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Influence of tillage and nutrient management on fodder productivity and economics of Oat in rice-oat cropping system

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Abstract
The research took place over three consecutive rabi seasons from 2011 to 2014 at the AICRP on Forage Crops, Department of Agronomy, College of Agriculture, Jabalpur (MP). The soil at the experimental site is sandy clay loam with medium organic carbon content (0.61%). It has moderate levels of available nitrogen (365.20 kg N/ha) and phosphorus (17.97 kg P_2O_5/ha), but high levels of available potassium (308.12 kg K_2O/ha). The soil's pH is close to neutral (7.24), and its soluble salt concentration (0.35 ds/m) is within safe limits. The experiment followed a split-plot design with three replications. The main plots were assigned three tillage methods: zero tillage, minimal tillage, and conventional tillage. The sub-plots received four levels of nutrient management: 75% recommended dose of fertilizer (RDF), 75% RDF with bio-fertilizers (Azotobacter and PSB), 100% RDF, and 100% RDF with a combination of bio-fertilizers. Higher yields of green fodder were observed with minimal tillage, followed by conventional tillage. The lowest yield was recorded with zero tillage (6.14 t/ha). Maximum green fodder yield was achieved with the application of 100% RDF along with bio-fertilizers, which was statistically similar to the application of 100% RDF alone. The lowest yield was recorded with 75% RDF under conventional tillage.

Keywords: Crud protein yield, economics, green fodder yield, nutrient uptake and oat

Introduction
Oats have been cultivated for centuries across various regions worldwide, particularly in European countries. In India, oats are extensively grown as a cereal fodder during the winter season, particularly in the North, Central, and Western regions. It is favored for its lush growth, good palatability, high nutritional content and richness in soluble carbohydrates, making it a popular choice among all animals. Currently, India faces a 35.6% deficit in green fodder (IGFRI, 2011) [17], highlighting the need for increased attention to enhance fodder production and quality, especially for significant crops like oats. Oats can provide green fodder within 60-70 days during emergencies and yield a larger quantity after 90-100 days. Typically, green fodder contains 10-12% protein and 30-35% dry matter. Oat crops are generally cultivated in marginal lands with minimal fertilizer application, resulting in low production (Gangwar *et al*., 2011; Jha *et al*., 2023; Kantwa *et al*., 2019; Yadav *et al*., 2023a; Patel *et al*., 2023a; Bhayal *et al*., 2022b) [14, 33, 38, 95, 52, 6]. Integrating organic and synthetic nutrient sources not only provides essential nutrients but also enhances nutrient use efficiency, reducing environmental impacts Organic manure application helps recycle nutrients, reduce fertilizer costs, and improve soil nutrient availability, with potential positive residual effects on subsequent crops (Iqbal *et al*., 2014; Anjum *et al*., 2022; Patel *et al*., 2023b; Tomar *et al*., 2023a and b; Tanisha *et al*., 2023; Tiwari *et al*., 2011a) [18, 2, 80-81, 75, 79}. Fodder oats require ample fertilizers for succulent and high-quality herbage production (Kumar *et al*., 2015; Kumhar *et al*., 2021) [40, 47]. Balanced nutrient supply ensures efficient utilization of all nutrients. While inorganic fertilizers supply major plant nutrients, excessive use can lead to water pollution and soil degradation. Thus, there is a growing emphasis on bio-fertilizers like Azotobacter and phosphorus-solubilizing bacteria, which improve soil nitrogen and phosphorus status. Among various bio-fertilizers, phosphate-solubilizing bacteria (PSB) and Azotobacter can be applied with lower nutrient levels as an

alternative source to meet the high nutrient requirements of multi-cut forage oats. Tillage also significantly influences crop productivity (Jha *et al*., 2011; Dwivedi *et al*., 2012; Rai *et al*., 2019; Yadav *et al*., 2023b; Sahu *et al*., 2022; Raghuvanshi *et al*., 2023a; Tiwari *et al*., 2011b; Sanodiya *et al*., 2013; Jha *et al*., 2015; Sairam *et al*., 2023a; Verma *et al*., 2023a; Shri *et al*., 2014) [35, 13, 58, 94, 63, 77, 67, 28, 31, 65, 69]. Resource-conserving technologies (RCTs) such as reduced tillage (RT), no-till (NT), integrated nutrient management (INM), micronutrient use and residue retention have been validated in rice-wheat and maize-wheat cropping systems under irrigated conditions in the Indo-Gangetic Plains (Porwal *et al*., 2023; Khare *et al*., 2018; Chauhan *et al*., 2017; Singh *et al*., 2013a; Tomar *et al*., 2023b; Shrivasva *et al*., 2014; Gautam *et al*., 2018; Jha *et al*., 2014, 2016; Sahu *et al*., 2023) [53, 39, 8, 71, 81, 70, 15, 21, 24, 26, 22, 29, 60, 64]. However, research on the impact of RCTs on the productivity and sustainability of the rice-oat system in central India is lacking. Thus, this study aims to evaluate the impact of tillage and nutrient management on fodder productivity and economics in the rice-oat cropping system.

Materials and Methods

The research was conducted over three *rabi* seasons of 2011-12, 2012-13 and 2013-2014 at the AICRP on Forage Crops, Department of Agronomy, College of Agriculture, Jabalpur (MP). The experimental site had sandy clay loam soil with moderate levels of organic carbon (0.61%), available nitrogen (365.20 kg N/ha), and phosphorus (17.97 kg P_2O_5/ha), but high levels of available potassium (308.12 kg K_2O/ha). The soil pH was nearly neutral (7.24), and soluble salt concentration (0.35 ds/m) was within safe limits. Treatments followed a split-plot design with three replications. The main plots involved three tillage methods: zero, minimal, and conventional tillage, while the sub-plots received four nutrient management levels: 75% RDF, 75% RDF with bio-fertilizers (Azotobacter and PSB), 100% RDF, and 100% RDF with bio-fertilizers. Fodder oat cultivar JO 1 was sown in mid-November with a row-to-row distance of 25 cm and a seed rate of 80 kg/ha in a 5 m X 4 m plot area on medium land. Fertilizers were applied at sowing using urea, DAP, and MOP. Bio-fertilizers were applied as seed inoculants with additional urea top dressing. After oat harvest, paddy was transplanted during the kharif season using the same tillage levels and a uniform fertilizer dose of 120:60:40 NPK kg/ha, following standard agronomic practices. Seed treatments of Azotobacter and PSB were used. Various growth parameters and fodder yields were measured, along with chemical analysis of N, P, and K content and uptake by the oat plants. Statistical analysis was performed on the data collected.

Results

Growth parameters

Various growth parameters of oats, such as plant height, tiller density, and leaf-to-stem ratio, were monitored during each cutting to assess crop development. Both minimum tillage and conventional tillage resulted in taller plants, higher tiller counts, and greater leaf-to-stem ratios compared to zero tillage (Jha *et al*., 2007; Tiwari *et al*., 2013; Singh *et al*., 2013b; Jain *et al*., 2012; and Sinodia *et al*., 2014) [36, 78, 72, 19, 13]. The application of organic and inorganic nutrients together increased oat plant height compared to using only recommended doses of fertilizer, with the tallest plants observed in plots treated with a combination of 100% recommended fertilizer dose (RDF) and bio-fertilizer, similar to those treated with 100% RDF alone. The enhanced plant height and leaf count in bio-fertilizer treated plots may be due to rapid mineralization, with a significant nitrogen portion being in organic forms (Pandey *et al*., 2020) [51]. Additionally, bio-fertilizers stimulate the population of beneficial microorganisms like nitrogen-fixers and phosphorus-solubilizers, thereby boosting nitrogenase activity. The application of 100% RDF with bio-fertilizer produced the highest number of tillers, followed by 100% RDF and 75% RDF with bio-fertilizer, compared to using only 75% RDF. These findings contradict previous studies by Yadav *et al*. (2023c) [93], Verma *et al*. (2016a) [83], Gautam *et al*. (2021) [16}, Jayanthi *et al*. (2002) [20] and Jha *et al*. (2018) [25, 32] reporting that both organic and inorganic fertilizers increased tiller numbers in oats. Similarly, a leaf-to-stem ratio of 0.14 was observed under the treatment of 100% RDF with bio-fertilizer (Toppo *et al*., 2023; Verma *et al*., 2023c; Pahade *et al*., 2023; Soni *et al*., 2012; and Verma *et al*., 2016b) [82, 93, 50, 74, 91].

Nutrient Content and Uptake

The nutrient composition of forage oats was assessed at each cutting throughout the study period, and the data were aggregated for further analysis. The residual effect of rice did not significantly influence the primary and secondary nutrient contents of the fodder oats at both cutting stages. However, both tillage and nutrient management practices exerted significant effects on the nutrients, particularly N, P, and K, with minimal impact from tillage but notable effects from nutrient management. N, P, and K contents in forage oats under minimal and conventional tillage were higher as compared to zero tillage during both cutting stages, attributed to a higher mineralization rate enhancing nutrient availability and uptake. Małecka and Blecharczyk (2008) [48] found lower nitrogen intake in grain in zero tillage. Nitrogen content in oats during the second cutting was consistently lower than during the first, regardless of nutrient management and tillage, possibly because of efficient root development and increased nitrogen uptake, leading to a maximum leafy portion up to the first cut in conventional tillage (Jha *et al*., 2008) [30]. The decline in N content with the age of the cropwas due to dilution with increased structural carbohydrate content, particularly fiber, in aging crops. Additionally, nutrient uptake was affected by tillage management, with maximum uptake in conventional tillage, fb zero tillage and minimal tillage. Conversely, nutrient management significantly affected nutrient content in forage oats at both cutting stages up to 125% recommended dose of fertilizer (RDF). Moreover, N, P, and K content at 100% RDF were comparable to those at 75% RDF with bio-fertilizer. The interaction between tillage and nutrient management did not significantly affect forage oats' nutrient content. Nutrient uptake by oats, influenced by its content and dry fodder yield, was highest under conventional tillage. Several studies, including Bhayal *et al*. (2022a) [5], Jha *et al*. (2015) [28, 31], Kumar *et al*. (2022) [42], reported a continuous decrease in nitrogen content in plants with crop age but significant increases with higher levels of nitrogen at all stages, mainly because of increased nitrogen absorption, higher leaf area index (LAI), and a higher leaf-to-stem ratio.

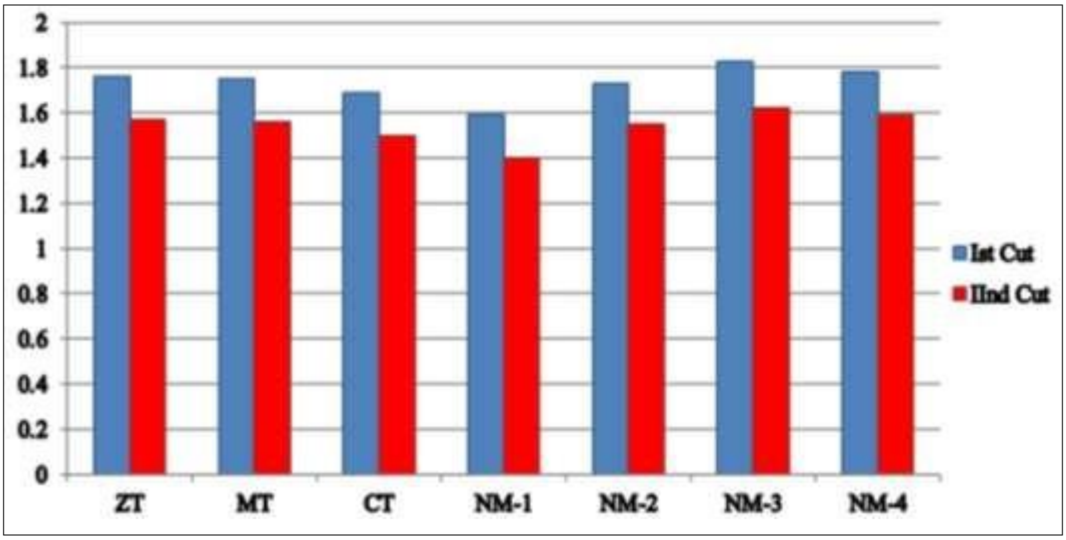

Fig 1: Nitrogen content as influenced by tillage and nutrient management

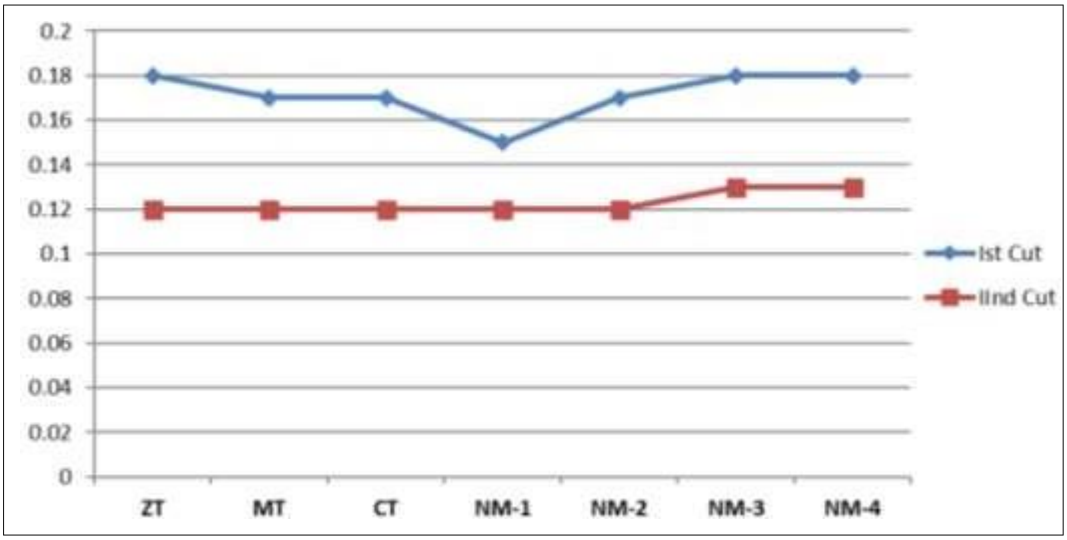

Fig 2: Phosphorus content as influenced by tillage and nutrient management

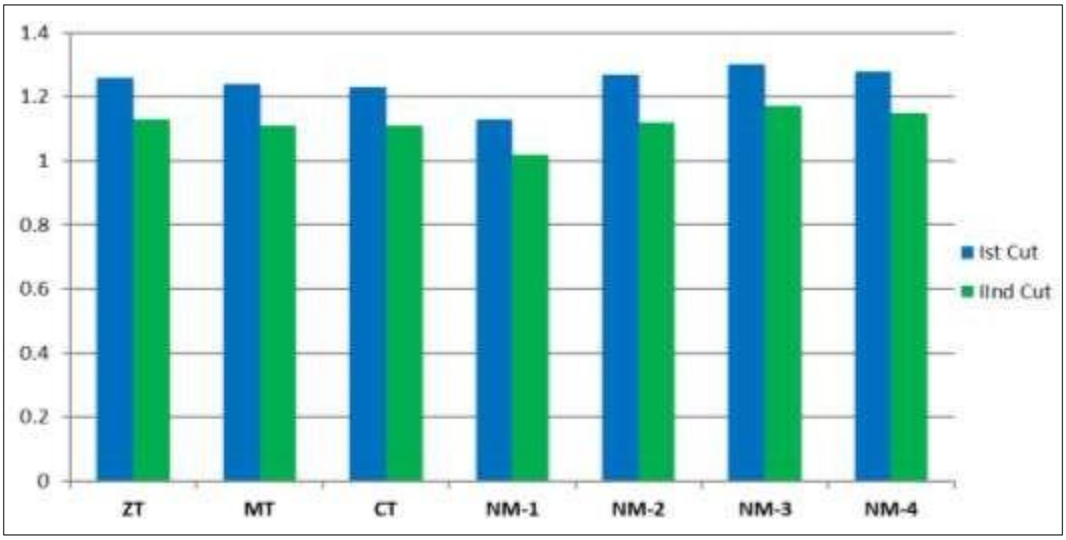

Fig 3: Potassium content as influenced by tillage and nutrient management

Quality Parameters

When comparing crude protein and crude fiber between conventional and zero tillage methods, they exhibited similar levels. However, minimal tillage resulted in increased crude protein (10.26% at the first cut) and crude fiber (27.98% and 29.56% at both cuts, respectively). Crude fat under zero tillage was significantly higher compared to both conventional and minimal tillage, with no notable difference between the latter two methods (Chauhan *et al*., 2018; Kumbhare *et al*., 2023; Sahu *et al*., 2020a; Bhalse *et al*., 2023) [9, 61, 45, 4]. Similar findings were reported by various studies (Deva *et al*. 2014; Jha *et al*. 2015; Jha *et al*. 2008; Dubey *et al*. 2010) [11, 28, 31, 30, 12], indicating that after the first cut, the root system started functioning faster for re-growth, absorbing higher nutrients, resulting in more DMP, more fiber content, and decreased protein content. Increasing RDF levels significantly increased crude protein & fiber. Higher crude protein at increased nitrogen levels was attributed to increased nitrogen availability and uptake by the crop, as reported in various studies (Tiwana *et al*. 2008; Shau *et al*. 2020b) [76, 62]. This trend was consistent with findings (Malviya *et al*. 2012; Kumar *et al*. 2023) [49, 41, 43, 44], indicating that plant tissue N content lowered with the crop age but increased significantly with higher nutrient levels. These results were supported by studies (Kumhar 2022) [46], reporting that higher nitrogen absorption through plants increased plant meristematic activities.

Green Fodder and Dry Matter Yield

A significantly higher yield of green fodder was observed with minimal tillage, followed by conventional tillage, while the lowest yield was recorded with zero tillage (6.14 t/ha). Green fodder yield is enhanced with increasing fertilizer doses, with or without bio-fertilizers. Among different nutrient management, a higher green fodder yield was achieved with the application of 100% recommended fertilizer dose (RDF) along with bio-fertilizers, which was statistically at parwith the yield obtained with 100% RDF alone. The minimum green fodder yield was recorded with 75% RDF. Conventional tillage improves soil properties and enhances nutrient availability, resulting in increased fodder yield (Jha *et al*., 2007) [36]. The oat green fodder yield crops was significantly influenced by fertilization, particularly nitrogen, with or without bio-fertilizers, showing a linear response from 75% RDF to 100% RDF with bio-fertilizers. Increasing fertilizer doses positively influenced yield attributes, likely due to increased plant height, population, tiller count, and dry matter, along with the supply of 100% nitrogen through chemical fertilizers and bio-fertilizers (Biswas *et al*., 2020; Ranjan *et al*., 2016; Jha *et al*., 2018; Jha *et al*., 2016; Sairam *et al*., 2023b; Sinodiya *et al*., 2014) [7, 59, 25, 32, 22, 29, 66, 13]. Azotobacter may stimulate plant growth by producing biologically active compounds like gibberellins and vitamins. Higher nitrogen doses may elevate nitrogen concentration in plants and consequently crude protein content. Increased protein yield due to applied nitrogen levels may be attributed to the conversion of observed nitrate (NO3) to ammonia (NH3), which is then transformed into amino acids. Proteins are formed by merging amino acids and releasing water molecules. Similar findings have been reported by Anjum *et al*. (2022) [2], Sharma *et al*. (2004) [68], Chauhan *et al*. (2013) [10], and Raghav *et al*. (2023) [55].

Economics

The highest B:C ratio was recorded in plots treated with minimal tillage, likely due to the increased fodder yield associated with this method. However, the B:C ratio reached its peak in zero tillage, primarily due to the lower initial investment costs in sowing compared to conventional tillage. Regarding nutrient management, plots treated with 100% recommended fertilizer dose (RDF) along with bio-fertilizers demonstrated the maximum NMR and B:C ratio, possibly due to the higher fodder yield obtained from this treatment. Among the interaction effects, zero tillage combined with 75% RDF along with bio-fertilizers showed the highest B:C ratio. Minimal tillage with 75% RDF along with bio-fertilizers proved to be economically viable. These findings align with previous studies by Verma and Dadheech (2005) [92], Patel *et al*. (2023) [52], and Agrawal *et al*. (2010) [1].

Table 1: Influence of till age management and nutrient management on nutrient up take (pooled)

Treatments	Nutrient uptake (kg/ha)					
	N		K		P	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
Tillage Management (T)						
Zero tillage	123.41	115.50	17.53	17.66	88.35	83.13
Minimal tillage	125.03	116.84	20.72	17.97	88.59	83.13
Conventional tillage	120.29	111.95	19.22	14.18	87.55	82.84
CDat 5%	0.95	0.85	0.89	1.21	1.41	1.56
Nutrient Management (NM)						
75% RDF	107.41	99.41	11.48	13.49	86.47	81.66
75% RDF + Biofertilizer	123.25	115.77	12.82	14.19	89.76	84.40
100% RDF	129.67	121.32	20.40	16.02	90.33	84.69
100% RDF + Biofertilizer	131.80	122.26	20.17	15.85	89.30	83.77
CD at 5%	2.56	2.32	3.11	2.36	3.25	3.54

Table 2: Influence of tillage management and nutrient management on quality parameters (Pooled)

Treatments	Crude protein (%)		Crude fat (%)		Crude fiber (%)	
	1st cut	2nd cut	1st cut	2 nd cut	1st cut	2nd cut
Tillage Management(T)						
Zero tillage	9.23	8.92	0.45	0.46	25.54	27.12
Minimal tillage	9.13	8.98	0.34	0.36	26.91	25.49
Conventional tillage	9.12	8.88	0.35	0.36	27.42	29.14
CD at 5%	0.49	0.41	0.52	0.52	1.36	1.36
Nutrient Management(N)						
75% RDF	8.98	8.54	0.4	0.41	25.24	26.81
75% RDF + Biofertilizer	9.52	8.88	0.38	0.4	25.75	26.33
100% RDF	9.53	9.23	0.38	0.39	25.44	27.01
100% RDF + Biofertilizer	9.78	9.31	0.36	0.38	26.08	27.65
CD at 5%	0.41	0.18	0.54	0.54	0.41	0.41

Table 3: Influence of different treatments on growth, yield attributes, green fodder yield, and economics

Treatments	Plant height (cm)	Number of tillers/m^2			Leaf Area Index		Crude protein yield (t ha^{-1})	Leaf: stem ratio	Dry matter yield (t/ha)	Green fodder yield (t/ha)	NMRs (Rs/ha)	B:C ratio
	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS						
Tillage practices (T)												
Zero tillage	133.1	158.00	332.10	346.20	3.24	4.44	0.12	0.80	1.40	6.14	80897	3.05
Minimum tillage	143.3	182.80	365.90	380.40	3.56	4.95	0.13	0.86	1.44	6.70	81302	2.94
Conventional tillage	138.6	161.40	345.67	371.89	3.42	4.64	0.13	0.82	1.43	6.25	77751	2.83
CD at 5%	1.1	2.96	3.60	4.76	0.28	0.38	0.005	NS	0.09	0.10	-	-
Nutrient management (NM)												
M_1 – 75% Recommended Dose of NPK (RDF)	125.0	157.20	310.60	316.60	3.00	3.08	0.11	0.78	1.35	5.83	78490	2.96
M_2 – 75% RDF + Biofertilizers (*Azotobacter* + PSB)	132.6	174.60	379.30	384.30	3.12	3.80	0.13	0.83	1.42	6.14	80625	2.98
M_{3-} 100% RDF	137.5	189.40	416.54	432.50	3.48	4.83	0.13	0.84	1.44	6.21	80525	2.92
M_4 – 100% RDF +Biofertilizers (*Azotobacter* + PSB)	142.2	199.80	434.10	444.80	3.72	6.45	0.14	0.86	1.45	6.35	80293	2.90
CD at 5%	1.6	3.1	3.60	4.58	0.24	0.34	0.003	0.11	0.11	0.12	-	-

Conclusion

The research findings indicated that employing minimal tillage alongside nitrogen application at 100% recommended dose of fertilizer (RDF) + biofertilizer resulted in notable enhancements in growth, yield, quality, and profitability of fodder oat in comparison to alternative methods.

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