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Effect of Zinc Application on Growth, Yield and Economics of Dual-Purpose Oats (*Avena sativa* L.) under North Eastern Region of India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: A field experiment was conducted with the objective to evaluate the effect of zinc application on growth, yield and economics of dual-purpose oats.

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Study Design: The experiment was laid out in Randomized Block Design (RBD) with 12 treatments and three replications.

Place and Duration of Study: The research was conducted at the Instructional-cum-Research (ICR) Farm of Assam Agricultural University, Jorhat, Assam during the *rabi* season of 2021 – 2022.

Methodology: The experiment was conducted with the crop variety 'Kent'. The crop was harvested at 60 and 120 days after sowing (DAS) to obtain green fodder, grain and straw, respectively. Zinc was applied along with recommended dose of fertilizer (RDF) as basal (5 kg ha^{-1}, 7.5 kg ha^{-1} and 10 kg ha^{-1}), as foliar spray (0.5%, 0.75% at 30 DAS and 75 DAS) and in combination of basal and foliar. The study of growth parameters was conducted at 60, 90 and 120 DAS. The influence of zinc on green fodder was observed at 60 DAS and at 120 DAS for grain and straw yield.

Results: The experiment resulted a significant improvement in plant growth parameters *viz.* plant height (69.59 cm, 44.58 cm, 79.33 cm), number of tillers per meter square (377.61, 450.61, 589.07), periodic dry matter accumulation (28.35 g $plant^{-1}$, 18.70 g $plant^{-1}$, 37.94 g $plant^{-1}$) and yield including green fodder yield (75.01 q ha^{-1}), dry matter yield (28.83 q ha^{-1}), grain yield (22.96 q ha^{-1}) and straw yield (60.84 q ha^{-1}) with combined application of 7.5 kg ha^{-1} $ZnSO_4$ and two foliar sprays of 0.5% $ZnSO_4$ at 30 and 75 DAS along with recommended dose of fertilizer (RDF) (T_{11}). The same treatment recorded highest gross return (Rs. 32,980 ha^{-1}), net return (Rs. 65,558 ha^{-1}) and benefit-cots ratio (2.99).

Conclusion: The application of zinc was beneficial in enhancing growth and yield of the crop in zinc deficient soil of Northeastern Region with subsequent increase in net return and benefit-cost ratio. Thus, widening the scope for conducting future research to eliminate fodder deficits of the region.

Keywords: Oats; zinc application; basal; foliar; growth; yield; economics.

1. INTRODUCTION

Livestock sector is the backbone of Indian economy. It is an integral component of Indian farming system mostly among the marginal and small farmers with more than 62% of the marginal households dealing with livestock farming [1]. It is the prime source of income for more than 70% of Indian population and playing a critical role in alleviating poverty. It contributes almost 26% to the income of small farmers and 24% to total rural households [2]. The contribution of livestock to overall agriculture and allied sector Gross Value Added (GVA) has risen to 30.19% in 2021-22 from 24.38% in 2014-15. Its contribution to total GVA in 2021-22 is 5.73% [3]. It plays a significant role in contribution to the GDP by 4.11% and accounts for 25.6% of total agricultural GDP [4]. According to the 20th livestock census (Department of Animal Husbandry and Dairying), the total livestock population has increased from 512.06 million in 2012 to 536.76 million in 2019, corresponding to a 4.6% increase in growth rate. India host 11% of the world's total livestock population but the area under fodder production is stagnating only at 4% of the gross cropped area for the last 40 years. According to ICAR - National Institute of Animal Nutrition and Physiology, there is a deficit of green fodder, dry fodder and protein by 36%, 23% and 36%, respectively. It is estimated that by 2025 the deficiency of green fodder, dry fodder and protein will further increase by 40%, 23% and 38%, respectively. This drastically impacts the animal production even though India is currently the largest producer of milk. The scarcity of green forage is primarily owing to a lack of land for fodder cultivation. Fodder production receives negligence as they comprise only the grasses grown on degraded or marginal lands without proper management and the crop residues. Moreover, fodder crisis is critical during the lean period such as floods and drought which are frequent under climate change scenario. Furthermore, in case of forages, regional and seasonal shortfalls are more critical than national deficiencies as transporting forage over long distances is uneconomical. Hence, there occurs a great disparity of fodder production, taking a toll on the productivity and health of the livestock. Thus, it becomes imperative to enhance the production of fodder crops both in terms of quality and quantity for achieving feed, nutritional and livelihood security alongside livestock productivity.

Oats (*Avena sativa* L.) is the sixth most important cereal crop after wheat, rice, maize, barley and sorghum in the world and first among the annual *rabi* fodder crop. It originated in Asia Minor and belongs to the family *Poaceae*. It has been established as a successful dual-purpose crop as it plays a pivotal role in supplying nutritious fodder during the lean period, and increase livestock productivity, besides providing nutrient rich grain for human consumption. It is the only source of antioxidants like avenanthramides (Ncinnamoylanthranilate alkaloids) and avenalumic acids (ethylenic homologues of cinnamic acids) which is not found in any other cereals [5]. It is a rich source of protein, varying from 12% to 24% that is equivalent to soy protein and milk protein. According to researches, oats is highly effective in reducing cholesterol levels, checks obesity, enhances immune system, generates prebiotics, acts as shield against celiac diseases, helps in lowering diabetes, etc. Its capacity to grow luxuriantly under temperature ranges of 15-20°C and well-drained acidic loamy soil, makes the Northeastern Regions ideal for cultivating oats during the *rabi* season.

Zinc in plants is responsible for maintaining growth and development by involving in the synthesis of tryptophane that is a precursor of growth hormone auxin and formation of chlorophyll, carbohydrates and proteins. It plays a significant role in combating drought stress by maintaining water balance, providing resistance against biotic stresses, maintaining cellular integrity, pollen grain formation, activating over 300 enzymes like carbonic anhydrase, alcohol dehydrogenase, superoxide dismutase, carboxy peptidase, aldolase and RNA polymerase, etc. [6-9]. Heavy rainfall, acidic soil pH and the abundance of iron/aluminum oxides and hydroxides that co-precipitates zinc, are the reason for its deficiency in the soils of Northeastern regions [10, 11]. Moreover, cereals in particular are poor sources of zinc as much of it is present in the aleurone layer that is removed while milling [12]. The deficiency of zinc in plants curtails the production potentiality of crop owing to stunted growth, sparse tillering, chlorosis and reduced leaf area, susceptibility to various biotic and abiotic stresses due to prolonged crop duration, spikelet sterility and poor quality of harvested produce. Hence, it becomes imperative to apply zinc to improve the overall growth and yield of the plant. Micronutrients are made easily available to the plants when applied as foliar and is regarded as the simplest, affordable and superior method of correcting zinc deficiency in plants, thus, maintaining adequate crop growth. Hence, through this research an effort was made to improve crop yield with zinc application in otherwise deficient soil.

2. MATERIALS AND METHODS

An experiment was conducted on dual-purpose oats variety ‘Kent’ at the Instructional-cum-Research (ICR) farm of Assam Agricultural University, Jorhat, Assam during the *rabi* season of 2021-2022 to evaluate the effect of zinc application on growth, yield and economics. The experimental site was geographically situated at 26°45'N latitude and 94°12'E longitude and at an altitude of 87 meters above the mean sea level (MSL). The site was uniformly fertile, well drained, sandy loam in texture with a pH of 5.5. The soil samples were collected before conducting the experiment and oven dried at 105°C and analyzed for organic carbon content, available nitrogen, available (bray) phosphorus, 1N NH_4OAc extractable potassium, DTPA extractable zinc by atomic absorption spectrophotometer by following standard protocols according to Jackson [13]. The soil was low in organic carbon content (0.46%), medium in available nitrogen (308.93 kg ha^{-1}), low in available phosphorus (21.36 kg ha^{-1}), medium in available potassium (150.75 kg ha^{-1}) and low in available zinc (0.58 mg kg^{-1}). During the crop growing season (from 30th November, 2021 to 1st April 2022), the mean weekly maximum and minimum temperature varied from 21.2°C to 33.3°C and 8.2°C to 18.9°C, respectively. The overall precipitation was 110 mm, with the highest of 33.7 mm during the last week of March.

The investigation was laid out in Randomized Block Design (RBD) with 12 treatments that were replicated thrice. The treatments were: T_1: Control (RDF: N: P_2O_5: K_2O at the rate 40-20-20 kg ha^{-1}), T_2: RDF + soil application of $ZnSO_4$ at the rate 5 kg ha^{-1}, T_3: RDF + soil application of $ZnSO_4$ at the rate 7.5 kg ha^{-1}, T_4: RDF + soil application of $ZnSO_4$ at the rate 10 kg ha^{-1}, T_5: RDF + one foliar application of 0.5% $ZnSO_4$ at 30 DAS, T_6: RDF + one foliar application of 0.75% $ZnSO_4$ at 30 DAS, T_7: RDF + two foliar applications of 0.5% $ZnSO_4$ at 30 and 75 DAS, T_8: RDF + soil application of $ZnSO_4$ at the rate 5 kg ha^{-1}+ foliar application of 0.5% $ZnSO_4$ at 30 DAS, T_9: RDF + soil application of $ZnSO_4$ at the rate 5 kg ha^{-1}+ foliar application of 0.75% $ZnSO_4$ at 30 DAS, T_{10}: RDF + soil application of $ZnSO_4$ at the rate 5 kg ha^{-1}+ foliar application of 0.5% $ZnSO_4$ at 30 and 75 DAS, T_{11}: RDF + soil application of $ZnSO_4$ at the rate 7.5 kg ha^{-1}+ foliar application of 0.5% $ZnSO_4$ at 30 and 75 DAS and T_{12}: RDF + Water spray at 30 and 75 DAS. The crop was grown as ratoon by harvesting at 60 DAS for green fodder and 120 DAS for grain and straw. The RDF for dual purpose oats is 40-20-20 kg N, P_2O_5 and K_2O per hectare as urea, single super phosphate (SSP) and muriate of potash (MOP). The first 2/3rd of urea was applied at the time of last land preparation along with full doses of SSP, MOP and $ZnSO_4$ (at the rate of 5 kg ha^{-1}, 7.5 kg ha^{-1} and 10 kg ha^{-1} as per the treatments). The remaining 1/3rd urea was applied 2 days after the first cut. Foliar spray of $ZnSO_4$ (at the rate of 0.5% and 0.75%) was applied 15 days after the first cut *i.e.,* at 75 DAS.

For studying the growth parameters like plant height, number of tillers per meter square and periodic dry matter accumulation per plant and yield (green fodder yield, dry fodder yield, grain yield and straw yield) standard procedures were followed. The cost of cultivation was calculated on per hectare basis considering all the cultural practices followed during the cultivation. The gross return was calculated from the total fodder equivalent yield by considering the prevailing market price of the produce. The net return was calculated for each treatment on per hectare basis following the formula:

Net return = Gross return (₹ ha^{-1}) - Cost of cultivation (₹ ha^{-1}).

Benefit-cost ratio was calculated for each treatment by using the following mathematical expression:

$$\text{B/C ratio} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

The data recorded on various parameters were analyzed statistically following the analysis of variance for randomized block design as suggested by Panse and Sukhatme [14].

3. RESULTS AND DISCUSSION

3.1 Effect of Zn Application on Growth

The results for the growth parameters revealed that, combined application of RDF and 7.5 kg ha^{-1} $ZnSO_4$ and two foliar sprays of 0.5% $ZnSO_4$ at 30 and 75 DAS (T_{11}) significantly increased the growth parameters observed at 60, 90 and 120 DAS *viz* plant height (69.59 cm, 44.58 cm, 79.33 cm), number of tillers per meter square (377.61, 450.61, 589.07), periodic dry matter accumulation per plant (28.35 g $plant^{-1}$, 18.70 g $plant^{-1}$, 37.94 g $plant^{-1}$), as shown in the Table 1. This might be due to the fact that application of zinc triggers auxin synthesis and later tryptophan that is involved in cell enlargement, stem elongation and photosynthetic activity. These results were in conformity with Amanullah et al., [15] and Mahato et al., [16].

3.2 Effect of Zn Application on Yield

The performance of yield as influenced by zinc application is graphically presented in Fig. 1. The green fodder yield, dry matter yield, grain yield and straw yield were significantly highest (75.01 q ha^{-1}, 28.83 q ha^{-1}, 22.96 q ha^{-1} and 60.84 q ha^{-1}, respectively) when RDF was applied in combination with 7.5 kg ha^{-1} $ZnSO_4$ and two foliar sprays of 0.5% $ZnSO_4$ at 30 and 75 DAS (T_{11}) due to the greater absorption and utilization of nutrients by the crop that has positively affected the photosynthesis and consequently the growth parameters. The increased in grain yield might be due to the role of zinc in the synthesis of RNA and transcription of substrates. Similar results were reported by Amanullah et al*.,* [15] and Augustine and Kalyanasundaram, [17].

3.3 Economics of Dual-Purpose Oats as Influenced by Zinc Application

Economic analysis of dual-purpose oats production with zinc application increased the gross return, net return and benefit cost ratio. The gross and net return was highest (₹ 98,537 ha^{-1} and ₹ 65,558 ha^{-1}, respectively) when 7.5 kg ha^{-1} $ZnSO_4$ and two foliar sprays of 0.5% $ZnSO_4$ at 30 and 75 DAS was applied along with the RDF due to the increased yield (table 2). On the other hand, when RDF was applied only with water spray at 30 DAS and 75 DAS recorded the lowest gross and net return (₹ 73530 ha^{-1} and ₹ 43110 ha^{-1}, respectively). Similarly, the maximum benefit cost ratio (2.99) was resulted from the combined application of RDF with 7.5 kg ha^{-1} $ZnSO_4$ and two foliar sprays of 0.5% $ZnSO_4$ at 30 and 75 DAS, while the minimum (2.42) when only water was sprayed along with RDF. Thus, treatment T_{11} carries higher economic superiority compared to control and bears the potentiality of being recommended to the farmer's community. These results were in conformity with Krishna et al*.,* [18], Rajendran et al*.,* [19] and Singh et al*.,* [20].

Table 1. Effect on growth parameters of dual-purpose oats as influenced by Zn application

Treatments	Plant Height (cm)			Number of Tillers per Meter Square			Periodic Dry Matter Accumulation (g plant^{-1})		
	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS
T_1	53.37	33.09	67.84	364.11	437.11	567.34	15.33	10.12	23.26
T_2	62.54	38.66	73.41	370.58	443.58	578.10	21.69	14.47	30.52
T_3	63.15	38.72	73.47	370.70	443.70	578.30	21.79	14.51	30.64
T_4	63.17	38.83	73.58	370.91	443.91	578.62	21.99	14.64	30.69
T_5	56.45	35.87	70.62	367.07	440.07	572.63	18.23	12.12	26.66
T_6	56.61	35.92	70.67	367.46	440.46	573.24	18.56	12.34	26.56
T_7	59.57	35.99	70.74	367.59	440.59	573.43	18.69	12.45	26.72
T_8	66.25	41.46	76.21	374.00	447.00	583.44	25.11	16.82	34.32
T_9	66.38	41.5	76.25	374.25	447.25	583.82	25.24	16.85	34.33
T_{10}	66.48	41.58	76.33	374.45	447.45	584.13	25.38	16.96	34.45
T_{11}	69.56	44.58	79.33	377.61	450.61	589.07	28.35	18.70	37.94
T_{12}	53.23	33	67.75	363.59	436.59	567.20	15.21	10.12	23.00
S.Em(±)	**1.05**	**0.76**	**0.76**	**0.95**	**0.96**	**1.50**	**0.90**	**0.38**	**1.16**
CD(P=0.05)	**3.079**	**2.217**	**2.217**	**2.784**	**2.819**	**4.410**	**2.653**	**1.111**	**3.414**

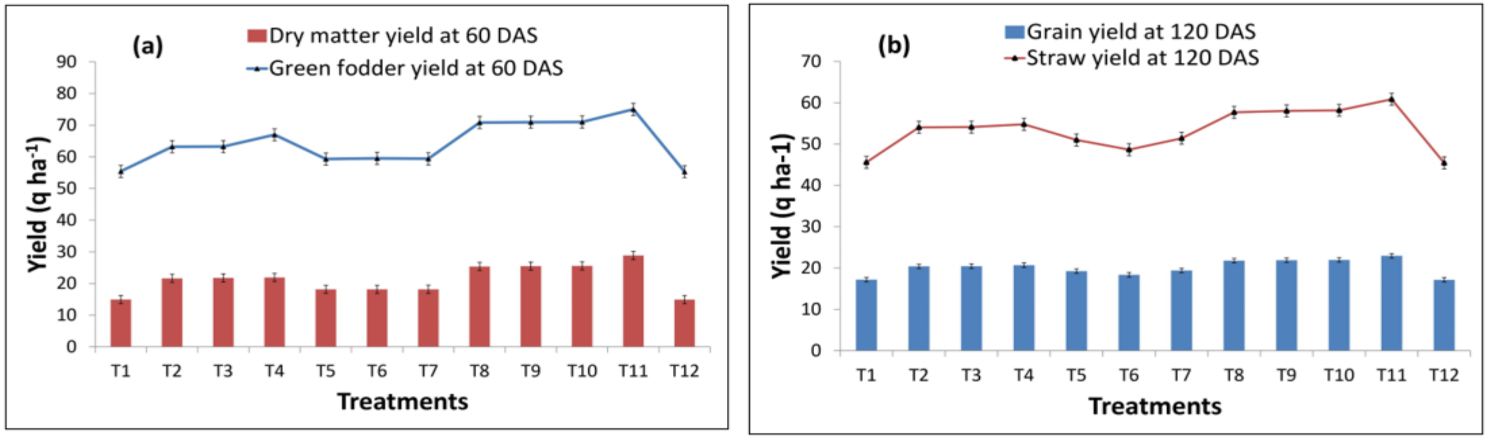

Fig. 1. (a) Effect on green fodder yield and dry matter yield of dual-purpose oats as influenced by Zn application (b) Effect on grain and straw yield of dual-purpose oats as influenced by Zn application

Fig. 2. (a) Data Collection, (b) Foliar application treatment of zinc sulphate and (c) Field visit by the faculty of Department of Agronomy, Assam Agricultural University, Jorhat, Assam

Table 2. Comparative economics of different treatments on dual purpose oats

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B-C ratio
T_1	30020	73740	43720	2.46
T_2	30889	87165	56276	2.82
T_3	31324	87290	55967	2.79
T_4	31758	88654	56896	2.79
T_5	30848	82257	51409	2.67
T_6	30870	78749	47879	2.55
T_7	31676	82821	51145	2.61
T_8	31717	93402	61685	2.94
T_9	31739	93889	62150	2.96
T_{10}	32545	94133	61588	2.89
T_{11}	32980	98537	65558	2.99
T_{12}	30420	73530	43110	2.42

4. CONCLUSION

Application of zinc has positive role in enhancing oats production. The present experiment revealed that zinc sulphate applied as basal at the rate of 7.5 kg ha^{-1} in combination with 0.5% foliar sprays at 30 and 75 DAS along with RDF, significantly improved the growth parameters of dual-purpose oats, including plant height, number of tillers, and periodic dry matter accumulation. These enhancements ultimately resulted in higher green fodder yield, dry matter yield, grain yield, and straw yield. Consequently, this led to an increase in both gross and net returns, thereby achieving a higher benefit-cost ratio. As these findings are based on a single year of experimentation, further investigations over multiple years are needed to derive a valid conclusion before recommendation to the farming community.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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