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Performance of oat under different cutting scheduling and integrated nutrient management in Eastern Himalayan agroclimatic conditions of India

R. Joseph Koireng[1]✉, Kholu Mary[2], Jeti Konsam[3], T. M. Chanu[4], Konjengbam Maheshwari[5], Abhinash Moirangthem[6], Punabati Heisnam[2], Sumitra Phurailatpam[7], Gayatri Khangjarakpam[7] & Khumukcham Stina[7]

Oat is versatile and highly nutritious crop and it can be effectively utilized as dual-purpose for fodder and seed production. Generally, farmers are growing oat in very limited and poor in quality in Manipur state of India. Growing fodder oat with correct nutrient management results in increased productivity as well as quality fodder production of oat. Therefore productivity of livestock in study area can be increased with full amount of fodder supplied to livestock. A two-year study was conducted to examine the effect of different cutting management and nutrient management on performance of fodder oat and economics of the system using factorial randomized block design (FRBD). The results revealed that among the different cutting scheduling, three cuts at 60, 90 and 120 days after sowing gave significantly higher green fodder production. However, the maximum gross return, net return, benefit: cost (BCR) and crude protein (CP) percentage was observed under single cut at 60 days after sowing (DAS) + seed. Among the different level of nutrient management, 50% NPK of RDF + 7.5 t FYM ha^{-1} significantly increased the green fodder yield, dry matter production, seed yield, crude protein content and economics of oat in Eastern Himalayan region of India The study inference that combination of cutting scheduling of fodder at 60 DAS with the application of 50% NPK of RDF + 7.5 t FYM ha^{-1} can be recommended for higher productivity of quality fodder of dual purpose of oat in Eastern Himalayan region of Manipur state of India.

Keywords Cutting scheduling, Fodder oat, FYM, Nutrient management

Oat (*Avena sativa* L.) is one of the most important *rabi* fodder crops grown in temperate and subtropical regions of worldwide during winter season. In India, oat cultivated during winter (*rabi*) season has advantage that dry matter content increased, 7–10 % protein content increased, disease tolerance and sustainability for silage production[1]. Oat has great advantages on multiple cuttings as compared to other fodder species because of its high yield potential, nutrition and high regeneration capacity, particularly during early winter months[2]. Cutting management is one of the key elements affecting the development, productivity, and quality of fodder crops. Multi-cut crops required more nutrients as compared to single cut, which directly influences the nitrogen content, protein content and other quality parameters of the oat. The high yielding potential and multicut ability with high nutritional value containing high fat, protein, Vitamin B1, phosphorus and Iron has proven oat to

[1]All India Coordinated Research Project on Forage Crops and Utilization, Department of Agronomy, College of Agriculture, Central Agricultural University, Imphal, Manipur 795004, India. [2]Department of Agronomy, Collegeof Agriculture, Central Agricultural University, Imphal, Manipur 795004, India. [3]All India Coordinated Research Project on Maize, Department of Entomology, College of Agriculture, Central Agricultural University, Imphal, Manipur 795004, India. [4]Directorate of Extension Education, Central Agricultural University, Imphal, Manipur 795004, India. [5]Department of Basic Sciences and Humanities, College of Agriculture, Central Agricultural University, Imphal, Manipur 795004, India. [6]Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal, Manipur 795004, India. [7]MTTC & VTC, College of Agriculture, Central Agricultural University, Imphal, Manipur 795004, India. ✉email: josephkoireng1980@gmail.com

be one of the productive and appropriate fodder crops for feeding the animal[3]. Mostly oats is grown for green fodder, straw, hay and silage. It provides succulent and highly palatable green fodder in two or three cuttings extending from December to February months. Fodder oat is a heavy nutrient feeder crop, hence productivity and quality of the fodder oat depends on several factors like fertilization and cutting management[4]. Farmers usually practice higher doses of inorganic fertilizers in order to meet the demands but it is uneconomical for fodder production. The integration of organic sources and synthetic sources of nutrients not only supplies essential nutrients but also has some positive interaction with chemical fertilizers to increase their efficiency and thereby reduce environmental hazards. A judicious combination of chemical fertilizers and organic manures has vital importance in order to achieve an optimum and economic yield of fodder oat and maintain soil fertility status. Therefore, considering the above facts in view, the experiment was conducted with an objective to evaluate the impact of cutting scheduling and integrated nutrient management to get maximum dry matter production and worked out optimum doses of organic and inorganic fertilizer in fodder oat in Eastern Himalayan region of Manipur in India.

Materials and methods

The field experiment was conducted at Central Agricultural University, Imphal during *rabi* seasons of 2019–20 and 2020–21. The farm site is located at about latitude of 24°0.4589``N and longitude of 94°0.0346``E with an altitude of 875 m above mean sea level. The experiment was laid out in factorial randomized block design (FRBD) with three replications and twelve combinations. The treatments consisted of three levels of different day of cutting management [C1 = no cutting (seed), C2 = single cut (60 DAS) + seed), C3 = Three cuts (60, 90 and 120 DAS)] and four levels of integrated nutrient management [N1 = RDF (N, P_2O_5 and K_2O @ 80: 40:40 kg ha^{-1}), N2 = 75% NPK of RDF + 5 t FYM ha^{-1}, N3 = 50% NPK of RDF + 7.5 t FYM ha^{-1}, N4 = 25% NPK of RDF + 10 t FYM ha^{-1}]. The full doses of phosphorus and potassium were applied as basal. While the nitrogen was applied in split doses (40% as basal, 20% at 30 DAS, 20% at 60 DAS and 20% at 90 DAS) because it is highly soluble in water and it does not meet to plant at the growth stages. The oat variety 'JHO-822' was sown at 25 cm row spacing @ 100 kg ha^{-1}. Cuttings of green fodder was taken at 10 cm above the ground level from net plot, then weighed and converted into quintal ha^{-1} to obtain green fodder yield. After harvesting green fodder, the crop was left for seed purposes in single cut (60 DAS) + seed production. Simultaneously, a random sample of 500 g was taken from each net plot, chopped well and first dried in sun and then oven dried at 70 °C till constant weight. On the basis of these samples, the green fodder yields were converted into dry fodder yields and were converted as q ha^{-1}.

Five plants from each net plot were selected and tagged to observe the plat height and leaf: stem ratio. At the time of each cutting, plant height was measured with the help of meter scale from the ground level to tip of the plant. The leaves and stem portions were separated and kept in an open area for few days and dried again in an oven at 70 °C till a constant weight was recorded. Crude protein content of fodder oat was estimated by multiplying the nitrogen content (%) of produce in each plot with a factor 6.25[5]. Crude protein yield (q ha^{-1}) was calculated by multiplying the crude protein content (%) with the dry matter yield obtained in each respective treatment and converted into q ha^{-1}. The gross return was calculated by considering the price of market value of fodder oat and the net return was estimated by subtracting the cost of cultivation from the gross return of the respective treatment and expressed as Rs. ha^{-1}. The benefit: cost ratio for each treatment was calculated by dividing the gross return by the cost of cultivation of the corresponding treatments. The statistical analysis was done by using Fischer's method of analysis of variance (ANOVA) and interpreted as out lined by Gomez and Gomez[6].

Results and discussion

Effect of cutting scheduling and INM on growth parameters

The two years pooled data (Table 1) revealed that plant height and leaf-stem ratio were influenced significantly by cutting scheduling during winter seasons (*rabi*). The plant height was found to be significantly highest (106.0 cm) where no cutting was taken and left the crop for seed production as compared to single cut at 60 DAS (days after sowing) and three cuts at the interval of 60, 90 and 120 DAS (Fig. 1). The findings were aligned with[7], who noted that decreased in plant height from single cut or more than single cutting scheduling which can be attributed to the interruption of growth of multi-cut fodder oat crop. The regeneration of oat crop took more time to reach previous heights due to decreased in growth period. While, the leaf stem ratio (L: S ratio) of the fodder oat was found to be significantly highest (0.70) under the treatment where three cutting were taken at the intervals of 60, 90, and 120 DAS (Fig. 2). The results were consistent with the findings of[8].

The plant height of oat was increased consistently with balanced use of nutrients but it does not show any tangible different among the treatments on the basis of two years pooled data (Table 1). However, maximum highest plant height (94 cm) was measured with 75% NPK + 5 t FYM ha^{-1} was applied. Similarly, the leaf: stem ratio did not exhibit any significant differences across the integrated nutrient management in oat crop. Similar, results were reported[8,9].

The combined effect of integrated nutrient management and cuttings scheduling showed a significant effect on the plant height under no cutting over to single cut three cuttings with different levels of nutrient management. However, maximum plant height was recorded when no cutting was taken and treated with N3 (103.46 cm). The interaction effect of cutting scheduling and integrated nutrient management in fodder oat on leaf stem ratio was not reflected positive. However, the highest leaf stem ratio (0.78) was recorded when three cuts were taken at an interval of 60, 90 and 120 DAS in combination with N_1 (RDF - N, P_2O_5 & K_2O @ 80: 40:40 kg ha^{-1}).

Treatment	Plant height (cm)			Leaf stem ratio			Green fodder yield (q ha^{-1})			Dry matter yield (q ha^{-1})			Seed yield (q ha^{-1})		
	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled
Cutting Scheduling															
C1	100.9	111.2	106.0	–	–	–	–	–	–	–	–	–	21.4	21.7	21.6
C2	76.2	89.3	82.8	0.23	0.53	0.38	218.0	224.8	221.4	29.4	37.5	33.4	20.2	20.1	20.1
C3	83.2	86.9	85.0	0.78	0.62	0.70	519.5	533.6	526.5	85.5	99.0	92.3	–	–	–
SEm±	2.21	1.32	1.77	0.03	0.02	0.025	9.58	5.36	7.47	2.09	1.49	1.79	0.97	0.53	0.75
CD at 5%	6.48	3.88	5.18	0.09	0.07	0.08	29.1	16.26	22.65	6.34	4.51	5.43	NS	1.61	1.61
Integrated Nutrient Management (INM)															
N1	83.9	96.9	90.4	0.55	0.56	0.555	342.9	355.9	349.4	55.4	65.2	60.3	19.2	19.6	19.4
N2	92.4	95.6	94.0	0.48	0.52	0.50	345.3	370.2	357.8	52.9	67.4	60.1	21.3	20.8	21.0
N3	85.9	92.6	89.2	0.52	0.60	0.56	404.6	409.1	406.8	62.0	71.8	66.9	23.8	23.3	23.5
N4	84.8	98.0	91.4	0.48	0.63	0.56	382.1	381.8	381.9	59.4	68.6	64.0	19.1	19.9	19.5
SEm±	1.91	1.14	1.53	0.02	0.02	0.02	6.77	3.79	1.95	1.48	1.05	1.27	0.68	0.38	0.53
CD at 5%	5.62	3.36	NS	NS	0.05	0.05	20.54	11.5	5.93	4.48	3.19	3.84	2.07	1.14	1.61
Interaction between cutting scheduling and integrated nutrient management															
SEm±	3.83	2.29	1.99	0.04	0.03	0.02	13.54	7.58	3.91	2.96	2.1	2.53	1.37	0.75	1.06
CD at 5%	11.61	6.94	6.04	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 1. Effect of cutting scheduling and integrated nutrient management on plant height, leaf stem ratio and yield of fodder oat. Y1 = 2019–20, Y2 = 2020–21, C1- No cutting (Seed), C2- Single cut (60 DAS) + Seed, C3- Three cuts (60, 90 & 120 DAS), N1- RDF (N, P_2O_5 & K_2O @ 80:40:40), N2-75% NPK of RDF + 5 t FYM ha^{-1}, N3-50% NPK of RDF + 7.5 t FYM ha^{-1}, N4-25% NPK of RDF + 10 t FYM ha^{-1}.

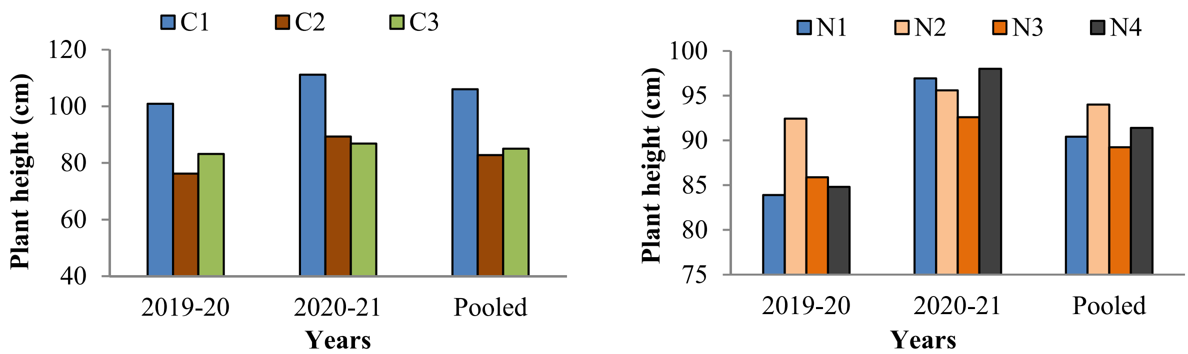

Fig. 1. Effect of cutting scheduling and integrated nutrient management on plant height.

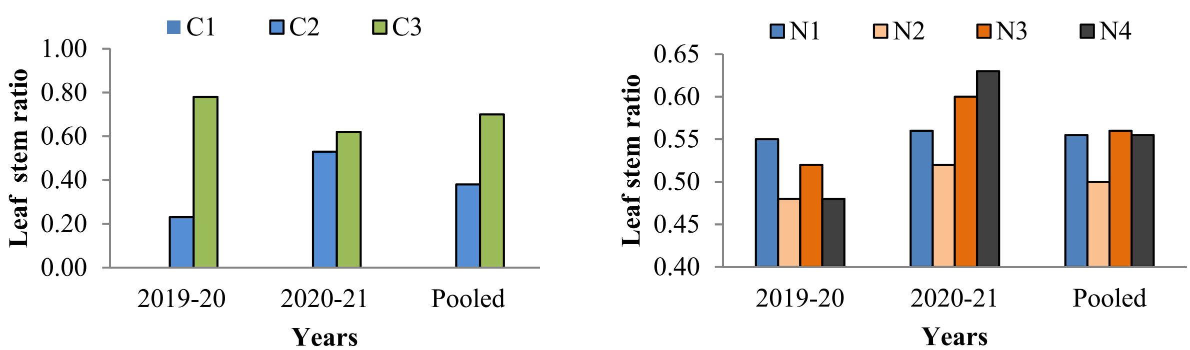

Fig. 2. Effect of cutting scheduling and integrated nutrient management on leaf stem ratio.

Effect of cutting scheduling and integrated nutrient management on yield

The data showed in Table 1 and Fig. 3 revealed that green fodder, dry matter production and seed yield of oat were remarkably influenced by different cutting schedules and different nutrient management. The two years pooled data on green fodder yield of oat was highest in the treatment where three cuttings were taken (526.5 q ha^{-1}) at 60, 90 and 120 DAS. Similarly, three cuts at 60, 90 and 120 DAS recorded significantly highest dry matter yield (92.3 q ha^{-1}) as compared to where single cut was taken at 60 DAS (33.4 q ha^{-1}). The regeneration capacity of the oat after each cutting may explain the higher green fodder production and dry matter yield was observed. Similar findings were also reported by[8,10,11]. However, among the cutting scheduling, significant highest seed yield was recorded in no cut treatment (21.6 q ha^{-1}). The results are in line with the findings of[12–14].

The response of fodder oat crop to different nutrient management revealed that combined application of manure (FYM) and chemical fertilizers *i.e.* 50% NPK of RDF + 7.5 t FYM ha^{-1} significantly increased the green fodder yield (406.8 q ha^{-1}), dry matter yield (66.9 q ha^{-1}) and seed yield (23.5 q ha^{-1}). The results were aligned with the findings of[15,16]. The increase in yield is association with the application of FYM that may be attributed to enhance supply of nutrients, as well as improvements in the soil physical and biological properties. Three cuts at 60, 90 and 120 DAS (C3) when combined with integrated nutrient management (N3) produced highest green fodder yield (564.0 q ha^{-1}) and dry matter yield (93.5 q ha^{-1}). The results were in line with[2,4]. The interaction effect of two years pooled mean data on different cutting scheduling and integrated nutrient management on seed yield did not prove significant effect. However, highest seed (23.6 q ha^{-1}) yield was recorded when no cutting was taken and combined application with integrated nutrient management (N3).

Effect of cutting scheduling and integrated nutrient management on quality indices of oat

The two-year pooled data presented in Table 2 indicated that the highest crude protein content (%) was recorded in the single cut at 60 DAS, which had a protein content of 11.16%. The elevated crude protein content at this stage is likely due to a higher nitrogen concentration in the dry fodder of oat, as the nitrogen plays a key role in protein synthesis. However, the highest crude protein yield was realized under three cuttings at 60, 90, and 120 DAS, with a value of 9.61 q ha^{-1}. This increased in crude protein yield may be attributed to higher fodder and dry matter yields at these growth stages. These findings are consistent with similar studies conducted by[8].

It was observed that nutrient management caused significantly influenced both crude protein content and crude protein yield. The pooled results (Table 2) revealed that the highest crude protein content (11.46%) and crude protein yield (7.43 q ha^{-1}) were recorded in the treatment with 50% NPK of RDF + 7.5 t FYM ha^{-1}, followed by the treatment with 75% NPK of RDF + 5 t FYM ha^{-1}. The higher crude protein content observed in the treatment with farmyard manure (FYM) in combination with inorganic fertilizers, as compared to the full inorganic fertilizer treatment, may be attributed to the significant improvement in green fodder and dry matter yields of oats, which was enhanced by the beneficial effects of FYM. These results are consistent with the findings of[17].

The pooled data showed that the interaction effect between cutting scheduling and nutrient management did not significantly affect on crude protein content and crude protein yield of fodder oat. However, it was observed

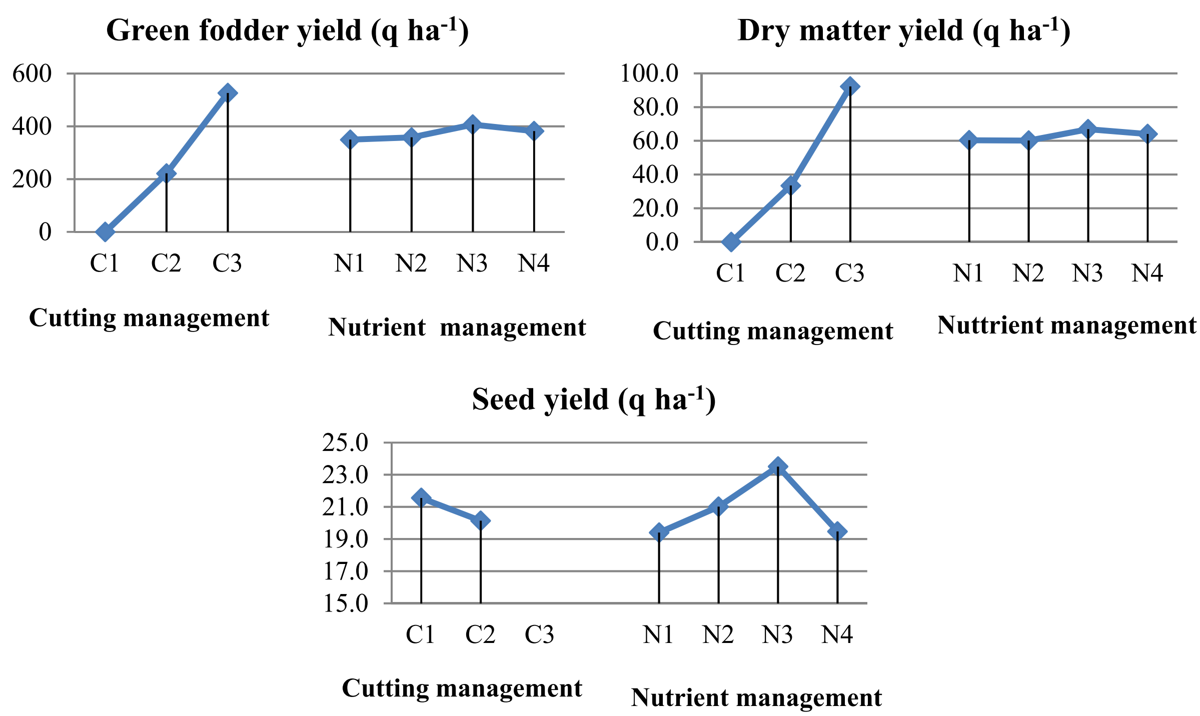

Fig. 3. Graphical representation for 2 years pooled data of green fodder, dry matter yield (q ha^{-1}) and seed yield of oat.

Treatment	Crude protein content (%)			Crude protein yield (q ha^{-1})			Gross return (Rs. ha^{-1})			Net return (Rs. ha^{-1})			B:C ratio		
	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled	Y1	Y2	Pooled
Cutting scheduling															
C1	–	–	–	–	–	–	107,083	108,464	107,773	64,434	65,814	65,124	2.52	2.55	2.54
C2	11.77	10.54	11.16	3.46	3.96	3.71	133,762	134,012	133,887	84,081	84,331	84,206	2.70	2.71	2.71
C3	10.71	10.14	10.43	9.15	10.06	9.61	77,940	80,046	78,993	25,821	27,927	26,874	1.50	1.54	1.52
SEm +	0.39	0.32	0.36	0.37	0.29	0.33	3563	1989	2776	3563	1989	2776	0.08	0.04	0.06
CD at 5%	1.19	0.96	1.08	1.11	0.89	1.00	10,451	5832	8141	10,451	5832	8141.5	0.22	0.13	0.18
Integrated Nutrient Management (INM)															
N1	10.70	9.50	10.10	5.65	6.03	5.84	98,244	100,939	99,591	54,370	57,064	55,717	2.31	2.37	2.34
N2	11.88	10.80	11.34	6.32	7.39	6.86	70,050	118,475	94,262	55,545	56,369	55,957	2.13	2.14	2.14
N3	12.00	10.92	11.46	7.19	7.66	7.43	105,395	106,218	105,806	70,050	68,900	69,475	2.43	2.41	2.42
N4	10.38	10.14	10.26	6.06	6.95	6.51	101,782	104,396	103,089	52,482	55,096	53,789	2.07	2.13	2.10
SEm +	0.28	0.22	0.25	0.26	0.21	0.24	3086	1722	2404	3086	1722	2404	0.07	0.04	0.06
CD at 5%	0.84	0.68	0.76	0.78	0.63	0.71	9051	5051	7051	9051	5051	7051	0.19	0.11	0.15
Interaction between cutting scheduling and integrated nutrient management															
SEm +	0.55	0.45	0.50	0.52	0.41	0.47	6172	3444	4808	6172	3444	4808	0.13	0.07	0.10
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of cutting scheduling and integrated nutrient management on quality and economics of fodder oat. Y1 = 2019–20, Y2 = 2020–21, C1- No cutting (Seed), C2- Single cut (60 DAS) + Seed, C3- Three cuts (60, 90 & 120 DAS), N1- RDF (N, P_2O_5 & K_2O @ 80:40:40), N2-75% NPK of RDF + 5 t FYM ha^{-1}, N3-50% NPK of RDF + 7.5 t FYM ha^{-1}, N4-25% NPK of RDF + 10 t FYM ha^{-1}.

that a single cut at 60 DAS (C2) allowed the plants to absorb relatively higher amount of nitrogen at a later stage. When this was combined with 50% NPK of RDF + 7.5 t FYM ha^{-1} (N3), it ensured an adequate nitrogen supplied throughout both the early and later stages of oat growth, resulting in highest crude protein content (12.26%) in the treatment single cut at 60 DAS + seeds and 50 % NPK of RDF +5 tFYMha^{-1} (C2N3). On the other hand, the significantly higher crude protein yield (10.07 q ha^{-1}) observed in the three-cut system with 50% NPK of RDF + 7.5 t FYM ha^{-1} (C3N3) can be attributed to the higher green fodder yield which resulted in higher weighted average value for crude protein yield. These findings are aligned with the studies by[18,19].

Effect of cutting scheduling and INM on economics

The data presented in Table 2 indicated that different cutting treatments significantly influenced the economics of fodder oat production. The pooled results indicated that a single cut at 60 DAS produced the highest gross return (Rs. 133887 ha^{-1}), net return (Rs. 84206 ha^{-1}) and benefit: cost ratio (2.71), all of which were significantly superior as compared to remaining treatments. Similar results were reported by[7,20].

The analysis of two years pooled data indicated that fodder oat economics is significantly influenced by integrated nutrient management rather than their sole application. The pooled data (Table 2) reflected that application of 50% NPK of RDF + 7.5 t FYM ha^{-1} was found more beneficial in terms of highest gross return (Rs. 105806 ha^{-1}), Net return (Rs. 69475 ha^{-1}) and benefit: cost ratio (2.42) as compared to other nutrient management. The findings are in line with[21] who reported that INM was found to be most effective in terms of fodder oat economics as compares to the sole application of manures or chemical fertilizers. Single cut in association with the application of 50% NPK of RDF + 7.5 t FYM ha^{-1} (N_3) resulted the highest gross return followed by single cut combined with the application of 75% NPK of RDF + 5 t FYM ha^{-1} (C2N2). The highest benefit-cost ratio was counted in the single cut (C2) combined with the RDF (N1), though this result was statistically on par with both C2N3 (Single cut at 60 DAS+ Seed and 50% NPK of RDF + 7.5 t FYM ha^{-1}) and C1N3 (No cutting and 50% NPK of RDF + 7.5 t FYM ha^{-1}) treatments. While the interaction between cutting scheduling and nutrient management did not significantly influence on net returns, the highest net return was achieved with the combination of a single cut and 50% NPK of RDF + 7.5 t FYM ha^{-1} (N3). This suggests that while different cutting scheduled may impact gross returns, the choice of nutrient management plays a central role in maximizing profitability in fodder oat production. These results are closely related to the findings of[22].

Conclusion

The two years study conducted on fodder oats revealed that application of 50% NPK of the recommended dose of fertilizers @ 80:40:40NPK kg ha^{-1} in combination of 7.5 t FYM ha^{-1}, along with a single cut at 60 days after sowing (DAS) for green fodder, followed by seed production, achieved the highest results. This management approach was found to enhance growth, produce high-quality green forage, and maximize seed yield. The study concluded that for the cultivation of fodder oat aim to fetched both green forage as well as seed production, the recommended practice for Manipur and similar regions in the North Eastern Himalayas (NEH) is to adopt cutting at 60 DAS in combination with the application of 50% NPK of RDF + 7.5 t FYM ha^{-1}. This methodology is particularly suited for maximizing both green forage quality and seed yield, benefiting both economic returns and resource use efficiency in the NEH region of India.

Data availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to private and ethical restrictions.

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Author contributions

R.J.K., led the research work, planned, supervised and conducted field experiments. Kh. M., J.K., T.M.C., collected plant samples and performed chemical analysis, also wrote the initial draft of the manuscript. K.M., A.M., P.H., read and edited the manuscript and prepared figures and tables. S.P., G.K., K.S., performed the statistical analysis and reviewed the manuscript with significant contributions. All authors have read and reviewed the manuscript.

Declarations

Seed source

Oat seeds used for the experiment were procured from Punjab Agricultural University, Ludhiana, Punjab, India.

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to R.J.K.

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