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Growth indices, correlation-regression analysis of some growth, yield and yield components as influenced by integrated nutrient management in fodder oats [*Avena sativa* (L)]

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Abstract
Fourteen INM treatment *viz.*100% RDF, 100% RDF + FYM @ 20.0 t ha^{-1}, 100% RDF + PSB, 100% RDF + PSB + $ZnSO_4$ @ 12.5 kg ha^{-1}, 75% RDF, 75% RDF + Vermicompost @ 5.0 t ha^{-1}, 75% RDF + Vermicompost @ 2.5 t ha^{-1}, 75% RDF + Vermicompost @ 2.5 t ha^{-1} + PSB, 75% RDF + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 12.5 kg ha^{-1}, 75% RDF + FYM @ 20.0 t ha^{-1}, 75% RDF + FYM @ 10.0 t ha^{-1}, 75% RDF + FYM @ 10.0 t ha^{-1} + PSB, 75% RDF + FYM @ 10.0 t ha^{-1} + PSB + $ZnSO_4$ @ 12.5 kg ha^{-1}, Control (untreated) were carried out in randomized block design with three replications and experiment was conducted at College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner during *Rabi* 2019- 2020. The results exhibited that the application of 75% RDF+FYM @ 10.0 t ha^{-1} +PSB+ $ZnSO_4$ @ 12.5 kg ha^{-1} was recorded significantly higher dry matter accumulation, leaf area index, crop growth rate and relative growth rate over rest of treatment but which was at par with 100% RDF + FYM @ 20 t ha^{-1}, and 75% RDF + FYM @ 20 t ha^{-1}. A significant and positive correlation also existed between fodder yield with growth, yield attributes and nutrient uptake of oats. The regression equations show that every unit increase in growth and yield attributes also increase the fodder yield of oats.

Keywords: Fodder yield, INM, net returns, PSB, vermicompost etc.

Introduction

India has about $^1/_5$ of the total livestock population of the world but we are highly lacking in various animal products *e.g.*, milk, meat and supplementary products like camouflage in the leather industries. Among the forage crops cultivated during winter season, oat (*Avena sativa* L.) has various advantages *viz.* high productivity and nutritional trait and ubiquitous of the cultivated fodder in Northern India. Most of the fodder cultivator depend only on nitrogenous fertilizers without mind for stabilize plant nourishment. It positions 6th in world Gramineae crops production following wheat, maize, rice, barley, and sorghum.

Integrated nutrient management has good expectation, not only for ensuring high crop potential but also for preventing soil deterioration. Continuous use of huge quantity of chemical fertilizers has had a adverse impact, resulting in a decline in productivity due to a lack of one or more essential micronutrients. It also had a adverse effect on soil quality and environmental pollution, resulting in various other issues (Anjum *et al.*, 2022) [2].

Furthermore, to prevent the environmental impacts and rises in prices of chemical fertilizers, organic sources of essential nutrients are now appearing as attractive option that can be used in conjunction with inorganic fertilizers because they are naturally stabilize [Mahato *et al.*, 2020] [1]. Integrated nutrient management (INM) using a consolidation of organic sources and chemical fertilizers may benefit soil properties and crop produce. This might be executed in a viable way that does not compromise soil health, environmental safety, and other natural resources. Beside this, INM phenomena assist in reduction production costs and boosting farmer income to evaluate the best economical dose of INM for achieving higher yield and better dietary quality of oat. The basic concept of integrated plant nutrient system is maintenance and improvement of soil fertility for sustaining crop productivity on everlasting basis (Singh, 2017) [3]. Therefore, keeping all the above facts in view, the present experiment was undertaken with the objective to integrated nutrient management in fodder oats in arid western Rajasthan.

Materials and Methods

The field experiment was carried out during the winter seasons of 2019-20 at the Instructional Farm, S. K. Rajasthan Agricultural University, Bikaner (28°38' N, 77°11' E, 228.6 m above mean sea-level), in split plot design with three replications. The soil of the experimental site was loamy sand, with bulk density of 1.55 g cm^{-1}. It had 0.15% organic carbon, 92.26 kg $KMnO_4$ oxidizable N ha^{-1}, 14.68 kg 0.5 N $NaHCO_3$ extractable P ha^{-1}, 207.06 kg 1.0 N NH_4OAC-exchangeable K ha^{-1}, 8.3 pH and 0.13 dSm^{-1} electrical conductivity at the start of the experiment. The fourteen INM treatment consisted *viz.*100% RDF, 100% RDF + FYM @ 20.0 t ha^{-1}, 100% RDF + PSB, 100% RDF + PSB + $ZnSO_4$ @ 12.5 kg ha^{-1}, 75% RDF, 75% RDF + Vermicompost @ 5.0 t ha^{-1}, 75% RDF + Vermicompost @ 2.5 t ha^{-1}, 75% RDF + Vermicompost @ 2.5 t ha^{-1} + PSB, 75% RDF + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 12.5 kg ha^{-1}, 75% RDF + FYM @ 20.0 t ha^{-1}, 75% RDF + FYM @ 10.0 t ha^{-1}, 75% RDF + FYM @ 10.0 t ha^{-1} + PSB, 75% RDF + FYM @ 10.0 t ha^{-1} + PSB + $ZnSO_4$ @ 12.5 kg ha^{-1}, Control (untreated). Crop was sown on 29 November and 1st cutting on 30 January & 2nd cutting 28 February in cropping season 2019-20. Full quantity of FYM, vermicompost, PSB and zinc were applied before sowing. Half 1/4 and full dose of P and K through urea, diammonium phosphate and muriate of potash, respectively were applied at the time of sowing and the remaining N was applied in two split doses *viz,* 1st and 3rd irrigation time.

Leaf area was measured with the help of LA meter. It was calculated at 1st and 2nd cut as per the formula given by Watson (1952) [10].

$$\text{Leaf area index} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Total land area (cm}^2\text{)}}$$

The sample taken for dry matter estimation were also used for calculating CGR per plant at periodical intervals from 0 to 1st cut and 1st to 2nd cut with the following formula given by Hunt (1978):

$$\text{CGR (g m}^{-2}\text{ day}^{-1}\text{)} = \frac{W_2 - W_1}{(T_2 - T_1)}$$

The relative growth rate of a plant at an instant time (t) is defined as the increase of plant material per unit of material present per unit time (Radford, 1967). It was calculated with the help of following formula and expressed in mg g^{-1} day^{-1}:

$$\text{RGR (g g}^{-1}\text{ day}^{-1}\text{)} = \frac{(\text{Ln } W_2 - \text{Ln } W_1)}{t_2 - t_1}$$

To assess the relationship, correlation and regression coefficients between fodder yield of oats (Y) and the independent variables (X) such as crop growth, yield attributes and nutrient uptake were computed using the method given by Snedecor and Cochran (1968). The regression equations were also fitted and tested for significance.

Results and Discussion

In the present investigation, result showed that the application of 75% RDF+ FYM @ 10 t ha^{-1}+PSB + $ZnSO_4$ @ 12.5 kg ha^{-1} reported significantly higher dry matter accumulation at 1st and 2nd cut (411.29 and 1210.43 g, respectively), leaf area index (4.12 and 5.34 cm, respectively) and crop growth rate (6.63 and 13.78 g m^{-2} day^{-1}, respectively) also relative growth rate (6.99 mg g^{-1} day^{-1}) over rest of treatment but which was at par with 100% RDF + FYM @ 20 t ha^{-1}, and 75% RDF + FYM @ 20 t ha^{-1}. Crop growth rate of 1st to 2nd cut also non significantly differ with 75% RDF+FYM @ 10.0 t ha^{-1} +PSB, 75% RDF+FYM @ 10.0 t ha^{-1}, 75% RDF + Vermicompost@ 5.0 t ha^{-1} and 100% RDF+PSB and growth rate with 75% RDF+FYM @ 10.0 t ha^{-1} +PSB. Application of FYM had additive effect on dry matter production. Similar findings were reported by Singh (2017) [3] and Yadav & Singh (2018) [9] in oat. The INM treatment assimilated organic and mineral inputs exhibited an early benefit in leaf area index during the initial growth stages. This was similar to the findings of Biswas *et al.* (2019) [4] and Amanullah *et al.* (2013) [5] in oat, Mahato *et al*. (2020) [1] in maize, in oat. The INM treatment confirm its capacity to enhance crop growth rate indicating its potential in assist accelerated crop growth. The timely application of nutrients might have helped in gathering crop nutrient demand leading to higher dry matter production and crop growth rate. These findings were in similarity to Amanullah *et al.* (2013) [5] and Kumar *et al.* (2022) [9] in oat. The INM treatment recorded the highest relative growth rate during the critical growth phase 2. Other treatments incorporating specific nutrient combinations also demonstrated comparable relative growth rate values indicating their efficacy in promoting crop growth. This was similar to the findings of Amanullah *et al.* (2013) [5] and Kumar *et al*. (2022) [9] in oat.

Correlation and regression

Improvement in fodder yield due to integrated nutrient management can be further substantiated by the significant and positive correlation (Table 1, 2) between total fodder and plant height (1st and 2nd cut, r= 0.976 and r= 0.950, respectively), fresh weight g m^{-1} row length (1st and 2nd cut, r= 0.961 and r= 0.942, respectively), dry weight r= 0.944, respectively), green fodder yield (1st and 2nd cut, r= 0.992 and r= 0.979, respectively), Leaf: Stem ratio (r = 0.900), Green fodder productivity (r = 1.00), total nitrogen uptake (r = 0.988), total phosphorus uptake (r = 0.989), total zinc uptake (r = 0.620) and total crude protein (r = 0.988). But fodder yield was recorded negatively correlated with fiber content (r = -0.911). Fodder yield 1st and 2nd cut also significant and positive correlated with all growth, yield and quality parameter of 1st and 2nd cut due to application of integrated nutrient management. The data further revealed that unit increase in growth, yield attributing characters and quality parameter like plant height (1st and 2nd cut,), fresh weight g m^{-1} row length (1st and 2nd cut), dry weight g m^{-1} row length (1st and 2nd cut), green fodder yield (1st and 2nd cut), Leaf: Stem ratio, green fodder productivity, total nitrogen uptake, total phosphorus uptake, total zinc uptake and total crude protein increased the total fodder yield by 87.72 & 78.70, 11.45 & 12.31, 18.69 & 1.68, 4.46 & 2.61, 4.46 &2.61, 11.57, 8.13, 18.21, 2.84, 73.39 and 14.52 kg ha^{-1}, respectively. Similar results were reported in oat by Premkumar *et al*. (2017) [6].

Table 1: Effect of integrated nutrient management on growth indices in fodder oat

Treatments	Dry matter accumulation m^{-2} (g)		Leaf area index (cm)		CGR (g m^{-2} day^{-1})		RGR (mg g^{-1} day^{-1})
	1st Cut	2nd Cut	1st Cut	2nd Cut	0 – 1st Cut	1st – 2nd Cut	1st – 2nd Cut
T_1 - 100% RDF (120.0 kg ha^{-1}N and 40 kg ha^{-1} P_2O_5)	311.91	888.58	3.43	4.49	5.03	9.94	6.69
T_2- 100% RDF+FYM @ 20.0 t ha^{-1}	383.60	1155.03	4.07	5.29	6.19	13.30	6.95
T_3 - 100% RDF+PSB	267.34	921.30	3.48	4.59	4.31	11.28	6.73
T_4 - 100% RDF+PSB+$ZnSO_4$ @ 12.5 kg ha^{-1}	289.71	910.46	3.44	4.55	4.67	10.70	6.71
T_5 - 75% RDF	210.90	721.76	3.21	4.39	3.40	8.81	6.48
T_6 - 75% RDF + Vermicompost @ 5.0 t ha^{-1}	266.87	921.90	3.48	4.59	4.30	11.29	6.72
T_7 - 75% RDF + Vermicompost @ 2. 5 t ha^{-1}	233.62	844.46	3.28	4.45	3.77	10.53	6.64
T_8 - 75% RDF + Vermicompost @ 2. 5 t ha^{1}+PSB	222.00	865.80	3.33	4.54	3.58	11.10	6.66
T_9 - 75% RDF + Vermicompost @ 2. 5 t ha^{-1}+ $ZnSO_4$ @ 12.5 kg ha^{-1}	244.45	821.90	3.34	4.41	3.94	9.96	6.61
T_{10} - 75% RDF+FYM @ 20.0 t ha^{-1}	365.55	1071.65	3.92	5.14	5.90	12.17	6.88
T_{11} - 75% RDF+FYM @ 10.0 t ha^{-1}	311.08	999.65	3.22	4.83	5.02	11.87	6.81
T_{12} - 75% RDF+FYM @ 10.0 t ha^{-1} +PSB	333.00	1021.62	3.45	4.60	5.37	11.87	6.83
T_{13} - 75% RDF+FYM @ 10.0 t ha^{-1} +PSB+ $ZnSO_4$ @ 12.5 kg ha^{-1}	411.29	1210.43	4.12	5.34	6.63	13.78	6.99
T_{14} - Control	233.10	611.15	3.18	4.31	3.76	6.52	6.32
S.Em ±	15.88	51.53	0.21	0.23	0.26	0.89	0.06
CD(P=0.05)	46.15	149.78	0.60	0.67	0.74	2.60	0.17

Table 2: Correlation coefficient, linear regressions equations and r^2 value showing relationship between independent variable (plant height, fresh weight, dry weight, green fodder yield, dry fodder yield, leaf: stem, green fodder productivity, total nitrogen, phosphorus, zinc uptake, crude protein and fiber content) and dependent variable (fodder yield)

Dependent variable (Y)	Independent variable (X)		Correlation coefficient (x)	Regression equations (Y= a+bx)	R^2 Value
Total fodder yield	Plant height	1st Cut	0.976**	$y = 1.8255x - 87.724X_1$	$R^2 = 0.9534$
		2nd Cut	0.950**	$y = 2.0701x - 78.699 X_2$	$R^2 = 0.9027$
	Fresh weight (g m^{-1} row length)	1st Cut	0.961**	$y = 0.1774x - 11.446 X_3$	$R^2 = 0.923$
		2nd Cut	0.942**	$y = 0.0997x + 12.312 X_4$	$R^2 = 0.8878$
	Dry weight (g m^{-1} row length)	1st Cut	0.883**	$y = 0.5633x + 18.69 X_5$	$R^2 = 0.7805$
		2nd Cut	0.944**	$y = 0.2386x + 1.682 X_6$	$R^2 = 0.8906$
	Green fodder yield	1st Cut	0.992**	$y = 0.253x + 4.4614 X_7$	$R^2 = 0.9843$
		2nd Cut	0.979**	$y = 0.4062x - 2.6128 X_8$	$R^2 = 0.9584$
	Dry fodder yield	1st Cut	0.992**	$y = 1.5811x + 4.4614 X_9$	$R^2 = 0.9843$
		2nd Cut	0.979**	$y = 2.5389x - 2.6128 X_{10}$	$R^2 = 0.9584$
	Leaf: Stem ratio		0.900**	$y = 221.44x - 11.573 X_{11}$	$R^2 = 0.8116$
	Green fodder productivity		1.00**	$y = 18.88x - 8E-13 X_{12}$	$R^2 = 1$
	Total nitrogen uptake		0.988**	$y = 1.3824x - 18.216 X_{13}$	$R^2 = 0.9755$
	Total phosphorus uptake		0.989**	$y = 0.1321x - 2.8412 X_{14}$	$R^2 = 0.9791$
	Total zinc uptake		0.620**	$y = 2.7333x - 73.391 X_{15}$	$R^2 = 0.3839$
	Total crude protein		0.988**	$y = 0.1129x + 14.523 X_{16}$	$R^2 = 0.9755$
	Fiber content		-0.911**	$y = -0.0969x + 32.724 X_{17}$	$R^2 = 0.8303$
Dry fodder yield (1st Cut)	Plant height (1st Cut)		0.955**	$y = 0.8137x + 52.607 X_1$	$R^2 = 0.9111$
	Fresh weight (g m^{-1} row length) (1st Cut)		0.948**	$y = 8.1877x + 118.94 X_2$	$R^2 = 0.8995$
	Dry weight (g m^{-1} row length) (1st Cut)		0.843**	$y = 2.107x + 2.8859 X_3$	$R^2 = 0.7105$
	Green fodder yield (1st Cut)		1.000**	$y = 6.25x + 1E-12 X_4$	$R^2 = 1$
	Nitrogen uptake (1st Cut)		0.977**	$y = 1.3122x - 11.055 X_5$	$R^2 = 0.9548$
	Phosphorus uptake (1st Cut)		0.985**	$y = 0.1257x - 1.4769 X_6$	$R^2 = 0.9698$
	Zinc uptake (1st Cut)		0.605**	$y = 2.5535x - 36.326 X_7$	$R^2 = 0.3665$
	Protein content (1st Cut)		0.762**	$y = 0.0473x + 4.5163 X_8$	$R^2 = 0.58$
	Protein yield (1st Cut)		0.977**	$y = 8.2012x - 69.095 X_9$	$R^2 = 0.9548$
Dry fodder yield (2nd Cut)	Plant height (2nd Cut)		0.911**	$y = 1.0848x + 40.697 X_1$	$R^2 = 0.8306$
	Fresh weight (g m^{-1} row length) (2nd Cut)		0.932**	$y = 22.849x - 76.665 X_2$	$R^2 = 0.8683$
	Dry weight (g m^{-1} row length) (2nd Cut)		0.937**	$y = 9.6095x + 10.698 X_3$	$R^2 = 0.8777$
	Green fodder yield (2nd Cut)		1.00**	$y = 6.25x - 9E-13 X_4$	$R^2 = 1$
	Nitrogen uptake (2nd Cut)		0.997**	$y = 1.4711x - 6.8064 X_5$	$R^2 = 0.9944$
	Phosphorus uptake (2nd Cut)		0.993**	$y = 0.1393x - 1.3036 X_6$	$R^2 = 0.9854$
	Zinc uptake (2nd Cut)		0.637**	$y = 2.9289x - 35.281 X_7$	$R^2 = 0.4059$
	Protein content (2nd Cut)		0.942**	$y = 0.056x + 6.065 X_8$	$R^2 = 0.887$
	Protein yield (2nd Cut)		0.997**	$y = 9.1942x - 42.54 X_9$	$R^2 = 0.9944$

** Significant at 1% level of significance

Conclusion

Our result concluded that application of 75% RDF+FYM @ 10.0 t ha^{-1} +PSB+ $ZnSO_4$ @ 12.5 kg ha^{-1} was recorded significantly higher dry matter accumulation, leaf area index, crop growth rate and relative growth rate over rest of treatment but which was at par with 100% RDF + FYM @ 20 t ha^{-1}, and 75% RDF + FYM @ 20 t ha^{-1}. Positively linear correlation was recorded fodder yield with all growth, yield and quality parameter.

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