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Studies on Growth, Productivity and Economics of Oats Fodder as Influenced by Different Levels of NPK Fertilizers and Foliar Spray of $ZnSO_4$ and Borax in Red and Lateritic Soil of West Bengal

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ABSTRACT

A field experiment was carried out during November, 2020–January, 2021 and November, 2021–January, 2022 at Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India to evaluate the response of NPK fertilizers and foliar application of $ZnSO_4$ and borax towards growth, yield attributes, productivity and economic return from fodder oats cultivation. The experiment was laid out in factorial randomized block design having four levels of NPK fertilizers (viz., no fertilizer, 60:30:30, 80:40:40 and 100:50:50 kg ha^{-1}) and three foliar spray [(viz., no foliar spray/water spray, $ZnSO_4$ at 0.5%, borax at 0.2% and $ZnSO_4$+borax at (0.5%+0.2%)] with three replications. Experimental findings revealed that NPK fertilizers with 100:50:50 kg ha^{-1} registered highest growth attributes (plant height, dry matter accumulation, number of tillers, leaf area index and crop growth rate), green fodder (36.46 t ha^{-1}), dry fodder (9.18 t ha^{-1}), gross return (₹ 54,685 ha^{-1}), net return (₹ 25,681 ha^{-1}) and return $rupee^{-1}$ invested (1.89). Foliar spray of $ZnSO_4$+borax was significantly superior to sole application of borax and $ZnSO_4$ with respect to growth attributes, green fodder (28.54 t ha^{-1}), dry fodder (6.37 t ha^{-1}), gross return (₹ 42,812 ha^{-1}), net return (₹ 15,517 ha^{-1}) and return $rupee^{-1}$ investment (1.54) in oats. Thus, NPK fertilizers at 100:50:50 kg ha^{-1} and combined foliar spray of $ZnSO_4$ and borax appeared to be the best option for higher fodder yield and profitability of fodder oats.

KEYWORDS: Borax, fodder, NPK fertilizers, oats, zinc sulphate

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1. INTRODUCTION

In rural India, agriculture and animal husbandry forms integral parts which are interlinked with each other towards social, cultural and economical relations. India contributes about 10.7% to the world's livestock population (Roy et al., 2019). As par 20th census, in India, total livestock population is 535.8 million. With world's largest livestock population (Sonavale et al., 2020). Out of total cultivated area in India, only about 5.0% area under forage corps with a yearly green forage production of 734.1 mt and dry forage production of 326.4 mt to support the existing livestock population (Roy et al., 2019). In West Bengal, only 1.2% of the total cultivated area is under fodder (Jana et al., 2019). The current feed and fodder resources supply 61.8% of total requirement, with a huge shortage of 38.2% of green fodder (Roy et al., 2019). This huge deficit results in scarcity of feed for the animals making them to suffer from malnutrition. Owing to deficit of green and dry fodder in the country, dairy farmers are forced to use costly concentrated feeds resulting in an increased cost of production. The productivity of fodder crops must be increased by making the greatest use of the resources available in the current production systems, as the area that may be expanded under cultivated fodder (5% of cultivable land) is limited (Barik et al., 2016). Oats (*Avena sativa* L.) is a significant global feed resource (Ma et al., 2022). Approximately, 13.9 mha of land are used to grow oats worldwide (Singh et al., 2017). One of the main cereal fodder crops grown in India during the *rabi* season is oats (Paul et al., 2022a, Paul et al., 2022b).

Nitrogen is vital for enhancing both the quality and quantity of fodder production (Nanda and Nilanjaya, 2022) as it affects cell elongation, cell division and cell expansion. Phosphorus is vital for crop growth and development (Munir et al., 2004), key component of nucleic acids, ATP (adenosine triphosphate) and phospholipids. Phosphorus also involve in cell division and root formation (Prajapati et al., 2023). Potassium is important for cation–anion balancing, stomatal regulation, plant water relation, protein synthesis and osmo regulation (Oosterhuis et al., 2014).

Application of micronutrients improves enzymatic activities and it leads to increase growth and yield of the fodder (Prajapati et al., 2023). Its deficiency affects growth, productivity, metabolism and reproduction in plants. The most commonly deficient micronutrient in Indian soil are zinc and boron (Shukla et al., 2021). Zinc is mainly required for photosynthesis, nitrogen assimilation, respiration and chlorophyll production (Mattiello et al., 2015). It helps in the synthesis of indole acetic acid, tryptophan (an essential amino acid) and also proteins (Suganya et al., 2020). It improves root and vegetative growth and relative water content (Grewal and Williams, 2000). Plants will produce less tillers and shorter internodes due to deficiency of zinc (Shivay et al., 2015). Boron plays a key role in synthesis of cell wall metabolism of auxin, sugar and carbohydrate and enzyme activities in plant (Princi et al., 2016, Wimmer et al., 2019). In addition to deficiency of fertilizer, insufficiency of these nutrients may restrict growth of crops. These nutrients are mainly removed from soil by excess application of phosphatic fertilizers or may be removal by the crops or during application of ameliorants for acidity. Thus, excess or deficit of these minerals can cause nutritional imbalance by affecting the dry matter production. Keeping the above mentioned literature in view, this field experiment was conducted to evaluate the response of NPK fertilizers and foliar application of $ZnSO_4$ and borax on growth, productivity and economics of fodder oats.

2. MATERIALS AND METHODS

2.1. Experimental period and location

A field experiment entitled was conducted during November–January, 2020–21 and 2021–22 at Agricultural Farm, Institute of Agriculture, Visva-Bharati, West Bengal, India. The field was geographically located at 23⁰66'87'' N latitude and 87⁰65'96'' E longitude with an average altitude of 61 m above the mean sea level. The soil of the experiment field was sandy loam (*Ultisol*) in texture, slightly acidic (pH 5.78) in reaction, low in organic carbon (0.36%), low in available N (160 kg ha^{-1}), medium in available P (20 kg ha^{-1}) and medium in available K (152 kg ha^{-1}).

2.2. Experimental design and treatment details

The experiment was conducted in factorial randomized block design, consisting of sixteen treatments combinations, having four levels of NPK fertilizers (viz., no fertilizer, 60:30:30, 80:40:40 and 100:50:50 kg ha^{-1}) and four levels of foliar [(viz., no foliar spray/water spray, $ZnSO_4$ at 0.5%, Borax at 0.2% and $ZnSO_4$+Borax at (0.5%+0.2%)], which were replicated thrice. The gross and net plot size were 5×4.5 m^2 and 3×3 m^2, respectively.

2.3. Package and practices

The fodder oats cultivar "JHO–822" was grown as test crop and the seed rate was 100 kg ha^{-1}. The seeds were sown manually by making small furrows and placing fertilizer in the bottom layer and seeds in the upper layer at a soil depth of 3.0 cm. The space between rows was 30 cm. Urea, single super phosphate and muriate of potash were used to supply N, P_2O_5 and K_2O as per treatment. During sowing time, half quantity of N and full quantity of P_2O_5 and K_2O were applied as basal. Rest half of N was applied as top dressing at 30 and 45 days after sowing (DAS) in two equal splits. Borax at 0.2% and $ZnSO_4$ at 0.5% were applied as foliar spray at 35 and 50 DAS. To prevent weed infestation, pre-emergence herbicide pendimethalin at 1 kg ha^{-1} was applied. The crop was irrigated thrice at 15, 30 and 45 DAS.

2.3. Observations

The average plant height of randomly selected five plants from each plot were measured from ground level to top of the canopy. The area of fresh green leaves for each treatment was recorded by using leaf area meter (LICOR Model LI 3100). The leaves were then dried in the hot air oven at 70°C for 72 hours and then weights were recorded. The ratio of leaf area/weight of these leaves was used to measure the leaf area index (LAI) using the formula suggested by Evans (1972). It (LAI) was obtained by multiplying this ratio of area/weight with the dry weight of green leaf produced per unit area (square meter) of land surface.

LAI=Total leaf area/Ground area

From each plot in one meter running length total number of tillers were counted randomly at five places and converted in number of tillers m^{-2}. To determine the dry matter accumulation (DMA), the sample was cut at ground level from 25 cm area at 30 and 60 DAS. Samples were dried under the sun followed by in a hot air oven at 70°C for 72 hours. After drying the samples were weighed was directly converted to g m^{-2}. Crop growth rate (CGR) during the period of two growth stages was determined with the following formula as proposed by Watson (1952).

$CGR=(W_2-W_1)/(t_2-t_1)$ ________ [g m^{-2} day^{-1}]

Where, W_1 and W_2 are the initial and final total dry weights of all plant parts per unit land area (m^2) at the time t_2 and $t_{1,}$ respectively.

The total green fodder yield produced from each net plot was harvested at 70 DAS, weighed and then converted into t ha^{-1}. Green fodder from each net plot was sun dried for about 10 to 15 days to obtain dry fodder yield and weight was taken and then converted into t ha^{-1}.

2.4. Methods of statistical analysis

Statistical analysis of the pooled data was done as described by Gomez and Gomez (1984) at a 5% level of significance (polled analysis).

3. RESULTS AND DISCUSSION

3.1. Growth attributes

3.1.1. Effect of NPK fertilizers

Application of various levels of NPK fertilizers significantly influenced different growth attributes including plant height, dry matter accumulation (DMA), crop growth rate (CGR), leaf area index (LAI) and tiller (Table 1). The

Table 1: Effect of NPK fertilizers and foliar spray of micronutrients on growth, yield attributes and yield of fodder oats

Treatment	Plant height	DMA (g m^{-2})	No. of tillers (m^{-2})	LAI	CGR (g m^{-2} day^{-1})	Yield (t ha^{-1})	
						Green fodder	Dry fodder
Level of chemical fertilizers (CF) $N:P_2O_5:K_2O$ (kg ha^{-1})							
No fertilizer	83	189	204	1.10	06.04	12.06	2.04
60:30:30	106	370	225	1.66	10.16	25.06	4.41
80:40:40	117	482	260	2.18	13.87	30.87	6.86
100:50:50	130	592	317	2.79	18.47	36.46	9.18
SEm±	1.15	6.69	3.15	0.03	0.18	0.32	0.08
LSD (*p*=0.05)	3.33	19.31	9.09	0.07	0.53	0.94	0.23
Foliar spray (FS) of micronutrients							
No foliar spray	102	360	234	1.73	10.56	23.74	4.86
$ZnSO_4$ (0.5%)	106	395	246	1.87	11.60	25.44	5.38
Borax (0.2%)	111	422	258	1.99	12.69	26.72	5.89
$ZnSO_4$ (0.5%)+Borax (0.2%)	116	456	267	2.15	13.69	28.54	6.37
SEm±	1.15	6.69	3.15	0.03	0.18	0.32	0.08
LSD (*p*=0.05)	3.33	19.31	9.09	0.07	0.53	0.94	0.23
Interaction effect (CF×FS)							
LSD (*p*=0.05)	NS	NS	NS	NS	NS	NS	NS

Dry matter accumulation: DMA (g m^{-2}) at 60 day after sowing (DAS); LAI: Leaf area index; CGR: Crop growth rate (g m^{-2} day^{-1}) during 30–60 DAS; NS: Non-significant highest plant height (130 cm), DMA (592 g m^{-2}), number of tillers (317 m^{-2}), LAI (2.79) and CGR (18.47 g m^{-2} day^{-1}) of oats was recorded with application of NPK fertilizers at 100:50:50 kg ha^{-1}. This was significantly higher than NPK fertilizers at 80:40:40 and 60:30:30 kg ha^{-1}. Results having enhanced growth attributing characters of fodder oats with higher levels of NPK fertilizers were in conformity with the findings of Dubey et al. (2013), Jat et al. (2015) and Rakhi et al. (2024).

3.1.2. Effect of foliar spray of micronutrients

A significant response was found from different foliar use of micronutrients in respect of growth attributes of oats (Table 1). Combined foliar application of $ZnSO_4$ and borax produced significantly higher growth attributing characters of oats when compared with sole foliar application of $ZnSO_4$ and borax. The highest plant height (116 cm), DMA (456 g m^{-2}), number of tillers (267 m^{-2}), LAI (2.15) and CGR (13.69 g m^{-2}day^{-1}) was recorded with combined foliar spray of $ZnSO_4$+borax (0.5%+0.2%). Dambiwal et al. (2017), Saha et al. (2020) and Sher et al. (2022) also reported similar findings where foliar spray of $ZnSO_4$+borax combinedly accelerated growth attributes of fodder oats.

3.2. Green and dry fodder yield of oats

3.2.1. Effect of NPK fertilizers

Application of various levels of NPK fertilizers significantly influenced green as well as dry fodder yield of oats (Table 1). Significantly higher green and dry forage productivity (36.46 and 9.18 t ha^{-1}, respectively) of oats at harvest were obtained at 100:50:50 kg ha^{-1} of NPK fertilizers than 80:40:40 and 60:30:30 kg ha^{-1}. At higher level of NPK fertilizers, production of higher green as well as dry forage yield could be attributed to availability of adequate quantity of plant nutrients to the crop. These results were also in compliance with the works of Alipatra et al. (2013), Patil et al. (2018), (Singh et al., 2021) and Rakhi et al. (2024) where higher levels of NPK fertilizers achieved higher green fodder and dry fodder yield of oats.

3.2.2. Effect of foliar spray of micronutrients

A significant response was found from foliar application of $ZnSO_4$ and borax on green as well as dry forage yield of oats (Table 1). Significantly higher green and dry fodder productivity (28.54 and 6.37 t ha^{-1}, respectively) at harvest were achieved with foliar spray of both $ZnSO_4$ and borax which were significantly higher than foliar spray of borax and $ZnSO_4$ alone. Findings from Sheoran et al. (2017), Dambiwal et al. (2017) and Patil et al. (2018) revealed similar trend of higher fodder yield of oats with combined foliar spray of $ZnSO_4$ and borax. Higher green and dry fodder yield of oats might be attributed to beneficial effect of zinc in plant growth by promoting auxin production, which regulated cell expansion and stem elongation (Dhaliwal et al., 2020). Boron played a key role in metabolism of auxin, sugar and carbohydrate and enzyme activities (Wimmer et al., 2019), which may contribute to improved oats productivity.

3.3. Economics

3.3.1. Effect of NPK fertilizers

Application of different levels of NPK fertilizers significantly responded to gross and net return as well as return per rupee invested to fodder oats grown in *rabi* seasons of 2020–21 and 2021–22 (Table 2). Highest gross return (₹ 54,685 ha^{-1}), net return (₹ 25,681 ha^{-1}) as well as return rupee^{-1} investment (1.89) was achieved from application of 100:50:50 kg ha^{-1} of NPK fertilizers which was significantly higher than use of 80:40:40 kg ha^{-1} of NPK fertilizers and 60:30:30 kg ha^{-1} of NPK fertilizers in oats. Similarly, application of NPK fertilizers at 80:40:40 kg ha^{-1} showed higher gross and net return as well as return rupee^{-1} investment than use of NPK fertilizers at 60:30:30 kg ha^{-1}. Higher returns from oats green fodder at higher level of NPK fertilizers might be due to higher green fodder yield. Jat et al. (2014), Kumar et al. (2021) and Jha et al. (2024) also were in agreement

Table 2: Effect of NPK fertilizers and foliar spray of micronutrients on economics of oats fodder production

Treatment	CoC (₹ ha^{-1})	GR (₹ ha^{-1})	NR (₹ ha^{-1})	RRI
Level of chemical fertilizers (CF) N:P_2O_5:K_2O (kg ha^{-1})				
No fertilizer	23919	18089	(-)5830	0.76
60:30:30	26970	37590	10620	1.40
80:40:40	27987	46309	18322	1.66
100:50:50	29004	54685	25681	1.89
SEm±	-	486	486	0.02
LSD (p=0.05)	-	1403	1403	0.05
Foliar spray (FS) of micronutrients				
No foliar spray	26646	35611	8965	1.31
$ZnSO_4$ (0.5%)	26841	38166	11326	1.40
Borax (0.2%)	27100	40085	12986	1.46
$ZnSO_4$ (0.5%) +Borax (0.2%)	27295	42812	15517	1.54
SEm±	-	486	486	0.02
LSD (p=0.05)	-	1403	1403	0.05
Interaction effect (CF×FS)				
LSD (p=0.05)	-	NS	NS	NS

NS: Non-significant; 1 US$= INR 73.13 and 74.45 (Average during the January month of both 2021 and 2022) CoC: Cost of cultivation (₹ ha^{-1}); GR: Gross return (₹ ha^{-1}); NR: Net return (₹ ha^{-1}); RRI: Return rupee^{-1} Investment with these results reported similar findings where higher level of NPK fertilizers resulted in higher economic returns.

3.3.2. Effect of foliar spray of micronutrients

Foliar spray of $ZnSO_4$ and borax significantly influenced gross and net return as well as return rupee^{-1} investment in oats fodder (Table 2). Application of $ZnSO_4$ and borax combinedly as foliar spray showed highest gross return (₹ 42,812 ha^{-1}) and net return (₹ 15,517 ha^{-1}) as well as return rupee^{-1} invested (1.54) in oats which was significantly higher than foliar spray of borax and $ZnSO_4$ alone. It was also observed that foliar spray of borax fetched higher return than foliar spray of $ZnSO_4$. These findings have been corroborated by studies of Godara et al. (2016) with enhanced economic returns from foliar spray of micronutrients like zinc sulphate and borax in fodder oats (Saha et al., 2023).

4. CONCLUSION

Use of 100:50:50 kg of $N:P_2O_5:K_2O$ ha^{-1} as NPK fertilizers as well as combined application of $ZnSO_4$ at 0.5% and borax at 0.2% as foliar spray were found to be promising for highest green fodder, dry fodder and economic returns from fodder oats cultivation in lateritic soil of West Bengal.

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