LR-5605
[1-9]

RESEARCH ARTICLE Legume Research- An International Journal

Impact of Agromet Advisory Service on Yield and Economics of Cotton-Redgram Intercropping System

Bollaveni Sathish Kumar[1], I. Thirupathi[1], Srikanth Bairi[1], Venu Reddy Challa[2], M. Rajeshwar Naik[3], Shivakrishna Kota[3], Nagaraju Alugoju[3]

10.18805/LR-5605

ABSTRACT

Background: Production of pulses is a crucial need of the country because the India is important producer of pulses even though we are deficient in daily protein consumption. Encouraging of redgram intercropping in cotton is a fruitful way to increase the area of redgram and productivity along with income of cotton-redgram farmers.

Methods: Study conducted by DAMU (District Agromet Unit), Krishi Vigyan Kendra, Mancherial district to understand the impact of Agromet Advisory Service on yield and economics of Cotton- Redgram intercropping system during 2019-20 to 2021-22 in 5 locations of Mancherial and K.B. Asifabad districts. To understand the impact of Advisory service, encouraged the farmers to practice cotton-redgram inter cropping system over traditional sole cotton cropping to increase the crop yield and economics in the study area.

Result: Results of 5 locations revealed that the farmers followed and practiced cotton- redgram intercropping along with suggested management practices according to the Agromet advisory service experienced superior yields (Three years average of 5 locations inter cropping yield was 2031 kg ha^{-1} including cotton 1537 kg ha^{-1} and red gram 494 kg ha^{-1}) in all the three years compared to sole cotton crop (Three years average of 5 locations 1690 kg ha^{-1}). Luxury yields of intercropping through the AAS service also showed positive impact on LER and CER. These effective utilization of resources through LER and profitability through the CER leads to better gross, net income as well as B:C ratio in intercropping.

Key words: Agromet advisory service, Crop equivalent yield, DAMU, Inter cropping, Land equivalent ratio.

INTRODUCTION

All the agricultural methodologies that can be managed but the unpredictable nature of weather remains beyond human control. Weather is a key reason to decide the fate of agricultural production. It shows magnifying impact on operations and farm management practices. To provide the reliable medium range forecast of particular district, the District Agro-Meteorology Units (DAMUs) project was initiated by the India Meteorological Department (IMD) in 2018, in collaboration with the Indian Council of Agricultural Research (ICAR). This weather based agromet advisory service useful to increase the awareness, helpful for perception and control of economic loss and obtaining better yields (Ramachandrappa *et al*., 2018). Agromet Advisory Services (AAS) beneficious to the farming community to take advantage of favorable weather and mitigate the impacts of extreme weather conditions through the inputs in advisory. The risks associated with agricultural activities can be reduced by convert weather information into needful advisory for agricultural implications. DAMUs contribute to collect and organize crop, soil and weather information and to process them with forecast information to help the farming community in decision making (Standard Operating Procedure for Agromet Advisory Services, 2020).

Cotton grown in the monsoon season of Telangana, which is supporting the seasonal agricultural cycles. After the paddy production (14,485.0 thousand tons in *Kharif* and 11,182.0 thousand tons in *Rabi*) cotton occupies good area with large production in Telangana. Telangana had cotton area 17.82 lakh ha and production of 48.95 lakh bales of 170 kg with 467 kg ha^{-1} productivity (Anonymous, 2025).

Inter cropping is well known practice in crop production to utilize the resources efficiently, produce the additional income, enhance soil health, pest-disease prevention and

[1]Agricultural College, Professor Jayashankar Telangana Agricultural University, Polasa, Jagtial-505 529, Telangana, India.
[2]All India Coordinated Research Project on Long Term Fertilizer Experiments, Regional Agricultural Research Station, Professor Jayashankar Telangana Agricultural University, Polasa, Jagtial-505 529, Telangana, India.
[3]Krishi Vigyan Kendra, Professor Jayashankar Telangana Agricultural University, Bellampalli, Mancherial-504 251, Telangana, India.

Corresponding Author: Bollaveni Sathish Kumar, Agricultural College, Professor Jayashankar Telangana Agricultural University, Polasa, Jagtial-505 529, Telangana, India.
Email: sathishbollaveni44@gmail.com

How to cite this article: Kumar, B.S., Thirupathi, I., Bairi, S., Challa, V.R., Naik, M.R., Kota, S. and Alugoju, N. (2025). Impact of Agromet Advisory Service on Yield and Economics of Cotton-Redgram Intercropping System. *Legume Research.* 1-9. doi: 10.18805/LR-5605.

Submitted: 17-11-2025 **Accepted:** 27-12-2025 **Online:** 16-01-2026

weed suppression (Tandale *et al.,* 2018). This is a traditional practice to create interaction between two or more crops at a time, these crops coexist for a significant part of their life and they interact among themselves and with ecosystem (Maitra and Gitari, 2020). In other hand without extra allocation of land to extra crop farmers can harvest a larger yield proportion from both the crops (Pandagale *et al.,* 2019).

Red gram occupies 176.4 thousand hectares with 145.0 thousand tons production and green gram area 69,000 acres and production 20,000 tons (Telangana state at a glance 2024). The large range of cotton area can provide the opportunity of intercropping with pulses in Telangana. Cotton and Red Gram intercropping benefit the soil health and resource management through organic matter accumulation in soil and increasing of organic carbon in soil through root residues and shedding of leaves (Ammaiyappan *et al*., 2023 and Adepu and Latha (2025).

MATERIALS AND METHODS

Experimental site

Present study conducted by DAMU, Krishi Vigyan Kendra, Mancherial during three consecutive *kharif* seasons during the year of 2019-2020 to 2021-2022 at 5 locations (3 locations in Mancherial and 2 locations in K.B Asifabad district) of Telangana state.

The DAMU, Mancherial provided the information to the farmers of both the districts about Bi-weekly medium range weather forecast and AAS. In present investigation to understand the superiority and scope of cotton-red gram inter cropping system in Telangana provided AAS (Bi-weekly agrometeorological advisory bulletins) to cotton red gram inter cropping farmers based on forecast and real time rainfall data and suggested the management and cultural practices from land preparation to till the harvesting to obtain maximum yields.

Rainfall information

The Mancherial district received rainfall 1314.9, 1199.6 and 1145.0 mm in 2019-20, 2020-21 and 2021-22, respectively. K.B. Asifabad district received rainfall 1452.8, 1275.2 and 1662.7 mm in 2019-20, 2020-21 and 2021-22, respectively (Table 1).

In three consecutive *kharif* seasons (2019-20 to 2021-22) yield and economic results from the all 5 locations were observed in both AAS followed cotton- redgram and non-followed sole cotton fields.

Yield analysis

Yield of AAS followed intercropping as well as traditional sole cotton was observed and converted into hectares for convenance.

Land equivalent ratio (LER)

Land equivalent ratio is one of the important calculations to evaluate the performance of an intercropping system given by Beets (1982). Later number of researchers improved the concept of LER (Fukai, 1993). LER is described as the proportionate land area required under pure stand of crop species to yield the same produce as obtained under an intercropping at the same management level.

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Crop equivalent yield (CEY)

Crop equivalent yield (CEY) is the expression of both crops (Main and inter crop) yield into as main crop yield. Crop equivalent yield, which is useful in mixed cropping or intercropping or sequential cropping (De Wit, 1960).

$$CEY = \frac{\text{Yield of inter crop}}{\text{Price of main crop}} \times \text{Price of inter crop}$$

Economic analysis

Gross return (Rs. ha^{-1}), Net returns (Rs. ha^{-1}) and Benefit cost ratio.

Descriptive statistics and normality diagnostics

Data of above parameters categorized by district and village were gathered from two cropping systems over a three-year period (2019-20 to 2021-22).

The assumption of multivariate normality was confirmed prior to conducting any multivariate analysis. For tests like Wilks' Λ, Pillai's Trace, Hotelling-Lawley Trace and Roy's Largest Root in MANOVA, as well as the Discriminant Function in Linear Discriminant Analysis, to be valid, the joint distribution of dependent variables must approximate a multivariate normal distribution (Royston, 1982).

Multivariate normality was assessed using Royston's multivariate normality test, an extension of the Shapiro-Wilk W test to multiple variables. The procedure applies the Shapiro-Wilk test to each variable X_j (j = 1,2,....,p), obtaining statistics W_j, which are transformed into approximate standard normal scores: $Z_j = -\ln(1 - W_j)$ These are then combined into an overall test statistic: $Z = \frac{1}{p}\Sigma^{p}_{j=1} Z_j$, where $Z \sim x^2_{p,\alpha}$ and $Z_j \sim N(0, 1)$ under the null hypothesis (H_0) of MVN.

Royston's approach is better than alternatives like Mardia's skewness-kurtosis tests and works well for small to moderate samples. A significant result (p<0.05) implies a departure from multivariate normality, whereas a non-significant p-value (p>0.05) shows no evidence against it.

Multivariate Analysis of Variance (MANOVA)

Once normality was established, a MANOVA was conducted to investigate how cropping systems affected several dependent variables: yield, cost of cultivation (CC), benefit-cost ratio (BCR), net returns (NR) and gross returns (GR). MANOVA controls Type I error inflation while enabling the testing of correlated dependent variables simultaneously (Wilks, 1932).

The model was specified as:

$$Y = XB + E$$

Where,

Y_{nxp}= The matrix of dependent variables (*n* observations in *p* dependent variables).

X_{nxk}= Design matrix of predictors (*k* groups or predictors).

B_{kxp}= Matrix of regression coefficients and E_{nxp} is error matrix.

The group effect was tested under H_0: $B \neq 0$ (No group effect) and H_1: $B = 0$ (presence of group effect).

The hypothesis matrix (H) and pooled within-group error matrix (E) were computed as:

$$\sum_{i=1}^{g} n_i (\bar{y}_i - \bar{y})(\bar{y}_i - \bar{y})^T \text{ and } E = \sum_{i=1}^{g} \sum_{k=1}^{ni} (\bar{y}_{ij} - \bar{y}_i)(\bar{y}_{ij} - \bar{y}_i)^T$$

Where,

$\bar{y}_i$ i^{th}= Group mean vector.

$\bar{y}$= Overall mean vector.

n_i= Sample size in ith group.

MANOVA test statistics

Each test statistic is based on the eigenvalues.

i. Wilks' Lambda (Λ): Tests the proportion of variance in the dependent variables not explained by the factor.

Where,

s= The number of non-zero eigen values of E^{-1} H or min (p,dfg).

$$\Lambda = \frac{|E|}{|H + E|} = \Pi_{i=1}^{s} \frac{1}{1 + \lambda_i}$$

ii. Pillai's trace (V): A robust statistic, particularly effective when assumptions such as homogeneity of covariance are not fully met (Pillai, 1955).

$$V = \text{Trace}\,[H\,(H + E)^{-1}] = \Sigma_{i=1}^{s} \frac{\lambda_i}{1 + \lambda_i}$$

iii. Hotelling-lawley trace (T²): Measures the sum of the explained variances across canonical variates (Hotelling, 1931).

$$T = \text{Trace}\,(E^{-1} H) = \Sigma_{i=1}^{s} \lambda_i$$

iv. Roy's largest root (Θ): Tests the maximum separation between groups based on a single canonical variate (Roy, 1953).

$$\Theta = \max\,(\lambda_i)$$

Univariate analysis of variance (ANOVA)

Univariate ANOVAs tested mean differences of individual dependent variables (NR, CC, GR, BCR and Yield) across the two cropping systems. The model is:

$$Y_{ij} = \mu + \tau_i + \epsilon_{ij}$$

Where,

Y_{IJ}= Observation of the dependent variable in the i^{th} group and j^{th} replication.

μ= Overall mean of the dependent variable.

τ_i= Effect of the ith group.

ϵ_{ij}= Random error term.

$\epsilon_{ij} \sim N(0,\sigma^2)$ (Montgomery, 2019).

Significance was determined using p-values ($p<0.05$) and the percentage contribution of each variable's sum of squares (SS) to the total SS, indicating which traits most strongly explained group differences.

Linear discriminant analysis

Using the following explanatory variables, Linear Discriminant Analysis (LDA) was used to categorise and differentiate between two cropping systems: intercropping and sole cropping: Net returns (NR), benefit–cost ratio (BCR), cost of cultivation (CC), gross returns (GR) and yield. In order to minimise within-group variance and maximise between-group variance, LDA builds a linear combination of predictors (Fisher, 1936).

For each group $g \in \{1,2,\ldots,G\}$, the discriminant function is expressed as:

$$\delta_g (X) = X'\Sigma^{-1}\mu_g - \frac{1}{2}\mu_g'\Sigma^{-1}\mu_g + \ln(\pi_g)$$

Where,

$X = (x_1, x_2, \ldots, x_p)'$= Vector of predictor variables.

μ_g= The mean vector of group k.

Σ= The pooled within-group covariance matrix.

π_g= The prior probability of group g.

The pooled within-group covariance matrix is given by:

$$\Sigma = \frac{\Sigma_{g=1}^{G}(n_g - 1)\,S_g}{\Sigma_{g=1}^{G}(n_g - 1)}$$

Here,

n_g= The sample size of group g.

S_g= The covariance matrix of group g.

For two groups, only a single discriminant function is extracted:

$$D(X) = W'X + c$$

Here,

$$W = \Sigma^{-1}(\mu_1 - \mu_2)$$

The classification rule is:

$$X \in \begin{cases} \text{Group 1 (Inter - Cropping), if } D(X) > c \\ \text{Group 2 (Sole cropping), Otherwise} \end{cases}$$

The discriminant score for observation i is: $z_i = w'x_i$ and the posterior probability of belonging to group k is computed as:

$$P\,(G = g \mid x) = \frac{\pi_g f_g(x)}{\Sigma_{i=1}^{G} \pi_i f_i(x)}$$

f_g (X)= The multivariate normal density for group g.

Implementation in R

R version 4.3.1's tidyverse, psych and ggplot2 packages were used to perform descriptive statistics and graphical analyses for rainfall and yield by year, location and crop (R Core Team, 2023). The MVN package's Royston's MVN test was used to evaluate multivariate normality. The car package was used to perform the MANOVA.

The MASS, ggplot2 and pROC packages were used to implement the discriminant analysis, which produced discriminant scores and posterior probabilities to assess cropping systems' classification accuracy.

RESULTS AND DISCUSSION

Yield performance

Over three seasons 2019-20, 2020-21 and 2021-22 and five locations, the cotton-redgram intercropping system in a 6:1 row ratio consistently outperformed sole cotton. The system maintained a uniform and robust plant stand, with about 15,357 cotton plants and 2,527 redgram plants per hectare. This configuration delivered a mean system yield of 2031 kg ha^{-1}, comprising 1537 kg ha^{-1} from cotton and 494 kg ha^{-1} from redgram, compared with 1690 kg ha^{-1} under sole cotton (Table 2). The yield advantage reflects the complementary roles of the two crops: redgram fixes atmospheric nitrogen, improves soil physical conditions and helps buffer the microclimate within the canopy, which together support better boll retention and higher biomass in cotton.

These yield gains were also closely linked to the systematic use of Agro meteorological Advisory Services (AAS) throughout the study period. Location-specific weather-based advisories on sowing dates, irrigation scheduling, nutrient application and plant protection enabled farmers to time operations more precisely with short-and medium-range forecasts, lowering exposure to weather-related risks. Similar positive impacts of AAS on yields, income stability and risk reduction have been documented in other agro-climatic regions (Rakesh *et al.,* 2025) and are consistent with national assessments of the strengthened GKMS/AAS framework (Rathore *et al.,* 2025) and evidence that village-level agromet display boards and advisories promote adoption of weather-informed decisions (Roy *et al.,* 2025).

Resource-use efficiency

Intercropping also clearly improved how land and inputs were used. The cotton–redgram system recorded a mean Land Equivalent Ratio (LER) of 1.30 and a mean Cotton Equivalent Yield (CEY) of 1993 kg ha^{-1}, representing roughly 15% higher productivity compared with sole cotton. An LER above 1.0 indicates that the intercropping system uses light, water and nutrients more efficiently per unit area than when crops are grown alone. This pattern agrees with findings from other cotton-based intercropping systems, including cotton-pigeonpea, where LER values typically exceed 1.0 and CEY is substantially higher under intercropping (Table 2). Latheef *et al.* (2018) gains better yield and economic returns through complementary canopy structures and more efficient resource use.

Our results are further supported by broader multicropping literature showing that intercropping tends to enhance both resource-use efficiency and overall system productivity. Gao *et al.* (2023), for instance, used MANOVA in daylily-based intercropping trials to demonstrate multivariate gains in yield and associated traits. While Huang *et al.* (2022) show that tea-legume intercropping improves nitrogen availability, soil organic matter and microbial activity, thereby enhancing overall resource-use

Table 1: Mancherial and K.B Asifabad district rainfall information (mm).

Mancherial	Year	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Marc	AprilL	May	Total
		R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	
	2019-20	96.4	298.1	388.2	256.6	141.2	26.5	0.4	8.0	14.0	13.8	19.2	52.5	1314.9
	2020-21	175.3	277.9	422.0	233.0	64.9	0.0	0.0	0.5	0.5	0.0	5.4	20.1	1199.6
	2021-22	227.8	375.6	172.3	244.8	27.3	20.0	0.0	26.8	1.5	0.8	0.0	48.1	1145.0
K.B Asifabad	2019-20	136.6	409.8	418.2	249.0	88.8	12.7	1.6	13.9	10.2	47.1	37.6	27.3	1452.8
	2020-21	164.3	308.7	420.9	196.5	110.6	1.0	0.0	0.0	2.5	0.0	19.6	51.1	1275.2
	2021-22	322.0	514.3	326.1	324.0	47.2	24.3	5.0	60.8	0.0	0.5	4.9	33.6	1662.7

Table 2: Impact of Agromet advisory service on yield of cotton- red gram inter cropping in different locations.

S.no	Yield (kg ha^{-1}) 2019-20				Yield (kg ha^{-1}) 2020-21				Yield (kg ha^{-1}) 2021-22			
	Cotton	R.G	I.C	S.C	Cotton	R.G	I.C	S.C	Cotton	R.G	I.C	S.C
Kasipet	1796	500	2316	1920	1420	570	1990	1670	1400	455	1855	1560
Thandoor	1681	425	2136	1760	1595	545	2120	1725	1420	480	1900	1480
Bellampalli	1576	400	1926	1650	1470	610	2100	1690	1570	630	2200	1655
Tiryani	1596	400	1996	1835	1490	450	1940	1730	1355	540	1895	1590
Rebbena	1741	385	2126	1850	1450	435	1885	1665	1490	590	2080	1630
Average	1678	422	2100	1803	1485	522	2007	1696	1447	539	1986	1583

Year	Yield (kg ha^{-1})				LER	CER		%
	Cotton	Redgram	IC	Sole cotton		I.C	S.C	Yield increased
2019-20	1678	422	2100	1791	1.34	2083	1791	14.0
2020-21	1485	522	2007	1696	1.30	2091	1696	18.8
2021-22	1447	539	1986	1583	1.26	1804	1583	12.2
Mean	1537	494	2031	1690	1.30	1993	1690	15.0

I.C= Inter cropping and S.C= Sole cotton.

efficiency. By biologically fixing nitrogen and improving nutrient cycling, legumes reduce fertilizer dependence and allow tea plants to use soil resources more effectively.

Economics

Economically, cotton-redgram intercropping proved clearly superior to sole cotton. The mean cost of cultivation under intercropping was lower (₹ 50,284 ha^{-1}) than under sole cropping (₹ 52,262 ha^{-1}), yet the system generated higher gross returns (₹ 117,069 ha^{-1}) and net returns (₹ 66,434 ha^{-1}) (Table 3 and 4). As a result, the Benefit-cost ratio (BCR) under intercropping was 2.30, compared with 1.71 for sole cotton, indicating that each rupee invested in the intercropped system yielded substantially higher returns. The additional grain yield from redgram, more efficient use of shared inputs and operations and the spreading of risk across two crops all contributed to this economic advantage.

These outcomes also illustrate why intercropping should be evaluated using multi-trait criteria that combine yield and economic metrics rather than yield alone. Recent reviews on new statistical approaches for intercropping experiments have encouraged the use of multivariate tools such as MANOVA and discriminant analysis to capture integrated yield-income responses. In line with this perspective, our results corroborate earlier reports by Pandagale *et al.* (2019), which showed that cotton-legume intercropping not only increases profitability but also enhances economic resilience compared with mono-cropped cotton.

Multivariate statistical validation

Multivariate diagnostics and MANOVA

Before applying multivariate models, we assessed whether the data met key statistical assumptions. Royston's multivariate normality test was non-significant ($p = 0.473 > 0.05$), indicating that the joint distribution of the response variables did not deviate significantly from multivariate normality and was suitable for both MANOVA and LDA. A similar diagnostic strategy was followed in the Brazilian study "Selection of Indicators to Discriminate Soil Tillage Systems" (Kazmierczak *et al.*, 2020) where Shapiro–Wilk and Royston's tests were applied prior to discriminant analysis, underscoring the importance of careful assumption checking in agronomic datasets.

In our study, MANOVA results (Table 5) a highly significant effect of cropping system (Wilks' $\Lambda = 0.2693$), with the model explaining 73% of the total multivariate variance. Among the response variables, yield was the dominant contributor (65.9%, $p<0.01$), followed by cultivation cost, net returns and gross returns, while BCR made a comparatively minor and non-significant contribution. The Univariate ANOVA also results represented that the treatments clearly influenced NR, CC, GR and especially yield, as all of these traits show strong statistical significance. However, BCR did not respond much to the treatments, indicating that it remained relatively unaffected compared to the other traits.

Table 3: Impact of Agromet advisory service on economics (Cost of cultivation and Gross income) of cotton-red gram inter cropping.

Location	2019-20				2020-21				2021-22			
	Cost of cultivation (Rs/ha)		Gross returns (Rs ha^{-1})		Cost of cultivation (Rs/ha)		Gross returns (Rs ha^{-1})		Cost of cultivation (Rs ha^{-1})		Gross returns (Rs ha^{-1})	
	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C
Kasipet	51105	53180	120810	100800	49500	52550	100220	80995	51570	52700	132300	117000
Thandoor	53480	55555	111443	92400	50120	51770	110083	83663	52800	52950	135300	111000
Bellampalli	48480	50555	95003	86625	48460	51260	105815	81965	51420	52290	155550	124125
Tiryani	52605	54680	101490	96337	50005	51880	93297	85602	50930	52080	134025	119250
Rebbena	48830	50905	111038	97125	50910	51780	94250	79055	52300	53050	147150	122250
Average	50900	52975	107956.8	94657.4	49799	51848	100733	82256	51804	52614	140865	118725

Table 4: Impact of Agromet advisory service on economics (Net returns and B:C ratio) of cotton-red gram inter cropping.

Location	2019-20 20				20-21				2021-22			
	Net returns (Rs ha^{-1})		B:C ratio		Net returns (Rs ha^{-1})		B:C ratio		Net returns (Rs ha^{-1})		B:C ratio	
	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C
Kasipet	69705	47620	2.36	1.89	50720	28445	2.02	1.54	80730	64300	2.57	2.22
Thandoor	57963	36845	2.08	1.66	59963	31893	2.2	1.62	82500	58050	2.56	2.10
Bellampalli	46523	36070	1.95	1.71	57355	30705	2.18	1.6	104130	71835	3.03	2.37
Tiryani	48885	41658	1.92	1.76	43292	33722	1.86	1.66	83095	67170	2.63	2.29
Rebbena	62208	46220	2.27	1.90	43340	27275	1.85	1.53	94850	69200	2.81	2.30
Average	57056.8	41682.6	2.116	1.784	50934	30408	2.02	1.59	89061	66111	2.72	2.26

Year	Cost of cultivation (Rs ha^{-1})		Gross returns (Rs ha^{-1})		Net returns (Rs ha^{-1})		B:C ratio	
	I.C	S.C	I.C	S.C	I.C	S.C	I.C	S.C
2019-20	50250	52325	109610	94034	59306	41709	2.17	1.19
2020-21	49799	51848	100733	82256	50934	33408	2.02	1.69
2021-22	51804	52614	140865	118725	89061	66111	2.72	2.26
Mean	50618	52262	117069	98338	66434	47076	2.30	1.71

IC= Inter cropping and SC= Sole cotton.

Discriminant analysis and system separation

Linear Discriminant Analysis (LDA) provided additional insight into how well the two cropping systems could be separated using the measured variables. The first discriminant function was:

$$LD_1 = -0.00003499 \times NR + 1.994 \times BCR + 0.000392 \times CC - 0.0000306 \times GR - 0.00639 \times Yield$$

The large negative coefficient for yield indicates that higher yields strongly pulled LD scores toward the intercropping system, highlighting yield as the main driver favouring that system. In contrast, positive coefficients for BCR and cultivation cost shifted scores toward sole cropping, indicating that these traits, when considered jointly with others, tended to characterize the mono-cropped fields. Mean LD scores clearly distinguished the two groups (Intercropping = -1.3; Sole = +0.64 showed Fig 1) and the model achieved 100% correct classification showed in Fig 2, demonstrating very strong multivariate separation between the systems in different representation.

Comparable discriminant or Linear Discriminant Analysis Effect Size (LEfSe) type analyses have been used in agronomic and ecological studies to differentiate treatments or management systems (Gao *et al*., 2023) and our findings are in line with these reports. In all cases, discriminant analysis helps reveal which traits or

Table 5: MANOVA and ANOVA statistics.

MANOVA						
Measure	Df	Statistic value	F cal	Num Df	Den Df	Pr (>F)
Wilks lambda	1	0.22	17.37	5	24	0.000
Pillai's trace	1	0.78	17.37	5	24	0.000
HL trace	1	3.62	17.37	5	24	0.000
Royston largest root	1	3.62	17.37	5	24	0.000

Univariate ANOVA

Dependent variable	% of SS contribution	p-value
NR	24.73	0.005
BCR	6.04	0.191
CC	25.30	0.005
GR	20.7	0.012
Yield	65.91	0.000

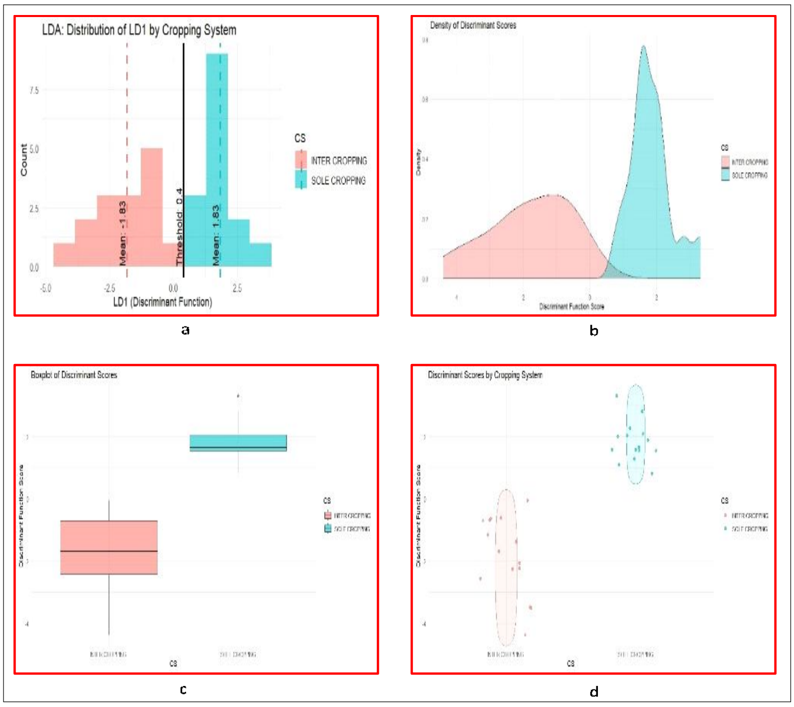

Fig 1: (a) Distribution of LD1 Scores based on cropping systems by Histograms, (b) Probability density curves of Discriminant scores, (c) Central tendency and spread of Discriminant scores over Box-plot and (d) Confidence eclipse around discriminant scores.

Fig 2: Observed vs predicted classification of cropping system.

combinations of traits which most strongly contribute to group separation.

Integrated interpretation and implications

Overall, the combination of field performance and multivariate statistics makes a strong case for cotton-red gram intercropping as a superior alternative to sole cotton. The system delivers higher yields, better economic returns and more efficient use of land and inputs, while also satisfying key statistical model assumptions and showing clear multivariate separation from mono-cropping. These features echo earlier work on the multivariate stability and discriminant potential of diversified cropping systems (Gao *et al*., 2023).

The simultaneous improvements in yield, reduced cultivation costs and complementary use of light, water and nutrients position intercropping as both economically attractive and ecologically sound. This aligns with foundational intercropping concepts proposed by Raseduzzaman and Jensen (2017), who emphasized the potential of mixed cropping to increase overall system efficiency. In the present context, cotton-redgram intercropping, especially when supported by robust AAS-based management, emerges as a practical pathway towards sustainable intensification under variable and changing climatic conditions.

CONCLUSION

Indian meteorological department providing weather forecast and advisories through district agromet units. The following and practicing of agromet advisory service is beneficial for farming community to take necessary management practices in field according to weather.

According to present investigation, concluded that AAS followed farmers achieved maximum yields and productivity through practicing redgram as intercrop in cotton and weather-based need full actions in intercropping. Telangana offers significant potential for cotton-redgram intercropping, owing to the extensive acreage under cotton cultivation across the region. The synergetic impact of pulse crop increases the soil health by increasing organic matter and microbial activity.

Conflict of interest

On behalf of all the authors of the manuscript we declare that there is no conflict of interest.

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