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Research article

Legume integration and zinc fortification enhanced yield and quality of maize-based forage systems

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Abstract

The synergistic effects of maize-legume intercropping and zinc fortification were studied on forage yield, quality and profitability in the temperate climate of Kashmir in the years 2020 and 2021. Treatment sets included five cropping systems viz. sole maize, sole cowpea, sole soybean, maize + cowpea (2:1), maize + soybean (2:1) and three zinc levels; Zn0= control, Zn1 = 20 kg $ZnSO_4$ ha^{-1} (basal soil application) and Zn2 = 20 kg $ZnSO_4$ ha^{-1} (basal soil application) + 0.5% $ZnSO_4$ spray twice (30 DAS and 50 DAS). Among the cropping systems, sole maize recorded the highest green (45.57 t $ha^{-1)}$ and dry (13.82 t ha^{-1}) fodder yield, followed by maize + soybean intercropping. Soil + foliar zinc application (Zn2) recorded an increase of 10% in green fodder and a 33% increase in dry fodder over control (Zn0). Maize + legume intercropping significantly increased dry matter intake (2.14 and 2.13%), digestible dry matter (62.62 and 61.99%) and total digestible nutrients (64.22 and 63.77%) in maize + cowpea and maize + soybean intercropped systems, respectively, over sole maize. Maize + legume intercropping also improved relative feed value over sole maize and produced good quality fodder. Zinc fertilization significantly increased relative feed value from 106.30% in Zn0 to 111.61% in Zn1 and 116.38% in Zn2. Application of $ZnSO_4$ @ 20 kg as soil application + 0.5% $ZnSO_4$ sprayed twice at 30 and 50 DAS to maize + soybean/cowpea intercropping (2:1) system resulted in enhanced yield, better quality and higher profitability.

Keywords: Fodder yield, Intercropping, Legumes, Maize, Quality, Zinc fortification

Introduction

Fodder deficiency is identified as one of the major constraints in achieving the desired level of livestock productivity (Arif *et al*., 2023). The actual milk production potential of livestock in India is not realized because of the poor quality of available fodder and the costly nature of concentrate feeds (Mahanta *et al*., 2020; Manoj *et al*., 2022). Thus the forage that is nutritionally rich and has a high dry matter intake, digestibility, and low fiber content would help to lower the cost of livestock feeding and increase animal productivity (Chaudhary *et al*., 2012; Prajapati *et al*., 2023). Among forage cereals, maize (*Zea mays* L.) is the most versatile crop, having high yield potential and wider adaptability in diverse ecologies. However, it produces forage with low protein content and is hence considered low-quality forage. On the other hand, legume monocultures are a rich protein source but have low water-soluble carbohydrate and dry matter yields (Alvarez *et al*., 2020). In this context, cereal–legume mixed cropping systems are a viable option to meet the quality forage and fodder demand. Forage cultivation from cereal + legume mixed cropping systems can ensure equitable and judicious utilization of resources, increase fodder productivity, improve protein content and other quality parameters (Zhang *et al*., 2015) and produce highly nutritive forage.

Cowpea [*Vigna unguiculata* (L.) Walp] is an important fodder crop due to its short duration, high yield and quick growth along with high protein content and palatability. Leguminous cowpea is mostly indeterminate in growth and thus maintains forage quality over longer periods (Bimbraw, 2013), is a good source of protein and can help to lower the cost of fodder production (Gupta *et al*., 2019). Soybean [*Glycine max* (L.) Merrill] is also an annual legume with a long history of being grown as a forage crop. Harvesting of soybean forage at certain growth stages has been considered highly suitable for animal feed, as it has high protein, greater digestible energy and low fiber content at these stages (Kulkarni *et al*., 2018). Maize and soybean are the nitrogen-consuming C4 and nitrogen-fixing C3 crops, respectively, grow in the same season, make judicious use of resources (Yang *et al.*, 2015) and result in quality fodder.

Zn, as an important nutrient for plants, also plays a critical role in quality fodder production (Mahdi *et al*., 2012; Ramakrishna *et al.*, 2022). Like other crops, lower levels of Zn cause a reduction of yield in fodder crops and a deficiency of zinc affects animal health and milk production severely. Direct linkages between available micronutrients in the soil and their contents in forage and fodders have been widely studied and clearly established (Nube and Voortman, 2006). Zinc deficiency in soil is a worldwide nutritional problem in crop production. Approximately 50% of Indian soils are deficient in Zn and as such, there is a necessity to improve the Zn availability in the soil. In Kashmir valley also, the Diethylene triamine pentaacetic acid (DTPA)-extractable Zn has been reported to vary from 0.35 to 0.65 mg kg^{-1} in high altitude soils while benchmark soils of Kashmir are deficient (0.15–1.00 mg kg^{-1}) in zinc (Jalali *et al*., 1989 and Kakar *et al*., 2018). Hence, in addition to increasing crop yields, zinc fertilization or agronomic bio-fortification of Zn in crops may also address nutritional and micronutrient dietary concerns in the plant-animal-human system (Cakmak, 2009). Keeping in view the aforementioned points, the present study was conducted to evaluate the synergistic effects of maize-legume intercropping and zinc fortification on forage yield, quality and profitability.

Materials and Methods

Study site: The experimental investigations were carried out at ICAR-IGFRI, Regional Research Station, Srinagar, in the *kharif* seasons of 2020 and 2021. The experimental site is situated in the temperate zone of Jammu and Kashmir and lies between 33° 59′ 23.9″ N latitude and 74° 48′ 0.2″E longitude at an altitude of 1650 m above the mean sea level. The total rainfall received during the period of crop growth (April-July) was 29.49 cm and 58.07 cm during 2020 and 2021, respectively. The minimum temperature ranged from 6.21 to 17.00^{0}C during 2020 and 5.60 to 19.99^{0}C during 2021; the maximum temperature ranged from 19.21 to 33.21^{0}C and 17.07 to 33.29^{0}C during 2020 and 2021, respectively. The main soil type was designated as well-drained sandy clay loam in texture having a normal pH of 6.9, bulk density (1.23 Mg m^{-3}) and electrical conductivity (0.28 dS m^{-1}). The mineral nutrient analysis indicated medium organic carbon (0.72%), available nitrogen (295 kg/ha), available phosphorus (16.7 kg/ha), high available potassium (364.5 kg/ha) and low zinc (0.36 ppm) levels in the soil.

Experimental details: The fodder maize variety SFM-1 developed by SKUAST-K was evaluated along with cowpea (Shalimar cowpea-1) and soybean (Shalimar Soybean-3), under the present study. The experiment was laid out in a Factorial Randomized Block Design with two factors and each treatment was replicated thrice. Treatment combinations included five cropping systems, i.e., sole maize, sole cowpea, sole soybean, maize + cowpea (2:1), maize + soybean (2:1) and three zinc levels; Zn0= control or no zinc application, Zn1 = 20 kg $ZnSO_4$ ha^{-1} (basal soil application) and Zn2 = 20 kg $ZnSO_4$ ha^{-1} (basal soil application) + 0.5% $ZnSO_4$ spray twice (30 DAS and 50 DAS). Seeds at recommended rates were sown at 30 cm row spacing.

***Quality parameters analysis*:** Plant samples from each treatment were collected at harvest, oven-dried, powdered and used for the analysis of quality parameters. All the oven-dried samples were ground in a Willey mill using a 2 mm sieve. In the case of intercropping systems, the plant samples were mixed as per the row proportion adopted in the treatment. Total N was determined using the Kjeldahl method and crude protein was calculated by multiplying the N content by 6.25. Plant and soil nutrient status results have already been published (Mir *et al*., 2024). Neutral and acid detergent fibers (NDF and ADF) were determined according to Van Soest's (1991) procedure. Dry matter intake (DMI), digestible dry matter (DDM), relative feed value (RFV), relative forage quality (RFQ), total digestible nutrients (TDN), net energy for lactation (NEL) and digestible feed energy (DFE) were estimated from the measured variables according to the following equations adapted from Lithourgidis *et al*. (2006); Kumar *et al.* (2016) and Manoj *et al*. (2021).

Total digestible crude protein yield = (0.97 × CPY) – 0.67
Dry matter intake, DMI (%) = 120/NDF
Digestible dry matter, DDM (%) = 88.9- (0.779 × ADF)
Relative feed value, RFV (%) = (DDM × DMI)/1.29
Relative forage quality, RFQ (%) = (TDN × DMI)/1.23
Total digestible nutrients, TDN (%) = 87.84- (0.7 × % ADF)
Net energy for lactation, NEL (M cal kg^{-1}) = 1.5 – (ADF × 0.0267)
Digestible feed energy, DFE (M cal kg^{-1}) = 4.4 × (TDN/100)

Statistical analyses: The data collected on different parameters were subjected to statistical analysis after averaging the two-year data. The software package used for the analysis of data was 'OPstat,' wherever the 'F' test was found significant at 5% probability; critical difference values were used to compare the treatment means (Sheoran *et al.*, 1998).

Results and Discussion

Yield studies

***Fodder yield*:** Among the cropping systems, sole maize recorded the highest green (45.57 t ha^{-1}) and dry (13.82 t ha^{-1}) fodder yield, followed by maize + soybean intercropping, which recorded 42.90 and 12.64 t ha^{-1} green and dry fodder yield, respectively (Table 1). Zinc fertilization significantly increased the fodder yield of all the crops. Soil + foliar zinc application (Zn2) recorded a yield increase of 10% in green and a 33% increase in dry fodder yield over control (Zn0).

Fodder yield is ultimately the most important determinant of the efficacy of multiple agronomic practices. In addition to the main crop, the associated intercrops also determine the total yield in an intercropping system. In the present investigation, sole maize recorded the highest green and dry fodder yields, followed by maize + soybean intercropping. Maize, with a higher biomass potential, when intercropped with legumes (cowpea and soybean) in the replacement series, loses on plant population, leading to a yield reduction. Higher stover yield from sole cropping as compared to intercropping might be due to less interspecific competition and increased habitation population (Singh *et al*., 2006). They also reported a higher stover yield of sole soybean (2.07 t ha^{-1}) over sole cowpea (1.13 t ha^{-1}). Lower production potential of legumes compared to maize coupled with mutual shading of intercrop components reduces fodder yields of grass-legume intercropped systems compared to sole grass (maize) based production systems. Baghdadi *et al.* (2016) reported higher forage dry matter with maize and maize + soybean intercropping and lowest with soybean monocropping. Htet *et al.* (2017) reported that monocrop maize had a higher biomass yield (46.2 t ha^{-1}) than other intercropped fodder.

Soil + foliar application of zinc (Zn2) recorded a yield increase of 10% in green and 33% in dry fodder over control or no zinc application. The favorable impacts of zinc resulted in taller plants, an increase in leaf area, leaf-stem ratio and dry matter production and hence higher fodder yield. The increase in yield might be because of the importance and role of zinc as a cofactor of enzymes and proteins involved in cell division, photosynthesis, hormone production, cellular growth, protein synthesis, differentiation and metabolism and extensive plant root system, which results in vigorous plant growth (Marschner, 1986 and Ramakrishna *et al.,* 2022). The improved fodder yield due to zinc application has also been reported by Kumar *et al.* (2017) in fodder maize and Porwal *et al.* (2024) in oats.

Table 1. Effect of different cropping systems and zinc levels on total green and dry fodder yield

Treatment	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})
Cropping system		
Maize	45.57a	13.82a
Cowpea	22.46d	5.38e
Soybean	25.58d	6.61d
Maize + Cowpea	41.18c	11.89c
Maize + Soybean	42.90b	12.64b
SEM ±	0.19	0.20
CD (P≤ 0.05)	0.55	0.59
Zinc		
Zn0	33.71c	8.53c
Zn1	35.92b	10.30b
Zn2	36.98a	11.38a
SEM ±	0.14	0.15
CD ($p \leq 0.05$)	0.43	0.46

Fodder quality parameters

***Crude protein*:** Average crude protein content varied from 9.09% in sole maize to 13.86% in cowpea. Maize + cowpea intercropping increased protein content by about 26.40%, while maize + soybean intercropping increased protein content by 22% over sole maize (Table 2). Double zinc application through soil and foliar applications resulted in the highest crude protein content (11.91%), which was 3.02% higher than the control (Zn0).

Maize + soybean forage samples recorded the highest crude protein yield of 12.07 q $ha^{-1}$and DCPY of 11.03 q ha^{-1}, followed by maize + cowpea recording 11.83 and 10.80 q ha^{-1}CPY and DCPY, respectively. Zinc fertilization also had a pronounced effect on crude protein yield. Soil + foliar application of zinc (Zn2) recorded the highest crude protein yield (11.35 q $ha^{-1)}$ and DCPY (10.30 q ha^{-1}). Further, Zn2 increased CPY by 13.27% over Zn1 and 42.05% over no zinc application.

Intercropping of maize and legumes resulted in increased crude protein yield over maize and legumes. Higher protein yield in these treatments may be due to higher dry matter and protein content, as crude protein yield is a product of the protein content and dry matter yield. The higher crude protein content and yield with legume and maize + legume systems might be attributed to nitrogen fixation by legume crops that led to more availability and uptake of nitrogen and, thus, higher protein biosynthesis (Manoj *et al.,* 2022). Saad *et al.* (2016) and Htet *et al.* (2017) have reported higher protein yield with maize + cowpea and maize + soyabean systems, respectively, over either cereal or a legume monocrop system.

The application of zinc also increased crude protein content and its yield significantly. Zinc increases N content and uptake due to synergistic effects on N uptake

Table 2. Effect of different cropping systems and zinc levels on crude protein content, crude protein yield, digestible crude protein yield, dry matter, ash and fiber fractions

Treatment	Crude protein (%)	Crude protein yield (q ha^{-1})*	Digestible crude protein yield (q ha^{-1})	Dry matter (%)	Ash (%)	Crude fiber (%)	NDF (%)	ADF (%)
Cropping system								
Maize	9.09e	11.06c	10.00c	26.12a	8.16e	30.29a	62.26a	35.99a
Cowpea	13.86a	6.42e	5.55e	20.82de	11.50ab	25.08de	45.01e	31.67cde
Soybean	13.27b	7.55d	6.65d	21.67d	11.53a	26.19d	46.67d	32.29cd
Maize + Cowpea	11.49c	11.83ab	10.80ab	24.88abc	10.10c	28.29abc	55.84bc	33.13bc
Maize + Soybean	11.09d	12.07a	11.03a	25.51ab	9.99cd	29.04ab	56.13b	34.13b
SEM ±	0.06	0.22	0.21	0.88	0.32	0.66	0.50	0.57
CD ($p \leq 0.05$)	0.19	0.64	0.62	2.56	0.95	1.93	1.46	1.68
Zinc								
Zn0	11.56c	7.99c	7.07c	22.69c	9.37c	28.47	54.57a	34.94a
Zn1	11.80ab	10.02b	9.04b	23.82b	10.53ab	27.77	53.12b	33.27b
Zn2	11.91a	11.35a	10.30a	25.12a	10.87a	27.09	51.85c	32.13bc
SEM ±	0.05	0.17	0.16	0.23	0.25	0.51	0.39	0.44
CD ($p \leq 0.05$)	0.15	0.50	0.48	0.68	0.73	NS	1.13	1.30

*10 quintals (q) = 1 ton (t)

and its involvement in nitrogen metabolism (Rathore *et al*., 2015). Zinc is essential for the functioning and stability of genetic material that plays a direct role in amino acid synthesis resulting in improved protein content. Kumar *et al*. (2017) reported an increase of 45.50% in crude protein content with zinc application in fodder maize.

***Dry matter, ash and fiber contents*:** Sole maize recorded the highest dry matter percentage (26.12%), crude fiber (30.29%), NDF (62.26%) and ADF (35.99%) contents, whereas legume monocultures recorded higher ash (11.50 and 11.53%) and lower fiber fractions. Zinc application increased dry matter and ash contents and reduced fiber percentages significantly over no zinc application (Table 2).

Maize with higher yield potential produces a higher dry matter percentage compared to legumes. Zinc application also increased dry matter percentage significantly. Zinc increases growth and dry matter accumulation, resulting in a higher dry matter percentage. Higher ash in legumes may, in part, be because of their higher mineral contents. Manoj *et al.* (2021) reported higher dry matter and lower ash percentage with sole maize over sole cowpea. Zinc fertilization also increased ash percentage, which could be because of the higher growth and dry matter accumulating capacity of the plants and the synergistic effect of zinc on nitrogen, potassium and other micronutrients also enhances ash content of the fodder crops (Jamil *et al*., 2015). Kumar *et al*. (2017) in fodder maize and Khinchi *et al*. (2018) in pearl millet have reported higher dry matter and ash contents with zinc application.

Higher CF, NDF and ADF contents for cereal monocrop compared to sole legumes and cereal-legume mixtures have also been reported by Baghdadi *et al*. (2016) and Manoj *et al.* (2022). Application of zinc reduced crude fiber, NDF and ADF contents significantly as compared to control (Zn0). Lower CF, NDF and ADF values with zinc application could be attributed to higher protein synthesis and lower soluble carbohydrate contents. Significant reduction in fiber content with zinc application has been reported by Kumar *et al*. (2017) and Kumar and Ram (2021) in maize and by Manisha *et al.* (2021) in cowpea fodder.

Estimated fodder quality and digestibility parameters

***Fodder quality*:** DMI varied from 1.92% in sole maize to 2.66% in sole cowpea (Table 3). Intercropped systems recorded significantly higher DMI (2.13 and 2.14%) over sole maize (1.92). Intercropping of maize with legumes also improved DDM over sole maize. Zinc application significantly increased both DMI (2.22–2.35%) and DDM (61.56–63.64%) over control. The two legumes recorded higher RFV and RFQ as compared to maize and maize-legume systems. Sole cowpea recorded significantly higher RFV (132.74%) and RFQ (142.37%). Sole maize recorded the lowest RFV (90.79%) and RFQ (98.04%). Maize + legume intercropping significantly improved RFV (103.09 and 104.12%) and RFQ (110.46 and 112.05%)

Table 3. Effect of different cropping systems and zinc levels on estimated quality parameters (two-year mean)

Treatment	Dry matter intake (%)	Digestible dry matter (%)	Relative feed value (%)	Relative forage quality (%)	TDN (%)	NE_L (M cal kg^{-1})	DF_E (M cal kg^{-1})
Cropping system							
Maize	1.92e	60.84de	90.79e	98.04e	62.63e	0.53e	2.74e
Cowpea	2.66a	64.22a	132.74a	142.37a	65.67a	0.65a	2.88a
Soybean	2.57b	63.74ab	126.99b	136.34b	65.23ab	0.63ab	2.87ab
Maize + Cowpea	2.14c	62.62bc	104.12c	112.05c	64.22bc	0.59bc	2.82bc
Maize + Soybean	2.13cd	61.99cd	103.09cd	110.46cd	63.70cd	0.57cd	2.81bcd
SEM ±	0.02	0.44	1.19	1.23	0.40	0.01	0.01
CD ($p \leq 0.05$)	0.06	1.30	3.48	3.58	1.17	0.04	0.05
Zinc							
Zn0	2.22c	61.56c	106.30c	114.60c	63.27c	0.55c	2.77c
Zn1	2.28b	62.84ab	111.61b	120.00b	64.42ab	0.60ab	2.83ab
Zn2	2.35a	63.64a	116.38a	124.95a	65.15a	0.62a	2.86a
SEM ±	0.01	0.34	0.92	0.95	0.31	0.01	0.01
CD ($p \leq 0.05$)	0.04	1.01	2.69	2.78	0.90	0.03	0.04

over sole maize and produced good quality fodder. Zinc fertilization significantly increased RFV from 106.30 to 116.38% and RFQ from 114.60 to 124.95% in control (Zn0) and soil + foliar application (Zn2), respectively.

***Digestibility and energy attributes*:** Total digestible nutrients (TDN%), net energy for lactation (NEL) and digestible feed energy (DFE) values were found higher in legume monocultures, intermediate in maize-legume intercropping systems and lowest in sole maize (Table 3). TDN ranged from 62.63 to 65.67%, NEL from 0.53 to 0.65 M cal kg^{-1} and DFE from 2.74 to 2.88 M cal kg^{-1} for sole maize and cowpea, respectively. Intercropping of maize with cowpea and soybean resulted in improved TDN, NEL and DFE parameters of forage samples over maize forage. Zinc application resulted in higher TDN (63.27–65.15%), NEL (0.55–0.62) and DFE (2.77–2.86 M cal kg^{-1}) with soil + foliar application compared to control.

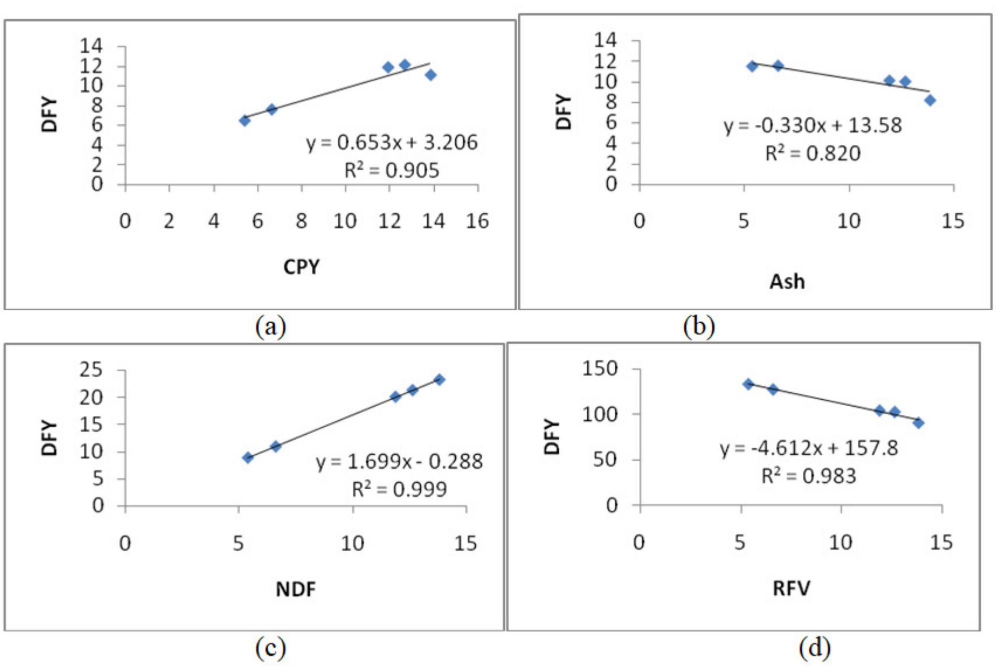

Fig 1. Linear regression line among cropping systems between dry fodder yield vs. (a) CPY (b) ash% (c) NDF% (d) RFV%

Table 4. Effect of different cropping systems and zinc levels on economic parameters

Treatment combination		Cost of cultivation ₹ ha^{-1}	Gross returns ₹ ha^{-1}	Net returns ₹ ha^{-1}	B:C ratio
Maize	Zn0	34179	87200	53020	1.54
	Zn1	35259	92100	56840	1.60
	Zn2	35841	94140	58299	1.62
Cowpea	Zn0	29589	51525	21936	0.74
	Zn1	30669	57400	26731	0.86
	Zn2	31252	59537	28285	0.88
Soybean	Zn0	29990	59512	29522	0.98
	Zn1	31070	65037	33967	1.08
	Zn2	31652	67312	35795	1.13
Maize + cowpea	Zn0	34003	82122	48119	1.41
	Zn1	35083	86680	51597	1.46
	Zn2	35666	89010	53344	1.49
Maize + soybean	Zn0	34138	86147	52009	1.52
	Zn1	35218	91225	56007	1.58
	Zn2	35801	93585	57784	1.61

*Input cost: Maize seed Rs 45/kg; Cowpea Rs 60/kg; Soybean Rs. 70/kg; Rate of green fodder: Maize Rs. 2/kg; Legumes = Rs. 2.5/kg

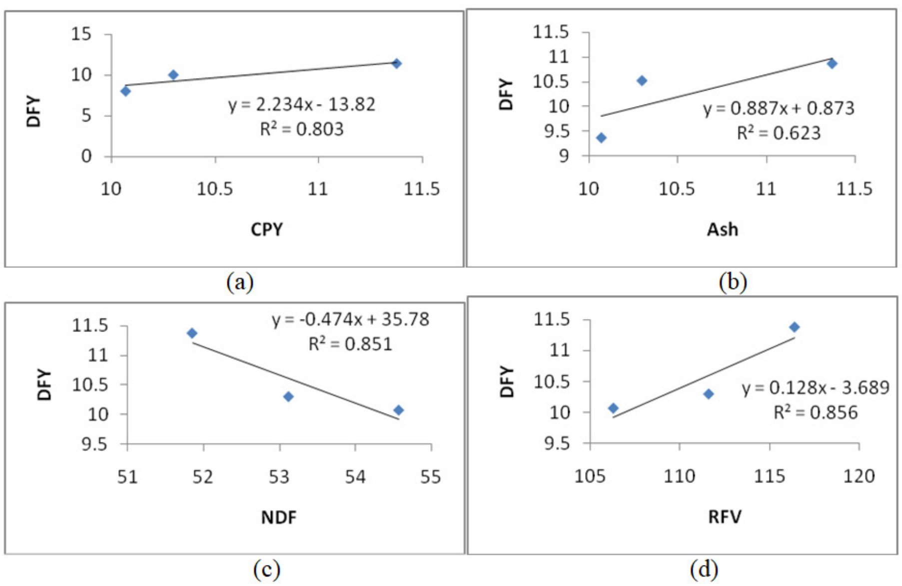

Fig 2. Linear regression line among zinc levels between dry fodder yield vs. (a) CPY (b) ash% (c) NDF% (d) RFV%

Both the legumes recorded higher dry matter intake (DMI), digestible dry matter (DDM), total digestible nutrients (TDN), net energy for lactation (NEL), digestible feed energy (DFE), relative feed value (RFV) and relative forage quality (RFQ) over sole maize. Intercropped treatments significantly improved all the estimated quality and digestibility parameters over sole maize. Lower intake, digestibility and energy values for sole maize might be due to more fiber and low *in vitro* nutrient digestibility compared to legumes. NDF and ADF are used to predict the dry matter intake and digestible dry matter, respectively. Dry matter intake is negatively correlated with NDF, whereas digestible dry matter is negatively correlated with ADF. The results further indicated that the two legumes with mean RFV of 132.74% (cowpea) and 126.99% (soybean) were categorized as premium quality, maize + cowpea (RFV 104.12%) and maize + soybean (RFV 103.09%) as good and sole maize (RFV 90.79%) as fair quality fodder. TDN content of forage is inversely related to its ADF concentration; therefore, as a concentration of ADF increases, there is a decline in TDN content, which limits an animal's ability to utilize the nutrients present in the forage (Carmi *et al*., 2006). Arif *et al*. (2023) reported higher estimated quality parameters in pearl millet + cluster bean intercropping with a higher proportion of legume. The fodder with higher protein and lower fiber fractions makes it more palatable and thereby improves the digestibility for livestock (Manoj *et al*., 2021). Kaithwas *et al*. (2020), Manoj *et al*. (2021) and Arif *et al*. (2023) reported higher fiber fractions, lower intake and lower digestibility with cereal fodder and vice-versa with legume and cereal-legume mixtures.

The application of zinc also influenced DMI, DDM and RFV significantly. Reduction in fiber values and enhancement of protein content of fodder with soil and foliar Zn application resulted in higher intake and digestibility. Kumar and Ram (2021) and Manisha *et al.* (2021) have reported higher forage intake and digestibility parameters with zinc application in fodder maize and fodder cowpea, respectively, over no zinc application.

Regression and correlation studies on fodder yield and quality parameters: With respect to cropping systems, dry fodder yield showed a significantly positive correlation with CPY and NDF contents and a negative correlation with ash and RFV percentages (Fig 1-2). The R2 for dry fodder yield with CPY (0.90), ash (0.82), NDF (0.99) and RFV (0.98) were highly significant and thus variations in CPY, ash, NDF and RFV could be explained to the extent of 90, 82, 99 and 98%. Among the different zinc levels, CPY, ash and RFV percentages showed a positive correlation, while NDF (%) showed a negative correlation with dry fodder yield.

Economic analysis: Economic evaluation plays a vital role in knowing the practical feasibility of any package of practice. The prevailing costs of inputs such as seed, fertilizer and, manures, mechanical and manual labor requirements were used for the evaluation. Results (Table 4) indicated that different treatment combinations influenced gross returns, net returns and benefit-cost ratio. The highest gross returns (₹94140 ha^{-1}), net returns (₹58299 ha^{-1}), and B: C ratio (1.62) were realized with a treatment combination of sole maize + Zn2 closely followed by the treatment combination of maize + soybean + Zn2 with gross returns (₹93585 ha^{-1}), net returns (₹57784 ha^{-1}) and B: C ratio (1.61). The higher returns were, of course, a result of higher productivity. Rehman and Raja (2020) reported a higher B: C ratio (2.43) with sorghum, followed by sorghum + soybean (2:1). Meena *et al*. (2023) reported the highest B: C ratio (3.77) with sole napier-bajra hybrid grass compared to other mono and multicrop systems.

Zinc application increased fodder yield significantly without much investment, hence leading to increased net returns and B: C ratio. Peddapuli *et al*. (2021) have also reported higher net returns and B: C ratio with zinc application in sweet corn.

Conclusion

In conclusion, the findings of the study revealed that maize-legume intercropping coupled with zinc application resulted in enhanced fodder yield and quality. Considering both fodder yield and quality, it is recommended that the maize-soybean/cowpea intercropping (2:1) system be adopted along with the application of zinc fertilization ($ZnSO_4$ @ 20 kg as soil application and 0.5% $ZnSO_4$ sprayed twice at 30 to 35 and 50 days after sowing) for achieving higher fodder yield, quality, increased profitability and soil sustainability.

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References

Alvarez, S., P. Méndez and A. Martínez-Fernández. 2020. Silage fermentation and chemical composition of *Chamaecitysus proliferus* var. *Palmensis* (Tagasaste) and *Pennisetum sp.* (Mar alfalfa) using different additives. *Journal of Animal and Plant Science* 31: 929-936.

Antwi, C., E.L.K. Osafoa, D.S. Fisher, H.M. Yacout, A. Donkoh, H. Adu-Dapaah, A. A. Hassan, S. M. M. Sobhy and A. Z. M. Salem. 2007. Characterization of four improved dual purpose varieties of cowpea. *Journal of Ghanaian Animal Sciences* 6: 11-16.

Arif, M., R. Pourouchottamane, A. Kumar, D. L. Gupta and B. Rai. 2023. Evaluation of different row proportions in intercropping of pearl millet and cluster bean for forage yield and quality. *Range Management and Agroforestry* 44: 126-133.

Baghdadi, A., R. A. Halim, A. Ghasemzadeh, M. Ebrahimi, R. Othman and M. M. Yusof. 2016. Effect of intercropping of corn and soybean on dry matter yield, nutritive value of forage corn. *Legume Research* 39: 976-981.

Bimbraw, A. S. 2013. Production, utilization and conservation of forage crops in India. 1st edn. Jaya Publishing House, Delhi.

Cakmak, I. 2009. Enrichment of fertilizers with zinc: An excellent investment for humanity and crop production in India. *Journal of Trace Elements in Medicine and Biology* 23: 281-289.

Carmi, A., Y. Aharoni, M. Edelstein, N. Umiel, A. Hagiladi, E. Yosef, M. Nikbachat, A. Zenou and J. Miron. 2006. Effects of irrigation and plant density on yield, composition and in vitro digestibility of a new forage sorghum variety Tal, at two maturity stages. *Animal Feed Science and Technology* 131: 120-132.

Chaudhary, D.P., A. Kumar, S. S. Mandhania, P. Srivastava and R. S. Kumar. 2012. Maize as fodder? An alternative approach. Technical Bulletin 2012/04. Directorate of Maize Research, Pusa Campus, New Delhi. pp. 32.

Gupta, M., S. Bhagat, S. Kumar, S. Kour and V. Gupta. 2019. Production potential and quality of fodder maize (*Zea mays*) varieties under varying intercropping systems with cowpea (*Vigna unguiculata*). *Range Management and Agroforestry* 40: 243-249.

Htet, M. N. S., R. N. Soomro and H. Bo. 2017. Effects of different planting pattern of maize (*Zea mays* L.) and soybean (*Glycine max* (L.) Merrill) intercropping in resource consumption on fodder yield and silage quality. *American Journal of Plant Sciences* 8: 666-679.

Jalali, V. K., A. R. Talib and P. N. Takkar. 1989. Distribution of micronutrients in some benchmark soils of Kashmir at different altitudes. *Journal of the Indian Society of Soil Science* 37: 465-469.

Jamil, M., A. Sajad, M. Ahmad, M. F. Akhtar, G. H. Abbasi and M. Arshad. 2015. Growth, yield and quality of maize (*Zea mays L.)* fodder as influenced by nitrogen-zinc interaction in arid climate. *Pakistan Journal of Agricultural Sciences* 52: 637-643.

Kaithwas, M., S. Singh, S. Prusty, G. Mondal and S. S. Kundu. 2020. Evaluation of legume and cereal fodders for carbohydrate and protein fractions, nutrient digestibility, energy and forage quality. *Range Management and Agroforestry* 41: 126-132.

Kakar, R., A. Sultanpuri, H. S. Sheoran and D. Tripathi. 2018. Soil micronutrient status assessment in North Western Himalayas of India. *Chemical Science Review and Letters* 7: 83-87.

Khinchi, V., S. M. Kumawat and M. Arif. 2018. Forage growth and quality of pearl millet (*Pennisetum americanum* L.) as influenced by nitrogen and zinc levels in hyper arid region of Rajasthan. *Range Management and Agroforestry* 39: 237-242

Kulkarni, K. P., R. Tayade, S. Asekova, J. T. Song, J. G. Shannon and J. D. Lee. 2018. Harnessing the potential of forage legumes, alfalfa, soybean and cowpea for sustainable agriculture and global food security. *Frontiers in Plant Science* 9: 1314.

Kumar, B., S. S. Dhaliwal, S. T. Singh, J. S. Lamba and H. Ram. 2016. Herbage production, nutritional composition and quality of teosinte under Fe fertilization. *International Journal of Agriculture and Biology* 18: 319-329.

Kumar, R., M. Singh, B. S. Meena, H. Ram, C. M. Parihar, S. Kumar, M. R. Yadav, R. K. Meena, U. Kumar and V. K. Meena. 2017. Zinc management effects on quality and nutrient yield of fodder maize (*Zea mays* L.*). Indian Journal of Agricultural Sciences* 87: 1013-1017.

Kumar, B. and H. Ram. 2021. Biofortification of maize fodder with zinc improves forage productivity and nutritive value for livestock. *Journal of Animal and Feed Sciences* 30: 149-158.

Lithourgidis, A. S., L. Vasilakoglou, K. V. Dhima, C. A. Dordas and M. D. Yiakoulaki. 2006. Forage yield and quality of common vetch mixtures with oat and triticale in two seeding ratios. *Field Crops Research* 99: 106-113.

Mahanta, S.K., S.C. Garcia and M. R. Islam. 2020. Forage based feeding systems of dairy animals: Issues, limitations and strategies. *Range Management and Agroforestry* 41: 188-199.

Mahdi, S. S., B. Hasan and L. Singh. 2012. Influence of seed rate, nitrogen and zinc on fodder maize (*Zea mays* L.) in temperate conditions of Western Himalayas. *Indian Journal of Agronomy* 57: 85-88.

Manisha, R. Kumar., H. Ram., N. Tyagi., R. K. Meena., D. Kumar., R. Kumar., K. Singh and D. Min. 2021. Effect of zinc fertilization on nutritional quality of cowpea cultivars. *Legume Research* 45: 974-980.

Manoj, K. N., B. G. Shekara, S. Sridhara, P. K. Jha and P. V. V. Prasad. 2021. Biomass quantity and quality from different year-round cereal-legume cropping systems as forage of fodder for livestock. *Sustainability* 13: 9414.

Manoj, K. N., B. G. Shekara, R. K. Agrawal, Mudalagiriyappa and N. M. Chikkarugi. 2022. Productivity and quality of fodder as influenced by different bajra napier hybrid and legume fodder cropping systems. *Range Management and Agroforestry* 43: 88-93

Marschner, H. 1986. *Mineral Nutrition of Higher Plants*. Academic Press, London

Meena, R. K., P. S. Hindoriya, R. Kumar, H. Ram, M. Singh and D. Kumar. 2023. Quality, productivity and profitability of diversified fodder-based cropping systems for year-round fodder production in Indo-Gangetic plains of India. *Range Management and Agroforestry* 44: 152-159

Mir, N.H., B. A. Alie, S. Ahmad, S. S. Bhat and A. Regu. 2024. Zn fortification and legume incorporation in forage based cropping systems: Implications for yield and nutrient dynamics. *Journal of Environmental Biology* 45: 780-787

Nube, M. and R. L. Voortman. 2006. Simultaneously addressing micronutrient deficiencies in soils, crops, animal and human nutrition: opportunities for higher yields and better health. Staff Working Paper; No. WP-06-02, Centre for World Food Studies, Amsterdam, Netherlands. pp. 11-14.

Peddapuli, M., B. Venkateshwarlu and V. S. S. Gowthami. 2021. Effect of zinc fortification on quality, yield and economics of sweet corn. *International Journal of Plant and Soil Science* 33: 155-164.

Porwal, M., S. R. Kantwa, S. S. Singh, P. Govindasamy, B. Verma and S. Ramakrishnan. 2024. Effect of intercropping and zinc management on weed density and fodder yield in oats. *Range Management and Agroforestry* 45: 171-174.

Prajapati, B., G. Nanda, K. Kumar, J. Prajapati and P. Giri. 2023. Evaluation of fodder cropping sequences under

Tarai region of Uttarakhand. *Range Management and Agroforestry* 44: 134-141.

Ramakrishna, C. H., A. M. Lata, B. Murali, A. Madhavi and M. Venkateswarlu. 2022. Yield and silage quality of fodder maize (*Zea mays* L.) as influenced by zinc fertilization. *The Pharma Innovation Journal* 11: 1799-1802.

Rathore, D. K., R. Kumar, M. Singh, V. K. Meena, U. Kumar, P. S. Gupta, T. Yadav and G. Makarana. 2015. Phosphorus and zinc fertilization in fodder cowpea. A review. *Agricultural Reviews* 36: 333-338.

Rehman, U. and W. Raja. 2020. Performance of fodder sorghum with different forage legumes combination under temperate conditions of Kashmir. *Forage Research* 46: 248-253.

Saad, A. A., U. Singh, A. Masood and C. S. Praharaj. 2016. Productivity and economics of *kharif* fodder intercropping under dryland condition of temperate Kashmir valley. *Range Management and Agroforestry* 37: 108-112.

Sheoran, O. P., D. S. Tonk, L. S. Kaushik, R. C. Hasija and R. S. Pannu. 1998. Statistical software package for agricultural research workers. In: D.S. Hooda and R.C. Hasija (eds). *Recent Advances in Information Theory, Statistics and Computer Applications*. Department of Mathematics Statistics, CCS HAU, Hisar. 8:139-143.

Singh, U., A. A. Saad and S. R. Singh. 2006. Production potential, biological feasibility and economic viability of maize (*Zea mays*)-based intercropping systems under rainfed conditions of Kashmir valley. *Indian Journal of Agricultural Sciences* 78:1023-27

Tamta, A., R. Kumar, H. Ram, R. K. Meena, U. Kumar, M. R. Yadav, D. J. Subrahmanya and A. K. Pandey. 2019. Nutritional portfolio of maize and cowpea fodder under various intercropping ratio and balanced nitrogen fertilization. *Indian Journal of Animal Sciences* 89: 276-280.

Van-Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Sciences* 74: 3583-3597.

Yang, F., X. Wang, D. Liao, F. Lu, R. Gao, W. Liu and W. Yang. 2015. Yield response to different planting geometries in maize-soybean relay strip intercropping systems. *Agronomy Journal* 107: 296-304.

Zhang, J., B. Yin, Y. Xie, J. Li, Z. Yang and G. Zhang. 2015. Legume cereal intercropping improves forage yield, quality and degradability. *PLoS ONE* 10: e0144813, pp. 1-14.