivation is its low seed yield, which affects availability and adoption (Raj and Vyakaranahal, 2014). Rising global food demands have intensified agricultural practices, often at the expense of fodder crops, leading to a nutritious feed deficit for livestock (Arif *et al*., 2023). The excessive application of chemical fertilizers negatively impacts soil health and nutrient balance, emphasizing the need for an integrated fertilization strategy (Biswas *et al*., 2020). The incorporation of organic amendments like vermicompost has been found to improve soil structure, microbial activity, and nutrient availability, thereby supporting enhanced productivity and sustainability (Dhaliwal *et al*., 2024). Additionally, biofertilizers such as phosphate-solubilizing bacteria (PSB) and nitrogen-fixing Azotobacter play an essential role in improving nutrient efficiency while reducing environmental impact (Jha *et al*., 2024; Maity *et al*., 2025).

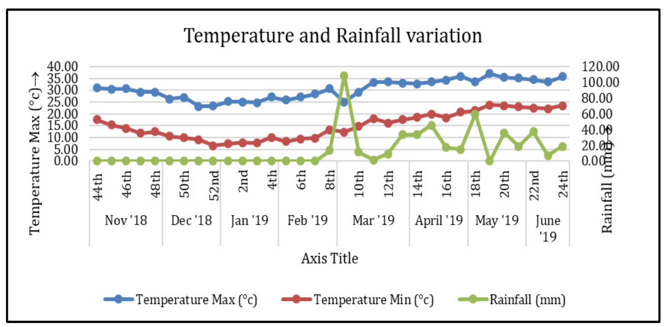
Integrating legume crops into cropping systems is a well-established strategy to improve soil fertility and boost overall agricultural productivity. Green gram (*Vigna radiata*), a short-duration pulse crop, is particularly beneficial due to its ability to fix atmospheric nitrogen and its high protein content, making it an essential nutritional source in developing regions (Raza *et al*., 2012). Cultivating green gram during the summer season allows for the effective utilization of residual soil nutrients, minimizes fallow periods, and enhances biological nitrogen fixation, thus improving soil fertility for subsequent crops (Biswas *et al*., 2020; Gorai and Mondal, 2023). Furthermore, green gram residues contribute to organic matter buildup, further enhancing soil health (Saha *et al*., 2023). Besides, nutrient release dynamics of both inorganic and organic nutrient sources in oats-green gram cropping sequence, carry-over effect of multiple nutrient sources in total system productivity, microbial diversity and soil organic carbon pool in different soil order lacks research quantification. Balanced and customized INM approaches might be a viable solution to obtain better yield and nutrient use efficiency at the same time. Given these advantages, incorporating green gram in sequence with oats is a promising approach to improving cropping system sustainability, with both economic and environmental benefits.

In light of these considerations, this study investigated the effects of combined organic and inorganic fertilizers on the growth, yield, and quality of dual-purpose oats. Additionally, the research sought to assess the residual effects of nutrient management on the succeeding green gram crop, thereby contributing to the development of a sustainable, resource-efficient cropping system.

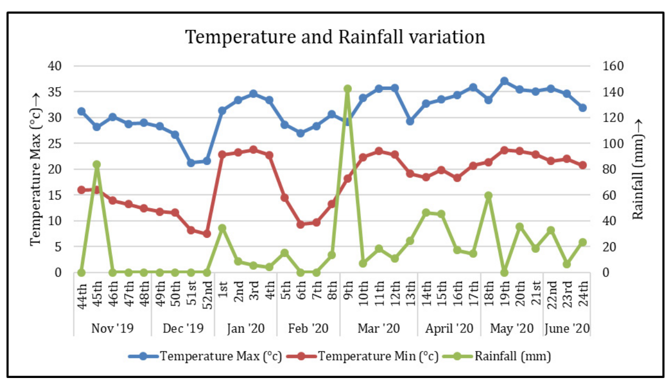
Materials and Methods

Study area and environmental conditions: A two-year field study was conducted during the *Rabi* seasons of 2018-19 and 2019-20 to assess the cultivation of dual-purpose oats, followed by green gram during the summer seasons of 2019 and 2020 at the Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, Nadia. The experimental site is situated at 23°N latitude and 89°E longitude, with an elevation of 9.75 meters above sea level, within the Indo-Gangetic plains. The region features a subtropical humid climate, characterized by hot summers and moderate winters, with an average annual rainfall of 1400-1600 mm, predominantly received during the monsoon season. Meteorological observations recorded during the 2018-19 and 2019-20 experimental periods confirmed that the climatic conditions were conducive to the growth and development of the dual-purpose oat-green gram cropping system (Fig 1a-1b). The experimental field soil was classified as sandy clay loam, with a bulk density of 1.32 Mg/ m^3 and a pH of 7.1 (1:2.5 soil-water ratio). The initial organic carbon content was 5.2 g kg^{-1}, while the available macronutrient levels were 196.9 kg N ha^{-1}, 46.6 kg P ha^{-1}, and 177.5 kg K ha^{-1}.

Treatment details: This study evaluated the impact of organic, inorganic, and microbial fertilizers on the productivity of dual-purpose oat (*Avena sativa* L.), followed by green gram (*Vigna radiata* L.) as a residual crop. There were seven treatments under this study (Table 1). The experiment was conducted following a randomized complete block design (RCBD) with three replications. The field was systematically divided into 21 plots, each having dimensions of 4 × 3 m. Treatment combinations were assigned to the plots randomly, ensuring unbiased distribution. In all treatments, 50% of the total N requirement was met through a combination of organic and inorganic sources (urea), while the full recommended doses of P and K were applied at the basal stage using single super phosphate (SSP) and muriate of potash (MOP), respectively, along with biofertilizers. The remaining half of the N dose was applied as a top dressing after the first fodder cut at 55 days after sowing (DAS) to support subsequent plant growth and grain development.



a



b

Fig 1. Meteorological data collected during the experimental periods of (a) 2018-19 and (b) 2019-20

Table 1. Treatment details

Treatment	Details
T_1	Control (No external fertilizer application)
T_2	Recommended dose of fertilizer: RDF (80 kg N, 40 kg P_2O_5, 40 kg K_2O per hectare)
T_3	75% of recommended dose of N (RDN) + vermicompost (2 t/ha)
T_4	T3 + Phosphate solubilizing bacteria (PSB) @15 kg/ha
T_5	T4 + Azotobacter (10 g/kg seed)
T_6	T5 + $ZnSO_4{\cdot}7H_2O$ (20 kg/ha)
T_7	50% RDN + Vermicompost (2 t/ha) + PSB (15 kg/ha) + Azotobacter (10 g/kg seed) + $ZnSO_4{\cdot}7H_2O$ (20 kg/ha)

Cultural operations: The study utilized the dual-purpose oat variety 'Kent', cultivated for both green fodder and grain production. Sowing was carried out on November 3, 2018, and October 31, 2019, using the '*kera*' method, maintaining a row spacing of 30 cm and plant-to-plant spacing of 10 cm. A seed rate of 80 kg/ha was adopted for optimal plant establishment. The crop reached a height of 1.3 to 1.5 meters, had a growth duration of 115-120 days, and exhibited a yield potential of 15 to 20 q ha^{-1}.

Pre-sowing irrigation was provided to facilitate uniform germination, followed by thinning and manual weeding at 25 days after sowing (DAS) to regulate plant density and suppress weeds. The crop received six irrigations in the first year and four in the second year, depending on moisture availability. The first fodder cut was taken at 55 DAS, allowing regrowth for grain production. At 120 DAS, the mature oat crop was harvested, sun-dried for 2-3 days, threshed, and winnowed to obtain clean grains. For the succeeding green gram crop, the variety 'Meha' (IPM 99-125) was selected. It attained a height of 75-80 cm, had a growth duration of 70-75 days, and demonstrated a yield potential of 1200-1500 kg ha^{-1}. As it was grown during the *Zaid* season, irrigation was applied as required. During the first weeding, excessive seedlings were removed to maintain an optimal plant density of 3.33 lakh plants per hectare, ensuring a plant-to-plant spacing of 5-7 cm. To manage pod borer (*Helicoverpa armigera*) infestation, two foliar sprays of Anaconda 505 (Chlorpyrifos 50% + Cypermethrin 5% EC) at a rate of 2 ml per liter were applied at post-flowering and pod development stages. The crop was harvested manually in two pickings, with the first at 76 DAS and the second seven days later. The harvested pods were sun-dried for 2-3 days, and threshed manually by beating with sticks to extract seeds, which were further dried to reduce moisture content to 12% before storage.

Observations recorded: Collected samples were sun-dried for seven days, followed by hot air oven drying at 60°C until a constant weight was achieved, typically within 48 to 72 hours (Thiex, 2009). Then the amount of dry matter (%) was calculated.

Major growth parameters of oats, such as leaf area index (LAI), plant height, and total dry aerial biomass, were recorded at the time of harvest. Observations were taken from five randomly selected plants per plot to measure plant height (cm), LAI, and total dry aerial biomass (g m^{-2}) using the destructive sampling method. At 55 DAS, green forage yield was assessed using a spring balance, and dry matter yield was estimated by multiplying the recorded green forage yield by its corresponding dry matter content (%).

In oat, yield-related parameters such as panicle length, number of grains per panicle, panicle weight, test weight, and grain yield were assessed. For green gram, yield characteristics including pods per plant, seeds per pod, 100-seed weight, and final seed yield were recorded at harvest.

***Statistical analysis*:** The replicated means were subjected to ANOVA using MS Excel (2010). The critical difference (CD) at *P=0.05* was calculated to determine statistically significant differences among treatments. Pearson correlation analysis between parameters was conducted using the R-squared value (*software R version 3.5.1*).

Results and Discussion

Growth parameters of dual oats: Plant height and dry aerial biomass increased as the crop advanced toward maturity, regardless of the N management source (Table 2). Pooled over two years, plant height was highest under $_{T6}$ (152.6 cm) and was statistically at par with T_5 (143.4 cm), while both were significantly superior to all other treatments. The lowest plant height (112.1 cm) was recorded in the control (T_1). A similar trend was observed for leaf area index (LAI) and dry aerial biomass. LAI under T6 (3.93) was at par with T_5 (3.92) and significantly higher than the rest. Dry biomass under T_6 (25.5 q ha^{-1}) was also at par with T_5 (24.7 q ha^{-1}) and significantly superior to other treatments.

Many agricultural lands in India lack the essential nutrients required for the growth and development of crops. Among these, N is a critical nutrient for plant growth. It is commonly supplied through chemical fertilizers such as urea. However, the excessive use of chemical fertilizers poses risks to soil health, including reductions in microbial populations. In this context, biofertilizers like Azospirillum play a pivotal role in sustainable agriculture. Researchers in plant physiology, microbiology, and agronomy concur that plant growth

Table 2. Effect of nitrogen fertilization along with organics on growth attributes of dual-purpose oats

Treatments	Growth attributes								
	Plant height (cm) (115 DAS)			Leaf area andex (115 DAS)			Dry aerial biomass at harvest (q ha^{-1})		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_1	111	113	112	3.49	3.56	3.52	13.2	14.7	13.9
T_2	127	130	128	3.78	3.86	3.82	20.6	23.0	21.8
T_3	133	134	133	3.83	3.90	3.86	21.7	24.1	22.9
T_4	135	138	136	3.83	3.91	3.87	21.9	24.4	23.2
T_5	142	145	143	3.88	3.96	3.92	23.4	26.0	24.7
T_6	151	155	153	3.88	3.99	3.93	24.1	26.8	25.5
T_7	121	125	123	3.57	3.64	3.60	20.5	22.7	21.6
SEM	2.88	3.20	2.01	0.03	0.04	0.05	0.54	0.52	0.20
CD (P<0.05)	8.32	9.41	4.97	0.09	0.12	0.13	1.59	1.53	0.50

and development are highly dependent on biological fertility factors. On the other hand, earthworms enhance microbial activity and metabolism while biofertilizers influence plant metabolic activities such as photosynthesis. This interaction releases more nutrients and microbial metabolites into the soil, improving fertility.

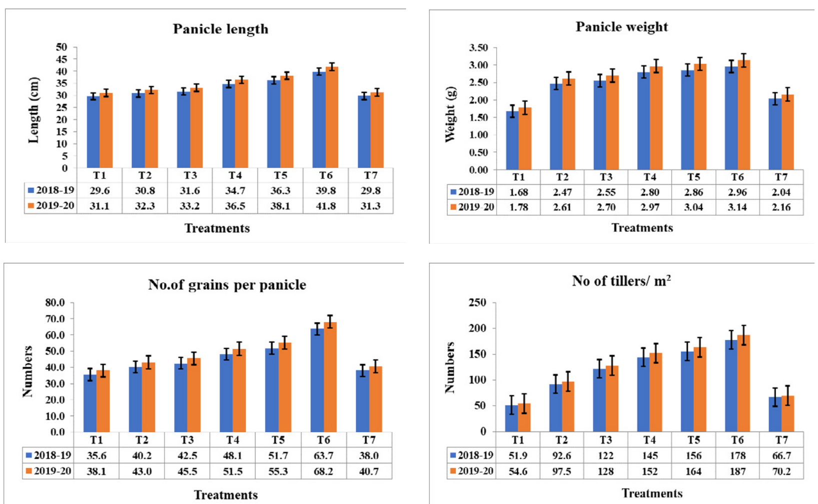
The application of N at different levels has been shown to increase the height of oat plants. This effect can be attributed to nitrogen's ability to promote internode elongation, thereby increasing plant height and the number of leaves. The increase in stem girth due to N application is likely because N enhances overall plant growth (Amin, 2011). The leaf area index (LAI), determined by leaf length and width, was also improved significantly with nitrogen application due to its influence on leaf elongation. Increased green forage yield at different N levels can be attributed to the beneficial influence of N on the key growth parameters. These results are consistent with the findings of Smith *et al.* (2020). Also, N promotes growth by enhancing cytokinin production, which affects cell wall elasticity (Bloom *et al.*, 2006), increases the number of meristematic cells, and promotes cell growth (Lawlor, 2002).

Yield attributes and yields of dual oats: Different N fertilization practices along with organics significantly influenced different yield attributes of oats (Fig 2). The T_6 resulted in the highest panicle length (40.8 cm), panicle weight (3.09 g), number of grains per panicle (65.9), and number of tillers per square meter (182.5), on the basis of pooled data of two years. These values were significantly higher (*P<0.05*) compared to other treatments in the experiment, except for panicle weight, which was statistically at par with treatments T_5 and T_4. The impact of different treatments on the grain and stover yield of dual oats along with the harvest index were also recorded (Table 3). The T_6 resulted in the highest grain yield (17.2 q ha^{-1}), stover yield (66.2 q ha^{-1}), and harvest index (20.0 %), on the basis of pooled data of two years. These values were significantly higher (*P<0.05*) compared to other treatments in the experiment.

Nitrogen plays a crucial role as a key component of the chlorophyll pigment. Nitrogen fertilization enhances chlorophyll content and leaf area, thereby maximizing light interception and the rate of photosynthesis. This, in turn, leads to increased biomass accumulation and higher yield (Azeez, 2009; Wortman *et al.*, 2011; Diacono *et al.*, 2013). Research by Patel *et al.* (2003) demonstrated that N levels significantly impacted the seed yield of oats. An increase in N application from 0 to 90 kg ha^{-1} resulted in a higher grain yield, although lodging occurred when nitrogen exceeded 90 kg ha^{-1} (Bhat *et al.*, 2000). Similarly, Rao and Patil (1979) found that a basal application of 80-90 kg N/ha was optimal for seed yield in oats. A multi-location study by Malik and Paynter (2010) highlighted the importance of adequate N and K levels to maximize the yield and quality of oat hay and grain. The maximum hay and grain yields were obtained with the combined application of 80 kg N ha^{-1} and 100 kg K ha^{-1}. Notably, higher rates of N or K did not adversely affect the quality of hay or grain. The beneficial role of K was particularly evident at higher levels, where it improved grain weight and reduced screenings. The results presented in Table 3 show that the application of vermicompost significantly increased the grain yield of oats. Each level of vermicompost application showed a notable improvement over the control. A higher vermicompost rate (5 t ha^{-1}) enhanced grain yield by 5.37 q ha^{-1} compared to 2.5 t ha^{-1}. The average increases in grain yield were 10.4% and 16.2% for 2.5 t ha^{-1} and 5.0 t ha^{-1}, respectively, relative to the control (Bahadur *et al.*, 2021). The beneficial effects of vermicompost are linked to its ability to provide essential nutrients, improve soil physical properties, and enhance biological activity in the soil.

Table 3. Effect of nitrogen fertilization along with bio-products on grain yield, stover yield and harvest index of dual-purpose oats

Treatments	Grain yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_1	6.67	7.33	7.00	37.0	39.6	38.3	15.1	15.7	15.4
T_2	11.2	12.3	11.8	57.8	61.8	59.8	16.6	16.6	16.6
T_3	12.0	13.3	12.7	61.1	63.4	62.2	16.6	17.3	16.7
T_4	12.8	14.1	13.4	61.6	64.7	63.1	17.2	17.9	17.4
T_5	13.5	15.7	14.6	62.6	66.9	64.7	17.7	19.0	18.4
T_6	17.0	17.5	17.2	63.9	68.4	66.2	21.0	19.1	20.0
T_7	10.7	11.8	11.2	56.7	60.6	58.6	15.8	16.2	16.0
SEM	1.30	0.96	0.74	0.85	1.36	1.23	0.28	0.34	0.32
CD (P<0.05)	3.84	2.82	2.08	2.50	4.00	3.05	0.80	0.95	0.91



*Error bars indicate standard error

Fig 2. Effect of nitrogen fertilization along with organics on different yield attributes of dual-purpose oat

Grain yield and yield attributes of residual green gram crop: Various yield attributes positively influenced the seed yield of green gram. The maximum seed yield was associated with the highest number of pods per plant (21.1) and seeds per pod (11.9). T_6 yielded the highest seed yield of 11.0 q ha^{-1} (Table 4). This was statistically comparable to that of T_5. In contrast, the lowest yield attributes and seed yield were recorded in the control (T_1). T_1 had the lowest number of pods per plant (13.6), seeds per pod (7.54), and seed yield (9.52 q ha^{-1}) (Table 4).

The yield response of cereals to the inclusion of summer green gram crop in the cropping sequence was more pronounced when lower levels of N fertilizer were applied. The combined application of 75% of the RDN with vermicompost, bio-fertilizers, and micronutrient (zinc) supplementation, might have exerted a positive residual effect on the yield, harvest index, and seed index of green gram. Principal component analysis (PCA) identified two principal components (PC_1 and PC_2), which collectively explained 97.49% of the total variance in the dataset. The PC_1 contributed 93.29%, while the PC_2 accounted for 4.20% of the variation, based on pooled data from two years (Fig 3).

A strong correlation was observed among various traits, including grain yield, plant height, leaf area index, green forage yield, dry matter yield, grain per panicle, and panicle weight. The values of the green forage yield, as well as the quality parameters of oat like crude protein content and crude protein yield can be found in the published paper by Mondal *et al*., (2024). The integration of seven nutrient management practices in the oat-green gram cropping sequence revealed that the combined application of 75% of the RDN with vermicompost, bio-fertilizers, and micronutrient (zinc) supplementation, *i.e.*, T_6, resulted in the highest values for the measured attributes. These practices showed significant correlations

Table 4. Pods per plant, seeds per pod and seed yield of residual mung bean as influenced by integration of nitrogen fertilization and bio-products during *pre-kharif* season (Pooled values of two years)

Treatments	Pods per plant	Seeds per pod	Seed yield (q ha^{-1})
T_1	13.6	7.54	9.52
T_2	17.3	9.93	9.86
T_3	17.9	10.7	10.1
T_4	18.6	10.7	10.3
T_5	19.3	11.5	10.9
T_6	21.1	11.9	11.0
T_7	16.8	8.57	9.66
SEM	0.88	0.44	0.13
CD (P<0.05)	2.20	1.09	0.32

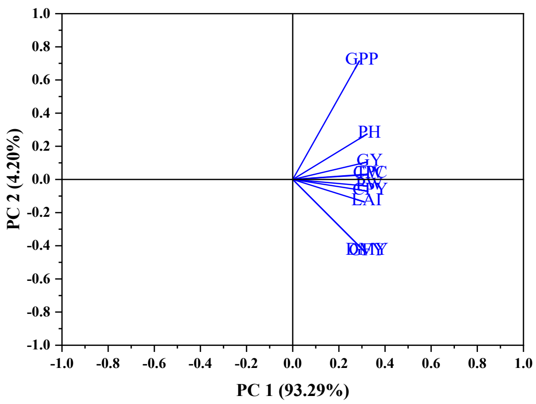


Fig 3. Biplot analysis of different important parameters of dual purpose oats [PH: Plant height; LAI: Leaf area index; GFY: Green forage yield; DMY: Dry matter yield; CPC: Crude protein content; CPY: Crude protein yield; GPP: Grain per panicle; PW: Panicle weight; TW: 1000-seed weight; GY: Grain yield]

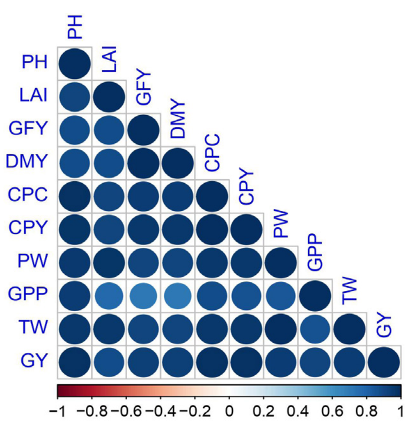


Fig 4. Correlation matrix among various plant growth and yield attributes, yield and quality parameters of dual purpose oats [PH: Plant height; LAI: Leaf area index; GFY: Green forage yield; DMY: Dry matter yield; CPC: Crude protein content; CPY: Crude protein yield; GPP: Grain per panicle; PW: Panicle weight; TW: 1000-seed weight; GY: Grain yield]

with the observed parameters. The next best treatment was T_5. As evident from the correlation matrix (Fig 4), significant positive correlations (*P<0.01*) were observed among several traits, including grain yield, green forage yield, plant height, leaf area index, dry matter yield, crude protein content, grains per panicle, and panicle weight, in the pooled analysis of two years.

Conclusion

The research experiment on oat-green gram cropping system for two consecutive years revealed superiority of T6 *viz.* 75% recommended doses of nitrogen with vermicompost, bio-fertilizers, and micronutrient (zinc) over the remaining treatments in all the aspects. This treatment excelled in terms of growth parameters, crop growth rate, green forage yield, grain yield from dual-purpose oats. Furthermore, it showed enhanced residual effect in growth parameters, crop growth rate, seed yield for the subsequent green gram in the dual-purpose oats-green gram cropping sequence during the *Rabi* and pre-*Kharif* seasons, respectively. Hence, this treatment is recommended for the new alluvial plains of West Bengal and the trial may afford site-specific integrated nutrient management modules to boost productivity, nutrient use efficacy and overall soil health in inceptisols as a sustainable model for cereal-legume cropping system.

References

Amin, M.E.M.H. 2011. Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). *Journal of the Saudi Society of Agricultural Sciences* 10(1): 17-23. https://doi.org/10.1016/j.jssas.2010.06.003.

Andersson, A.A.M. and G. Börjesdottir. 2011. Effects of environment and variety on oat lipid composition. *Journal of Cereal Science* 54(3): 299-305.

Arif, M., R. Pourouchottamane, A. Kumar, D.L. Gupta and B. Rai. 2023. Evaluation of different row proportions in intercropping of pearl millet and cluster bean for forage yield and quality. *Range Management and Agroforestry* 44(1): 126-133.

Azeez, J.O. 2009. Effects of nitrogen application and weed interference on performance of some tropical maize genotypes in Nigeria. *Pedosphere* 19(5): 654-662.

Bahadur, R., A.K. Pal, M. Pandey, A. Kumar, N. Nagar and V. Kumar. 2021. Effect of nitrogen and vermicompost on growth, yield and quality of oat (*Avena sativa* L.). *The Journal of Rural and Agricultural Research* 21(1): 84-88.

Bhat, M.D., K.N. Singh, A. Bali, M.H. Shah and A. Bali. 2000. Grain yield of oats (*Avena sativa*) as influenced by sowing time and nitrogen levels under temperate condition of Kashmir. *Indian Journal of Agronomy* 45(1): 199-204.

Biswas, S., K. Jana, R.K. Agrawal and A.M. Puste. 2020. Effect of integrated nutrient management on green forage, dry matter and crude protein yield of oat in oat–Lathyrus intercropping system. *Journal of Crop and Weed* 16(2): 233-238.

Bloom, A.J., J. Frensch and A.R. Taylor. 2006. Influence of inorganic nitrogen and pH on the elongation of maize seminal roots. *Annals of Botany* 97(5): 867-873.

Cui, L., Q. Jia, J. Zhao, D. Hou and S. Zhou. 2023. A comprehensive review on oat milk: From oat nutrients and phytochemicals to its processing technologies, product features, and potential applications. *Food and Function* 14(13): 5858-5869.

Dhaliwal, S.S., S.K. Dubey, D. Kumar, A.S. Toor, S.S. Walia, M.K. Randhawa, G. Kaur, S.K. Brar, P.A. Khambalkar and Y.S. Shivey. 2024. Enhanced organic carbon triggers transformations of macronutrients, micronutrients, and secondary plant nutrients and their dynamics in the soil under different cropping systems: A review. *Journal of Soil Science and Plant Nutrition* 24(3): 5272-5292.

Diacono, M., P. Rubino and F. Montemurro. 2013. Precision nitrogen management of wheat: a review. *Agronomy for Sustainable Development* 33(1): 219-241.

Gorai, M.S. and R. Mondal. 2023. Effect of date of sowing and level of phosphorus on growth and yield of summer mungbean (*Vigna radiata* L.) in red and lateritic soils of West Bengal. *Journal of Food Legumes* 36: 164-168.

Jha, A.K., P.S. Yadav, A. Shrivastava, A. Dubey and A. Jaiswal. 2024. Influence of tillage and nutrient management on fodder productivity and economics of oat in rice-oat cropping system. *International Journal of Research in Agronomy* 7(4): 607-614.

Jing, P. and X. Hu. 2012. Nutraceutical properties and health benefits of oats. In: Yu, L., R. Tsao and F. Shahidi (eds), *Cereals and Pulses: Nutraceutical Properties and Health Benefits.* John Wiley & Sons, Inc., USA. pp. 21-36.

Lawlor, D.W. 2002. Carbon and nitrogen assimilation in relation to yield: Mechanisms are the key to understanding production systems. *Journal of Experimental Botany* 53(370): 773-787.

Maity, S., R. Mondal and S. Goswami. 2025. Effect of root dipping with biofertilizer and foliar application of zinc on growth, yield and soil enzymatic activity in summer rice (*Oryza sativa* L.). *ORYZA- An International Journal of Rice* 62(2): 127-135.

Malik, R. and B. Paynter. 2010. Influence of N and K fertilization on yield and quality of oats hay and grain in Western Australia. In: *Proceedings of the 19th World Congress of Soil Science. pp.* 1-6.

Mondal, K., K. Jana, P. Saha, B. Paramanik, R. Mondal, R.K. Agrawal and A. Kundu. 2024. Effect of nitrogen fertilization integrated with bio-product on productivity, profitability, and resource use efficiency of dual-purpose oats–residual green gram system. *Journal of Plant Nutrition, pp.* 1-14. https://doi.org/10.1080/01904167.2024.2443112.

Patel, M.R., A.C. Sadhu, P.C. Patel and J.P. Yadavendra. 2003. Effect of cutting management and nitrogen levels on grain production of oats (*Avena sativa* L.). *Forage Research* 29(3): 107-109.

Raj, A. and B.S. Vyakaranahal. 2014. Seed production techniques and post-harvest quality management in oat (*Avena sativa* L.). *Indian Journal of Agronomy* 59(3): 389-394.

Rao, C.N. and B.D. Patil. 1979. Effect of nitrogen levels on yield of oats. *Forage Research* 5: 151-153.

Raza, M.H., G.U. Sadozai, M.S. Baloch, E.A. Khan, I. Din and K. Wasim. 2012. Effect of irrigation levels on growth and yield of green gram. *Pakistan Journal of Nutrition* 11(10): 974-977.

Redaelli, R., G. Scalfati, R. Ciccoritti, P. Cacciatori, E. De Stefanis and D. Sgrulletta. 2015. Effects of genetic and agronomic factors on grain composition in oats. *Cereal Research Communications* 43: 144-154.

Saha, A., S. Samanta, P. Dey, R. Halder and A.C. Sinha. 2023. Choice of varieties and organic–inorganic nutrient integrations in rainfed buckwheat can affect the performance of succeeding green gram grown on residual fertility. *Archives of Agronomy and Soil Science* 69(14): 3030-3043.

Smith, N.E., E.G. Tooley and B.R. Maricle. 2020. Inorganic fertilizer and salt tolerance in *Sorghum bicolor* (L.) Moench ssp. *bicolor. Journal of Plant Nutrition* 43(10): 1390-1399.

Sterna, V., S. Zute and L. Brunava. 2016. Oat grain composition and its nutrition benefits. *Agriculture and Agricultural Science Procedia* 8: 252-256.

Thiex, N. 2009. Evaluation of analytical methods for the determination of moisture, crude protein, crude fat, and crude fiber in distillers dried grains with solubles. *Journal of AOAC International* 92(1): 61-73.

Wortman, S.E., A.S. Davis, B.J. Schutte and J.L. Lindquist. 2011. Integrating management of soil nitrogen and weeds. *Weed Science* 59: 162-170.