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Effect of seed biopriming with liquid bacterial inoculants on quality of forage oats (*Avena sativa*)

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India possesses the largest livestock in the world comprising 12.5% world's cattle and 56.7% buffalo (Anonymous 2013). However, the country is having only 4.9% cultivated area, with a total annual forage production of 978.7 million tonnes (525.5 Mt green and 453.2 Mt dry forage) while the annual forage requirement of forage is 1325.7 Mt (816.8 Mt green and 508.9 Mt dry forage) to nurture the existing livestock (Kushwaha *et al.* 2018). In addition, long-term animal feeding with poor quality of forage results in animal malnutrition. Hence, there is an urgent need to improve the tonnage as well as the quality of forage.

Forage quality is one of the crucial factors that determine the animal productivity. Therefore, they must feed on nutrient and energy-rich crop for their proper maintenance, growth and reproduction. Oats (*Avena sativa* L.) is an emerging forage crop for the winter season and ranks 6th in world cereal production after wheat, maize, rice, barley and sorghum (Joshi *et al.* 2015). The nutritional composition of the crop consists of fibre (30.44%), protein (9.23%), fat (3.56%), calcium (0.82%) and phosphorus (0.27%) (Hameed *et al* 2014), dry matter (18-23%) with *in vitro* dry matter digestibility of 70% (Phogat *et al.* 2003). Oats are fed to almost all animals as their straw is soft and of much better quality and it's a valuable forage for milch and draught animals. Thus, it can act as a promising forage crop to enhance the productivity of animals.

The nutrient requirement of oats is comparatively higher than the other forage crops of winter (*rabi*) season. To improve forage yield and quality, it is imperative to determine the fertilizer needs of the crop, which will not only increase the yield but also improve forage quality. However, indiscriminate and continuous use of chemical fertilizers reduces crop productivity and negatively influences the soil health. To combat these adverse effects to some extent, bacterial inoculants are promising choice to boost the yield and quality of the crops. The bacterial inoculants may be defined as a substance containing living micro-organisms that colonize the rhizosphere or inside the cell and promotes plant growth by plethora of mechanisms such as biological nitrogen fixation, phosphate solubilization, production of phytohormones and encouraging favorable plant-microbe symbiosis etc. Bacterial inoculants (biofertilizers) are also useful in nutrient uptake by fixing the nutrients in the soil that are subjected to loss or by solubilizing the nutrients that are not available to the plants due to their fixation in the soil surface. Keeping in view the importance of bacterial inoculants, the present study was conducted to evaluate the influence of liquid bacterial inoculants on the quality traits of forage oats.

The pure cultures of *Burkholderia seminalis, Azotobacter* sp.*, Stenotrophomonas maltophilia* and *Bacillus thaonhiensis* with potential plant growth promoting features (phosphate solubilization, indole acetic acid production, gibberellic acid and ammonia production) were procured from the School of Organic Farming, Punjab Agricultural University, Ludhiana, Punjab. The field experiments were conducted at Punjab Agricultural University, Ludhiana and Regional Research Station, Bathinda during the winter (*rabi*) season 2021–22. This experiment consisted of 12 treatments, viz. T_1, RDF (recommended dose of fertilizer); T_2, RDF + *B. thaonhiensis*; T_3, RDF + *Azotobacter* sp.; T_4, RDF + *B. seminalis*; T_5, RDF + *S. maltophilia*; T_6, RDF + *B. thaonhiensis* + *Azotobacter* sp.; T_7, RDF + *B. thaonhiensis* + *B. seminalis*; T_8, RDF + *B. thaonhiensis* + *S. maltophilia*; T_9, RDF + *Azotobacter* sp. + *B. seminalis*; T_{10}, RDF + *Azotobacter* sp. + *S. maltophilia*; T_{11}, RDF + *B. seminalis* + *S. maltophilia*; T_{12}, RDF + Consortium (Commercially available biofertilizer of PAU, Ludhiana) and replicated thrice.

The oat cultivar OL-11 was sown (25 kg/ha) in 20 cm row spacing and full phosphorus and half nitrogen dose were applied to the soil at the time of sowing and the remaining nitrogen was broadcast after 40 DAS of sowing. The seeds

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of oats were inoculated with the liquid bacterial inoculants of *Burkholderia seminalis, Azotobacter* sp.*, Stenotrophomonas maltophilia* and *Bacillus thaonhiensis* as per treatments. The liquid bacterial inoculants were used @100 ml/acre. For the treatments where two liquid bacterial inoculants were used, the liquid bacterial inoculants of respective bacteria were mixed in equal volume so as to make a constant volume, i.e. 100 ml/acre. At the crop maturity, the plant samples were dried in the sun and later oven-dried at 60ºC to obtain a constant weight. Then, the dried samples were finely grinded by a Willey grinder and the quality attributes i.e. Crude protein, *in vitro* Dry Matter Digestibility (IVDMD), Ash Content, Total Sugars, Total phenols and Acid detergent and Neutral detergent fibre were estimated by the method of AOAC (2007), Tilley and Terry Method (1963), AOAC (2007), Dubois *et al.* (1956), Swain and Hillis (1959) and Goering and VanSoest (1970) respectively. The data were analyzed by using randomized block design (RBD) and the significance difference was tested at five per cent level of probability. The correlation studies were performed by using corrplot library in R studio.

The experimental treatments differ significantly for the quality attributes at both the locations (Table 1). The maximum crude protein, IVDMD, ash Content, total sugars and total phenols were recorded with the treatment T_{11} and minimum by the treatment T_1 at Bathinda and Ludhiana, respectively. The treatment T_{11} showed significant improvement in the crude protein (9.23%), ADF content (33.10%), IVDMD (71.66%) and total sugars (19.32 mg/g) at Bathinda and at Ludhiana, showed significant improvement in crude protein (8.92%), ADF content (33.50%), ash content (11.80%), IVDMD (70.20%) and total sugars (18.93 mg/g). The improvement in the quality attributes with the bacterial inoculation might be attributed to the improved availability of nitrogen (N) and phosphorus (P) accumulation because of bacterial biological nitrogen fixation and phosphorus solubilizing activity. Nitrogen is an essential constituent of amino acids, it regulates the cellular metabolism of amino acids and proteins, provides more succulency, palatability and influences photosynthetic pigments that increases more sugars and secondary metabolites in plants. Likewise, Phosphorus also plays a vital role in the synthesis of RNA and ATP. The appraisal of the data revealed that the liquid bacterial inoculants significantly decreased the ADF and NDF (slowly or indigestible fibre fractions of the cell wall) with respect to control at Bathinda and Ludhiana respectively. The application of treatment T_{11} recorded the minimum ADF and NDF content while the maximum was obtained with the treatment T_1 at both the locations. The decrease in the fibre content with the application of liquid bacterial inoculants might be ascribed to the higher nutrient supply (N, P and K) that accelerates the formation of proteins from the manufactured carbohydrates and thereby decreases the cellulose and lignin content-that are the major constituents of fibre (Tiwana *et al.* 2003).

Similarly, the maximum yield was observed in the treatment T_{11}. The percentage improvement in the green and dry fodder yield by the application of treatment T_{11}, RDF + *B. seminalis* + *S. maltophilia* was 12.07 and 14.69 over the treatment T_1, Control in the pooled analysis.

The correlation analysis was carried out to evaluate the degree of association between the quality attributes at both locations (Fig 1). All the treatments of liquid bacterial inoculants showed a significant strong positive correlation of CP with IVDMD (0.94), ash content (0.96), total sugars (0.90) and total phenols (0.90) while a negative strong correlation with ADF (-0.92) and NDF (-0.94) at Bathinda and Ludhiana respectively. Arora *et al.* (2022) also noticed

Table 1 Effect of liquid bacterial inoculants on the quality attributes of forage oats at Bathinda and Ludhiana, Punjab

Treatment	CP (%)		IVDMD (%)		ADF (%)		NDF (%)		Ash (%)		Total Sugars (mg/g)		Total Phenols (mg/g)	
	BTI	LDH	BTI	LDH	BTI	LDH	BTI	LDH	BTI	LDH	BTI	LDH	BTI	LDH
T_1	7.84	7.44	64.20	63.68	37.20	37.83	56.36	56.90	10.48	10.42	14.25	14.03	3.15	3.06
T_2	8.21	8.00	65.53	65.53	36.33	36.33	55.16	55.33	11.09	10.82	16.85	16.07	3.20	3.13
T_3	7.97	7.65	65.08	65.06	36.58	36.83	56.00	55.46	11.06	10.79	16.01	16.07	3.17	3.12
T_4	8.23	8.09	67.20	66.46	35.03	35.80	54.40	54.63	11.16	10.90	17.27	16.43	3.23	3.17
T_5	8.21	8.00	66.13	66.13	35.33	35.96	54.93	55.06	11.20	11.11	17.05	16.35	3.21	3.13
T_6	8.28	8.10	67.46	67.33	34.63	35.80	54.20	54.40	11.22	11.14	17.33	17.22	3.24	3.21
T_7	8.99	8.83	69.46	69.27	33.13	33.56	52.10	52.40	11.76	11.74	18.93	18.28	3.31	3.29
T_8	8.65	8.50	68.53	68.28	33.22	33.63	52.46	52.59	11.63	11.31	18.42	17.27	3.30	3.26
T_9	8.36	8.22	68.33	68.13	33.90	34.13	53.13	53.70	11.33	11.30	18.79	17.47	3.28	3.25
T_{10}	8.56	8.40	68.13	68.00	34.20	34.60	53.33	53.86	11.61	11.30	18.67	17.36	3.27	3.21
T_{11}	9.23	8.92	71.66	70.20	33.10	33.50	51.46	51.76	12.16	11.80	19.32	18.93	3.33	3.31
T_{12}	7.93	7.49	64.73	64.53	36.83	37.03	56.16	56.20	10.90	10.62	15.79	15.68	3.16	3.07
SEm	0.12	0.13	0.63	0.57	0.43	0.43	0.47	0.45	0.12	0.12	0.43	0.37	0.01	0.02
CD (P=0.05)	0.42	0.57	3.91	2.40	2.43	1.42	NS	NS	NS	0.78	0.90	1.16	NS	NS

Refer to the methodology for treatment details.

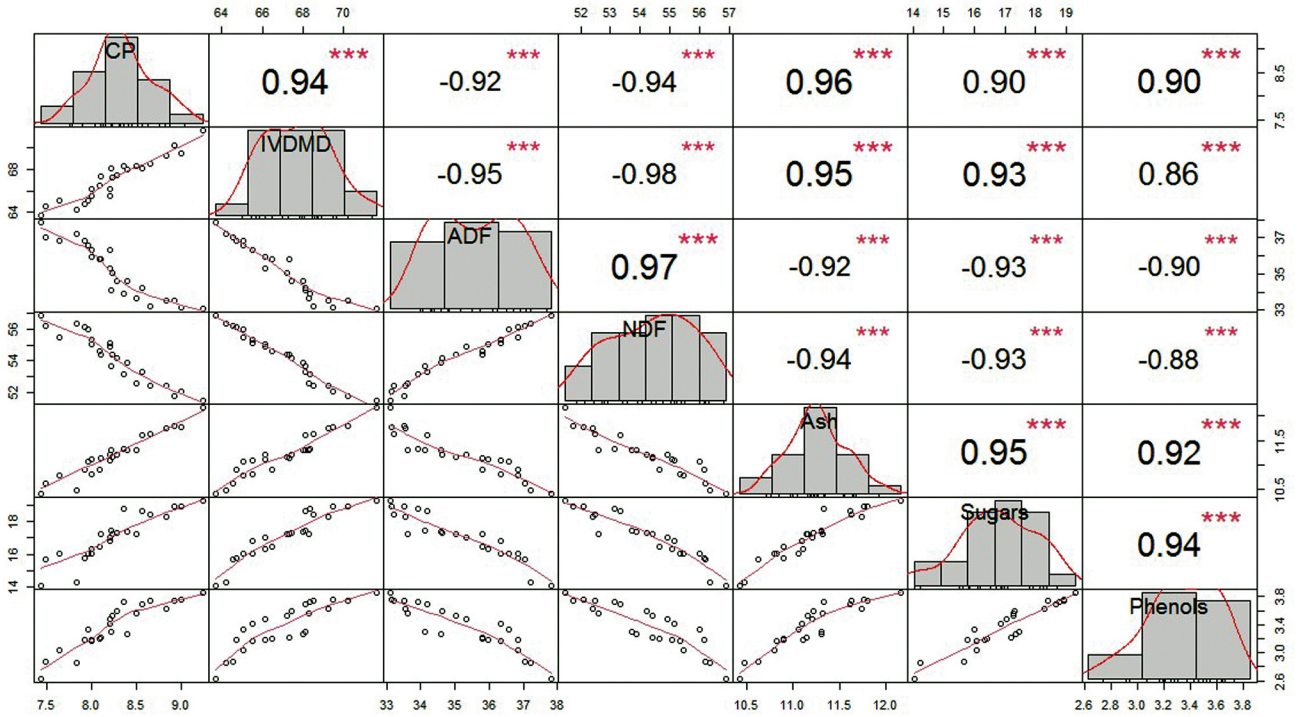

Fig 1 Correlation between the quality attributes of forage oats as affected by liquid bacterial inoculants at Bathinda and Ludhiana.

a positive correlation between CP with IVDMD, total sugars and ash content and negative with ADF and NDF in forage pearl millet. From this study, it can be suggested that an increase in the desirable attributes could simultaneously decreased the undesirable characteristics. Therefore, it is expected that liquid bacterial inoculants could play a vital role in improving the quality of forage crops.

SUMMARY

The application of liquid bacterial inoculants along with the recommended dose of chemical fertilization improved the quality of forage oats at Bathinda and Ludhiana. The best quality attributes were observed with the treatment T_{11} (RDF + *B. seminalis* + *S. maltophilia*) with significant improvement in the crude protein (9.23 and 8.92%), ADF content (33.10 and 33.50%) and IVDMD (71.66 and 70.20%) at Bathinda and Ludhiana respectively. Further, correlation studies showed positive and significant correlation between ADF and NDF and the negative correlation with the rest of the quality attributes. Therefore, it is believed that liquid bacterial inoculants can play a significant role in ameliorating the forage oats quality, thus can help to enhance the overall animal productivity. In addition, potential of these liquid bacterial inoculants can be explored in integrated nutrient management or organic cultivation of forage oats as well as in other crops.

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