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Optimizing fodder cropping systems for green fodder production and Lamb performance in scarce rainfall zone of Andhra Pradesh

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ABSTRACT

An experiment was conducted over three consecutive years (2021 to 23) at Agricultural Research Station, Anantapuramu, using a randomized complete block design (RCBD) with three replications. The study evaluated the performance of five fodder-based cropping systems Stylo + Rhodes grass (T_1), Lucerne + Anjan grass (T_2), Stylo + Sewan grass (T_3), Cowpea + Jowar (T_4), and Cowpea + Bajra (T_5) in alfisols, as well as the growth performance of lambs maintained with the fodder produced from these systems. The results demonstrated that the choice of crops in different cropping systems significantly influenced green and dry fodder yield, as well as their crude protein content. Among the systems, the highest green and dry fodder, and crude protein yield were recorded in the Cowpea + Bajra system (T_5), while the lowest yields were observed in the Stylo + Sewan grass system (T_3). Daily average fresh feed intake was also highest in T_5 (1.48 kg/lamb), followed by T_2 (1.25 kg/lamb) and T_3 (1.22 kg/lamb). The average daily gain (ADG) of lambs fed fodder from the T_1, T_2, T_3, T_4, and T_5 systems was 82, 82.5, 75.0, 80.5, and 88.0 g/day, respectively. Lambs in the T_5 system showed highest ADG, while the lowest values was observed in T_3 system. Although ADG was comparable among T_1, T_2, T_4, and T_5 systems, lambs in T_5 system exhibited a significantly higher live weight gain ($p<0.05$) compared to those in the T_3 system. These findings underscore the importance of incorporating diversified fodder crops into cropping systems to meet the nutritional requirements of livestock effectively. The enhanced average daily gain observed in lambs fed fodder from the T_5 system highlighted the critical role of nutrient-rich, diversified fodder in supporting optimal livestock growth and productivity.

Keywords: Average daily gain, Crude Protein, Fodder yield, Fodder cropping system, Lambs, Metabolizable energy

Ananthapuramu, located in the arid zone of Andhra Pradesh, is a region marked by low and erratic rainfall, making it one of the most drought-prone districts in India (Kasi, 2015). Livestock rearing, especially small ruminants like sheep and goats, plays a crucial role in the livelihood of marginal and small-scale farmers in this area (Sunayana *et al*. 2024). The district is home to approximately 15 % of the state's livestock population, which includes cattle, buffalo, sheep, and goats and ranks first in sheep and goat population (BAHFS, 2023). However, despite this impressive standing, the productivity per animal remains below the global average (DAHD, 2022). Several factors contribute to this lower productivity, with one of the most significant being the inadequate availability of quality feed and fodder for livestock (Mahanta *et al*. 2020). Currently, Ananthapuramu faces a significant deficit in both green and dry fodder due to recurrent drought and dry spells. The estimated deficit of green fodder in the region is around 50 %, while the shortfall for dry fodder stands at nearly 35 %. This shortage gets exacerbated during the lean seasons, forcing farmers to rely heavily on low-quality dry fodder such as groundnut haulms and crop residues, or on expensive concentrate feeds, directly impacting animal health, growth, and overall production efficiency, and thereby highlighting the urgent need for improved feed management strategies to bridge this gap.

Integrating suitable fodder crops into existing cropping systems can significantly enhance fodder availability. Numerous studies have demonstrated that perennial and biannual grasses, along with legumes such as napier grass, guinea grass, para grass, berseem, and lucerne, offer significant advantages over annual forage crops in terms of lower input requirements and higher yield potential (Manoj *et al*. 2022). Additionally, legume-based fodders consistently outperform cereal fodder crops in nutritional quality, providing higher levels of crude protein and essential nutrients (Kumar *et al*. 2020). Further, fodder cropping systems, such as legume-grass mixtures and

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dual-purpose crops, not only increase nutritious fodder availability crucial for maintaining health and productivity, especially in resource-limited settings like Anantapuramu. (Jha and Tiwari, 2018) but also improve soil fertility through nitrogen fixation and organic matter addition.

The present study aimed to evaluate various fodder cropping systems for year-round green fodder production and assess their impact on the growth performance of lambs in rainfed areas of scarce rainfall zone of Andhra Pradesh. The findings might provide valuable insights for developing sustainable, fodder-based livestock production systems, thereby contributing to the economic resilience and well-being of the farming communities in Ananthapuramu.

MATERIALS AND METHODS

Experimental site: The field experiment was conducted in rainfed alfisols for 3 years (2021 to 2023) at Agricultural Research Station (14.68 °N latitude and 77.60 °E longitude at about 335 m above sea level), Ananthapuramu in southern India. The climate is hot-arid with hot summers and very mild winters. The mean maximum air temperature varies from 29.6°C (December) to 40.0 °C (May), while the nighttime temperature varies from 16.3°C (December) to 26.5°C (May). Annual rainfall for the site is 594 mm, falling predominantly from June to November. The soils are sandy loam and shallow red soils with pH neutral to slightly acidic (pH 6.5 to 7.8). The initial soil fertility was low in organic carbon (0.20 %), available nitrogen, available potassium (95 kg ha^{-1}) but high in available phosphorous (110 kg ha^{-1}). An amount of 936, 759 and 443 mm rainfall was received in 44, 39, 27 rainy days during the crop season of 2021, 2022 and 2023 year, respectively at the experimental site. Depending on the requirement of the crop, life saving irrigation was given on need basis during 3rd year.

Establishment of fodder cropping systems: Three perennial grasses (Sewan grass - *Lasiurus sindicus,* CAZRI-30-5, *Anjan grass - Cenchurus setigerus, Var.* CAZRI-76*, Rhodes grass - Chloris gayana)*, two annual forages (multicut jowar - *Sorghum bicolor, Var.* Co FS-29, fodder bajra - *Pennisetum glaucum, Var.* TSFB-5) and three legume forages (Hedge lucerne - *Desmanthus virgatus*, stylo - *Stylosanthus hamata, Var.* Phule Kranti and fodder cowpea - *Vigna unguiculate, Var.* GFC-4) were chosen for establishment of five fodder cropping systems viz., stylo + rhodes grass (T_1), lucerne + anjan grass (T_2), stylo + sewan grass (T_3), cowpea and jowar (T_4) and cowpea + bajra fodder (T_5). Five fodder cropping systems were established in randomized block design with three replications (plot size: 12.0 x 10.8 m) during kharif 2021. Stylo, hedge lucerne, fodder cowpea, sorghum and bajra seeds were sown by line sowing at the spacing of 30 x 15, 45 x 30, 30 x 10, 30 x 10 and 30 x 10 cm, respectively. Sewan, anjan and rhodes grass rooted slips were planted at a spacing of 45 x 30 cm.

*Management of fodder cropping systems:*From 2021 onwards, the recommended dose of fertilizers for each grass/annual forage/legume forage was applied through urea, single super phosphate and muriate of potash. First cut of fodder crops was done at 65 days after sowing, second cut at 35 days after first cut and third cut at 30 days after second cut. One third nitrogen, entire dose of phosphorous and potash was applied at the time sowing. Second dose of nitrogen was applied after the first cut and third dose of nitrogen was applied after the second cut. The recommended package of practices were followed for different fodder crops.

Quantification of fodder: Fodder production from the experimental filed was estimated every year by determining within 0.2 x 0.2 m quadrates in all the replications at each cutting. The quadrant was taken at 5 different (four corners and a central) locations in each replication plot.

Animals and treatments: A feeding trail in growing lambs was conducted during 3rd year. A total of 30 Nellore lambs, each 3 months old, were randomly assigned to five different feeding treatments, with six lambs per treatment group. Prior to the study, all lambs were drenched for internal parasites and allowed to acclimatize for a week to the pasture and forage. Lambs were penned in five different pens as per the feeding treatment and then weighed for 3 consecutive days early in the morning before feeding. After measuring initial body weight, lambs were stratified by weight and randomly assigned to five feeding treatments. The feeding treatments consisted of stylo + rhodes grass (T_1), lucerne + anjan grass (T_2), stylo + sewan grass (T_3), cowpea and jowar (T_4) and cowpea + bajra fodder (T_5). Lambs were fed *ad libitum* with mixture of ⅓rd legumes and ⅔rd non-legume fodder after chopping. Daily feed offered and left-over feed was measured and intake was calculated for each group. Body weights of animals were recorded for 90 days at fortnightly interval for three consecutive times before feeding.

Laboratory and statistical analysis: The grass and forage samples were initially air-dried and then oven dried at 60 ± 5 °C. Dried haulm samples were ground to pass a 2 mm sieve in a Wiley Mill. They were analyzed for organic matter (OM), crude protein (CP), ether extract (EE) (AOAC, 1995) and cell wall constituents (Van Soest *et.al*., 1991). The *in vitro* true digestibility (IVTD) was determined by incubation of feed samples in filter bags in a Daisy II incubator (ANKOM Technology Corp., Macedon, NY) with rumen inoculum and buffer in a 1: 4 ratios for 48 h under anaerobic conditions at 39 °C as described by ANKOM Technology (2005) and Brons and Plaizier (2005). *In vitro* gas production was measured using *Ancom* gas production system (model RFS500N, ANKOM, Macedon, NY). The accumulated gas pressure of each module was recorded at 5 min intervals within a 48 h incubation period. The gas pressure values were then converted to the volume of gas as described in the manual of the device (ANKOM Technology, 2012). Subsequently, the cumulative gas production after 48 h of incubation (VolGas48) was determined.

Metabolizable energy (ME) content in GN haulms was estimated by using the following equation recommended by CSIRO (2007).

$$ME = 0.17 \times IVTD - 2 \quad (1)$$

where ME is metabolizable energy (MJ/kg DM) and IVTD is in vitro true dry matter digestibility (%).

Forage nutritional value (FNV) index was calculated (Yao *et al*. 2022) as per the method based on CP content (g/100 g DM), ME (metabolizable energy (MJ/kg DM), IVTD (g/100 g DM), and neutral detergent fiber (NDF) content (g/100 g DM) and calculated as

$$FNV = (CP + ME + 0.25\ IVTD) - 0.25\ NDF \quad (2)$$

The non-fibrous carbohydrate (NFC) and total digestible nutrient (TDN) (g/100 g DM) were calculated using the following equations from Mertens (1997) and Linn and Martin (1989), respectively.

$$NFC = 100 - (CP + Ash + EE + NDF) \quad (3)$$

$$TDN = 88.9 - (ADF * 0.779) \quad (4)$$

The values in g/100 g DM were later converted into g/kg DM

Data were subjected to analysis of variance according to the procedure described by Wilkinson *et al*. (1996) and the differences between means were tested using Duncan's multiple range test with a significance at $p<0.05$. All the statistical procedures were carried out using SPSS, version 22.0.

RESULTS AND DISCUSSION

Green fodder yield: Incessant rains in the early monsoon in 2021 year resulted in damage of cowpea/sorghum/bajra/ crops and poor establishment of stylo, sewan, anjan and rhodes grass, while in 2023 very low rainfall and prolonged drought at growing stage resulted in poor fodder yields. In 2022, rainfall was optimal and well distributed and resulted in good fodder yield comparted to 2021 and 2023 years. Three years pooled data (Figure 1) indicated that, significantly higher total green fodder yield was recorded with cowpea (18.791 t/ha) followed by rhodes (18.55 t/ha), bajra (17.18 t/ha), sorghum (15.50 t/ha) and hedge lucerne (13.97 t/ha). Sewan grass recorded significantly lower total green fodder yield (5.44 t/ha) (Figure 1). The differences between hedge lucerne, stylo, anjan, rhodes, cowpea and sewan grass were non-significant. Fodder crops develop swiftly and cover the ground surface, even in low-rainfall conditions, producing a significant amount of green fodder (Kumari *et al*. 2017). Reddy *et al*. (2022) reported that fodder bajra, sorghum and maize are the potential forage cereals as they could produce higher quantity and quality fodder. Lower grass yields in anjan and sewan could be due to low tillering and slower growth and are in agreement with Hedayetullah *et al*. (2018). A similar yield was reported in forage cowpea (Aamir *et al*. 2018), heduge lucerne and stylo (Kumari *et al*. 2023). Bajra yield was lower compared to Shekara *et al*. (2020) and it could be due to the variation in the variety and rainfall amount. Among the different fodder cropping systems, highest green, dry and crude protein yield was observed in cowpea + bajra (T_5), whereas lowest in stylo + sewan grass (T_3) system (Figure 2) and a similar higher crude protein yields were reported with cowpea systems (Meena *et al*. 2023).

Nutritive value of fodder crops: Among the established fodder crops, ash content ranged from 7.33 to 12.20 % with highest in anjan grass and lowest in bajra fodder. Similarly,

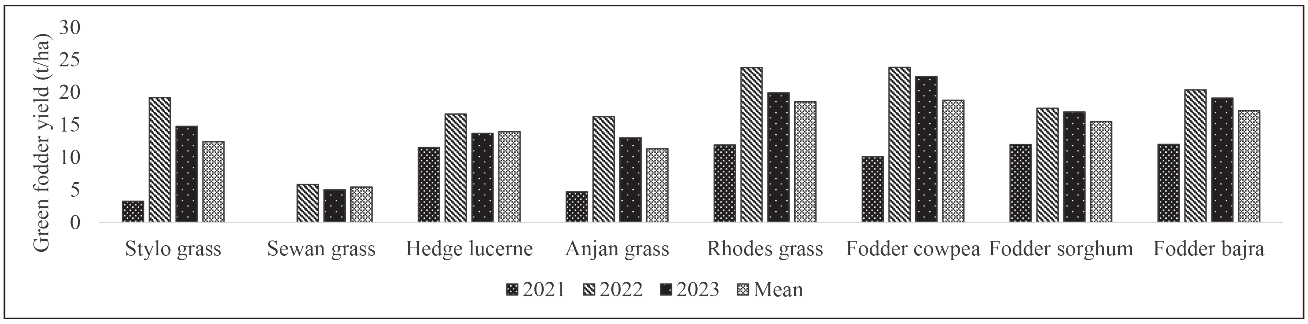

Fig. 1 Performance of different fodder crops for green fodder supply in the rainfed areas of Ananthapuramu.

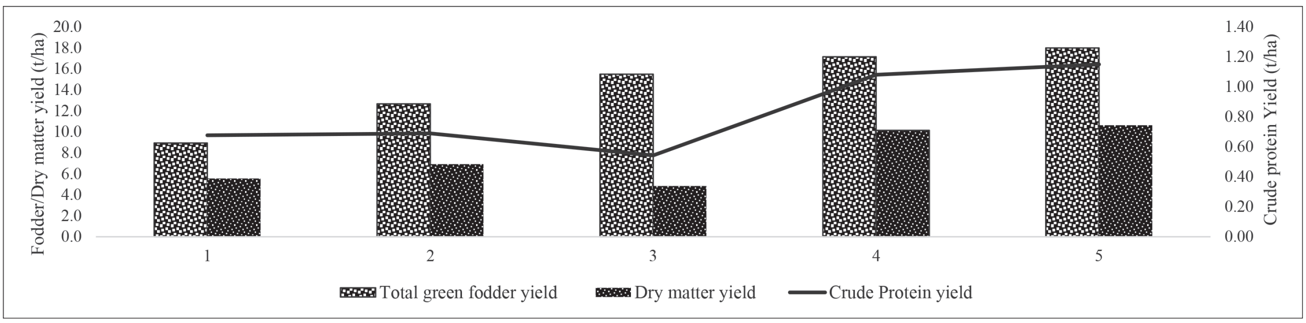

Fig. 2 Performance of different fodder cropping systems for green fodder, dry matter and protein supply in the rainfed areas of Ananthapuramu

Table 1. Nutrient composition (DM basis) of different green fodders

Name of the fodder crop	Ash	OM	CP	EE	CF	NDF	ADF	L	NFC	TDN	IVTD	ME	FNV	Ca	Mg	P	Zn	Cu
	%											MJ/kg DM		g/kg DM			mg/kg DM	
Stylo grass	7.86	92.14	14.1	2.3	34.7	52.3	41.4	8.8	23.44	56.65	57.55	7.78	23.20	12.6	3.4	1.52	42.1	11.4
Sewan grass	9.22	90.78	3.86	1.24	38.5	75.8	47.6	7.1	9.88	51.82	53.11	7.03	5.22	4.8	1.7	0.65	22.3	7.5
Hedge lucerne	7.33	92.67	13.95	2.02	36.58	48.22	39.07	14.3	28.48	58.46	54.76	7.31	22.89	13.4	6.44	2.97	28.5	9.3
Anjan grass	11.94	88.06	3.84	0.76	42.8	76.48	48.42	6.22	6.98	51.18	55.02	7.35	5.83	2.85	1.26	0.72	11.1	6.8
Rhodes grass	9.35	90.65	4.02	1.22	35.2	74.8	42.6	5.94	10.61	55.71	57.55	7.78	7.49	3.3	1.8	2.6	26	5.2
Fodder cowpea	10.8	89.2	14.6	2.3	25.4	39.2	28.5	4.2	33.1	66.70	60.38	8.26	28.16	10.2	2.7	2.2	34.2	22.1
Fodder sorghum	10.16	89.84	5.72	1.35	34.8	58.4	36.9	3.55	24.37	60.15	59.25	8.07	14.01	3.84	1.94	1.86	32.8	10.9
Fodder bajra	12.2	87.8	6.55	1.88	30.62	62.4	32.8	3.95	16.97	63.35	59.82	8.17	14.07	7.6	1.15	1.68	13.7	8.7

OM, organic matter; CP, crude protein; EE, ether extract; CF, crude fibre; NDF, neutral detergent fibre; ADF, acid detergent fibre; L, Lignin; NFC, non-fibre carbohydrates; TDN, total digestible nutrients; IVTD, *in vitro* true digestibility; ME, metabolizable energy; FNV, forage nutritive value index; Ca, Calcium; Mg, magnesium; P, Phosphorous; Zn, Zinc; Cu, copper.

organic matter content was high in bajra and low in anjan and ranged from 87.8 to 92.67 %. Legumes contained high CP, whereas the grasses contained low CP and EE was low in all the pastures and forages (Table 1). Their crude fibre (CF), NDF and ADF contents also ranged from 25.4 to 42.8, 39.2 to 76.48 and 28.5 to 48.20, respectively. Lignin content was higher in hedge lucerne (14.3 %) and lower in sorghum (3.55 %). Grasses contained low NFC, whereas legumes and forages contained high NFC. TDN and IVTD ranged from 51.18 to 66.70 and 53.11 to 60.38 %, respectively. Cowpea fodder contained highest and anjan grass lowest ME content. FNV was low for grasses, medium for forages and high for legumes. Ca, Mg and P contents were ranged from 3.3 to 13.4, 1.7 to 6.44 and 0.65 to 2.97 g/kg DM, respectively. Similarly, Zn and Cu ranged from 11.1 to 42.1 and 5.2 to 22.1 mg/kg DM, respectively. The lower ($p<0.01$) pasture quality of the anjan grass could be due to lower CP and IVTD and higher CF, NDF and ADF contents. All the nutritive values are within the normal range and results are in agreement with the earlier findings (Meena *et al*. 2023; Shekara *et al*. 2020; Ramya *et al*. 2017).

Feed intake and animal performance: Lambs were fed at a rate of 4.0 % of dry matter (DM) per 100 kg body weight, with the diet comprising ⅔ non-leguminous and ⅓ leguminous feed. Grass forages are crucial for feeding animals due to their high dry biomass yield and relatively low cost (Hassan *et al*. 2017). However, these grasses tend to have lower nutritive value, with minimal protein content and it is essential to incorporate leguminous forage crops to enhance the nutritional quality of the feed and ensure balanced livestock nutrition. Among the different feeding treatments, daily average fresh feed intake was highest in T_5 (1.48 kg/lamb) as compared to T_2 (1.25 kg/lamb) and T_3 (1.22 kg/lamb). Similarly, DM intake was also higher in T_5 (0.48 kg/lamb) as compared to T_2 (0.45 kg/lamb) and T_3 (0.44 kg/lamb), however it was comparable among T_5, T_1 and T_4 (Table 2). This variability in fresh and dry fodder intake reflected the differences in the nutritional value across the different fodder crops. Higher fodder intake

Table 2. Performance of lambs on different green fodder feeding combinations

Parameter	T_1	T_2	T_3	T_4	T_5
Average fodder intake (Fresh basis) (kg/lamb/day)	1.38^{ab}	1.25^{c}	1.22^{c}	1.34^{bc}	1.48^{a}
Average fodder intake (DM basis) (kg/lamb/day)	0.47	0.45	0.44	0.46	0.48
Initial body weight (kg)	14.00 ± 0.28	12.85 ± 0.49	13.20 ± 0.85	12.70 ± 0.99	12.45 ± 0.78
Final body weight (kg)	21.38 ± 0.42	20.30 ± 0.42	19.95 ± 0.85	19.95 ± 0.88	20.37 ± 0.53
Average daily gain (g)	82 ± 5.7^{ab}	82.5 ± 3.5^{ab}	75 ± 4.2^{a}	80.5 ± 6.3^{ab}	88 ± 4.24^{b}
Weight gain (90 days) (Kg)	7.38 ± 0.31	7.45 ± 0.22	6.75 ± 0.26	7.25 ± 0.45	7.92 ± 0.38

T_1, Stylo + Rhodes grass; T_2, Hedge lucerne + Anjan grass; T_3, Stylo + Sewan grass; T_4, Cowpea + Jowar; T_5, Cowpea + Bajra fodder enhances growth depending upon the quality of the fodder and the efficiency of its utilization by the animals (Smith *et al*. 2023; Brown *et al*. 2022). Higher intake in T_5 might be attributed to the higher quality and palatability of the fodder, aligning with the findings of Johnson *et al.* (2024), who demonstrated that better quality fodder significantly enhances intake and subsequent growth. However, total fodder intake on a dry matter basis was relatively consistent across treatments, showing all the fodder combinations had optimum quality and palatability.

The average daily gain (ADG) in lambs fed with the fodder available from T_1, T_2, T_3, T_4 and T_5, systems were 82.0, 82.5, 75.0, 80.5 and 88.0 g/d, respectively. T_5 lambs had highest ADG, whereas T_3 had lowest and this could be due to higher CP, ME and FNV of the cow pea compared to the sewan forage feeding, respectively in T5 and T3 lambs. ADG was comparable among T_5, T_1, T_2 and T_3 lambs. ADG showed a moderate positive correlation with CP (0.62), ME (0.58) and FNV (0.56) of fodders fed to the lambs. Similarly, live weight gain was significantly ($p<0.05$) higher in lambs fed with the fodder available from T_5 as compared to T_3, although the values among T_5, T_1, T_2 and T_3 lambs were comparable. Higher ME along with a matching protein directly helps the animal to gain weight. Higher ME was found in cowpea + bajra system, while the lowest ME was found in stylo + sewan system. The results are also in consistent with those of Gursoy *et al*. (2021).

Livestock require a balanced diet that provides adequate energy, protein, and essential micronutrients to meet their nutritional needs and to express their full genetic potential for optimal production (Kumar *et al*. 2020). Increased fodder intake can lead to improved ADG, but this effect is often moderated by the nutritional composition of the diet (Lee *et al*. 2023; Walker *et al*. 2022). A proper mixture of grass and legume is very important to meet the nutritional requirement and higher productivity of animals. The trend in our study suggest that while higher fodder intake tends to support better growth, the effect is not always linear, as seen in T_3 and T_5 having similar DM intakes but differing in weight gain. Animals receiving higher quality or more palatable fodder generally exhibit better weight gain (Harris *et al*. 2023; Taylor *et al*. 2022). Higher green fodder yields were observed with cowpea, followed by Rhodes grass, bajra, and sorghum, making these crops and their combinations suitable for the rainfed regions of Anantapuramu district. The feeding combination of cowpea and bajra fodder resulted in best outcomes, demonstrating higher weight gain and average daily gain in lambs. The increase in the average daily gain of lamb under study clearly evidenced the importance of diversified fodder crops in a system to meet the nutrient requirement of the livestock.

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AUTHORSHIP CONTRIBUTION STATEMENT

B. Sahadeva Reddy*:* Methodology, Investigation, Supervision, Project administration. G. Sri Manjula Reddy: Investigation, Data curation. D.B.V. Ramana: Writing – review & editing, Methodology, Conceptualization. J.M. Upendra: Formal analysis, Data curation. A. Malliswara Reddy: Investigation, Data curation. D.V. Srinivasulu: Investigation, Data curation. K. Lakshman: Investigation, Data curation.

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