



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(5): 46-49
Received: 25-02-2026
Accepted: 30-03-2026

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Influence of moisture conservation and nutrient management practices on productivity of bajra-cowpea cropping system

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i5a.5478>

Abstract

A field experiment was carried out over two seasons to assess the productivity of a Bajra (*Pennisetum glaucum*) + Cowpea (*Vigna unguiculata*) cropping system utilising a split plot design in Agricultural research Station Darsi, Prakasam District of Andhra Pradesh. The study included three main plot treatments and four subplot treatments, each with three replications. Bajra Equivalent Yield (BEY) was the major productivity measure. At the 1% level, statistical analysis indicated substantial differences between the main plot, subplot, and their interactions. The therapy combination m3 × s4 produced the highest BEY, indicating superior performance. A cross-year analysis showed consistent results, with no significant Year × Main plot interaction but substantial Year × Subplot interaction. The study shows the best treatment combinations for increasing productivity in Bajra-Cowpea systems.

Keywords: Bajra-cowpea cropping system, bajra equivalent yield, split plot design, rainfed agriculture

Introduction

Bajra, (*Pennisetum glaucum*), is a significant drought-resistant grain crop in India's arid and semi-arid areas. Its resilience to moisture stress, elevated temperatures, and suboptimal soil fertility renders it vital for rainfed food and nutritional security. The productivity of bajra is constrained by erratic precipitation, inadequate soil organic matter, and insufficient nutrients (Pushkar Deva *et al* 2023) ^[1]. The versatile legume cowpea (*Vigna unguiculata*) is farmed as a single crop or in intercropping systems because to its short lifespan, nitrogen-fixing capabilities, and adaptability to marginal areas. Cowpea enhances agricultural productivity, sustainability, and soil fertility through nitrogen fixation. The bajra-cowpea cropping system is favoured in dryland agriculture due to its enhancement of resource efficiency, mitigation of risk, and improvement of soil health. This method depends on moisture retention and nutrient management for success. In the light soils of Prakasam district, this investigation assesses the efficacy of conservation agriculture (CA)-based crop diversification systems that incorporate redgram and millets under various residue management practices (Beillouin *et al.*, 2021) ^[2]. The mean annual rainfall is approximately 794.5 mm, (apwrrms.ap.gov.in) often erratic in distribution, thereby predisposing the system to intermittent moisture stress. Seasonal temperature fluctuations are pronounced, with summer maxima reaching up to 45.0°C and winter minima declining to around 24.0°C. Nutrient management is crucial for production, particularly in light soils with limited nutrient retention capacity. Integrated nutrition management (INM) optimizes nutrient balance, enhances soil structure, and stimulates microbial activity through the application of chemical fertilizers, organic manures, and biofertilizers. Legumes such as cowpea enhance nitrogen economy and diminish reliance on synthetic fertilizers (Ram *et al* 2014) ^[3].

Materials and Methods

A comprehensive field investigation was undertaken at the Agricultural Research Station, Darsi, situated in Prakasam district of Andhra Pradesh, over three consecutive agricultural years spanning the *kharif* and *rabi* seasons of 2024-25 and 2025-26. Geographically, the experimental

site is positioned at an elevation of 110 m above mean sea level, at 15.7701° N latitude and 79.6793° E longitude. The experimental soil was sandy loam in texture, exhibiting medium organic carbon content, low available nitrogen (~180 kg ha⁻¹), and medium levels of available phosphorus (~12 kg ha⁻¹) and potassium (~160 kg ha⁻¹). The experiment was structured in a split plot design with three replications with a plot size of 7.2m X 5m, wherein the main plot treatments comprised of moisture conservation practices such as M1- ridge and furrow method, M2- Conventional planting and M3- working with subsoiler at 1.8m and subplots comprised of namely S1: Recommended Dose of Fertilizers (RDF), S2:- RDF + 1% KNO₃ foliar spray at 25-30 Days After Sowing (DAS), S3: S1 + Supplemental irrigation S4: S2 + Supplemental irrigation. The sole bajra was sown in *Kharif* season, while cowpea was cultivated during the *rabi* season as a succeeding crop in place of *kharif* bajra to assess system productivity and residual effects. The crop varieties employed included WCC-75 for bajra and TPTC-29 for cowpea. Observations were recorded on All experimental plots for plant height(cm). number of branches, days to flowering and maturity, number of pods/plants, seeds/pod, test weight and bajra equivalent yield. In statistical analysis the data collected from the experiment were subjected to statistical analysis appropriate for a split plot design. Analysis of variance (ANOVA) was performed to test the significance of treatment effects. Treatment means were compared using the critical difference (CD) at 5% level of significance.

Results and Discussion

The overall analysis of variance clearly demonstrates that all major sources of variation—replication, main plot, subplot, and

their interaction—were statistically significant, indicating that the experimental treatments had a strong and consistent influence on the response variable. The replication effect was significant ($F = 825.66$, 825.65 ; $p = 1 \times 10^{-5}$), suggesting some inherent variability among experimental units. However, its contribution was relatively small compared to treatment effects, confirming that the experimental design effectively controlled random variation. The main plot factor showed a highly significant effect ($F = 14747.01$; $p < 0.01$), indicating that the primary treatments (such as moisture conservation practices) played a dominant role in determining crop performance. Similar results have been reported by Sushila Kanwar *et al* 2017^[4] in Bajra and Syama (2016)^[5] in Cowpea. The magnitude of the F-value highlights the strong differentiation among main plot treatments. Similarly, the subplot factor was highly significant ($F = 1851.01$; $p < 0.01$), demonstrating that secondary treatments (such as nutrient management or foliar applications) also had a substantial impact on the response. Similar findings had been made in bajra by Sheeshpal Choudhary *et al* 2022^[6] and Tekle Joseph (2014)^[7] in cowpea. Importantly, the interaction between main plot and subplot treatments was significant ($F = 9.60$; $p = 8 \times 10^{-5}$), revealing that the effect of subplot treatments varied depending on the level of main plot treatments. This confirms that combined or integrated treatment approaches are more effective than individual applications, as the response is not independent but interdependent. The very low error mean squares—0.0097 for Error (a) and 0.0724 for Error (b)—indicate high experimental precision and reliability, ensuring that the observed differences are truly due to treatment effects rather than random noise.

Table 1: ANOVA for Bajra equivalent yield 2024-25

Source of Var.	DF	Sum of Sq.	Mean Sq.	F value	P value	Result
Rep	2	16.0155	8.0077	825.6589	1e-05	R ** Sig. at 1% level esult
Mainplot	2	286.0511	143.0256	14747.0139	<0.01	R ** Sig. at 1% level ult
Error a	4	0.0388	0.0097			Result
Subplot	3	402.2395	134.0798	1851.0082	<0.01	Re** Sig. at 1% level ult
MainplotxSubplot	6	4.1733	0.6956	9.6023	8e-05	R ** Sig. at 1% level sult
Error b	18	1.3039	0.0724			Result
Total	35	709.8221				Result

Table 2: ANOVA for Bajra equivalent yield 2025-26

Source of Variation	DF	Sum of Squares	Mean Square	F value	P value	Significance
Replication	2	29.6287	14.8142	825.66	0.00001	**Significant (1%)
Main Plot	2	529.1945	264.5974	14747.01	<0.01	**Significant (1%)
Error (a)	4	0.0718	0.0179			
Sub Plot	3	744.1421	248.0476	1851.01	<0.01	**Significant (1%)
Main Plot × Sub Plot	6	7.7216	1.2869	9.60	0.00008	**Significant (1%)
Error (b)	18	2.4122	0.1330			
Total	35	1313.1709				

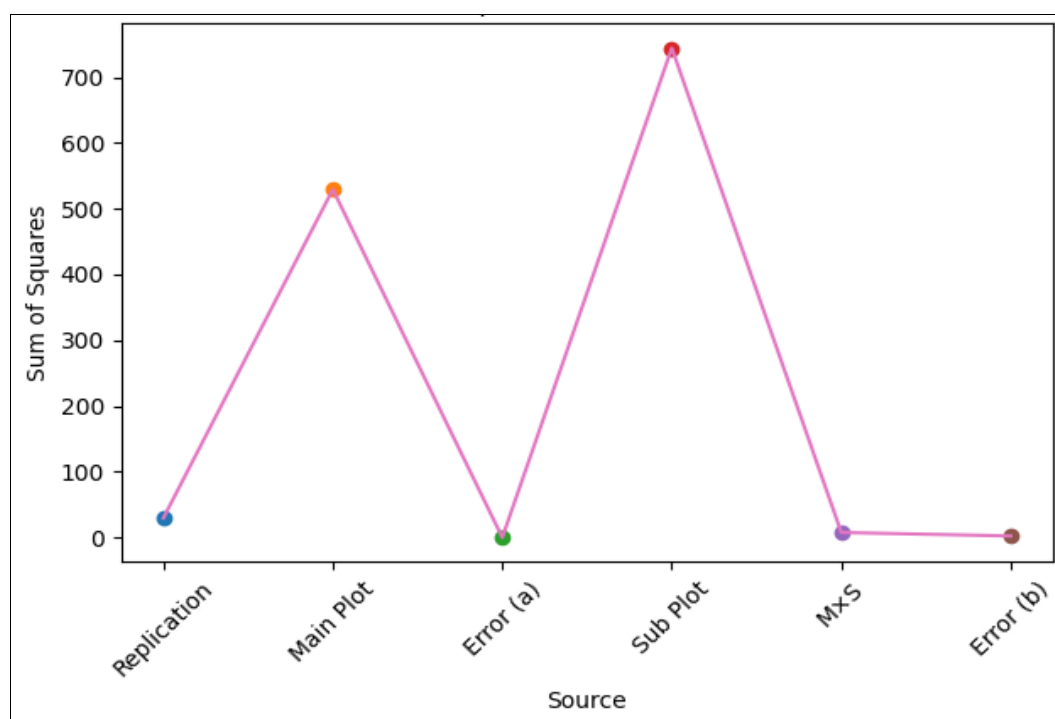


Fig 1: Contribution of different sources of variation for Bajra equivalent yield (Q/Ha)

The accuracy metrics in Table-3 corroborate this statistical significance. High precision was achieved in treatment mean estimation, since the main plot (0.0284), subplot (0.0897), and interaction (0.1554) had low SEM values. The main plot had the lowest standard error of difference (SEd) (0.0402), followed by subplot (0.1269) and interaction (0.2198), showing valid treatment mean comparisons. The 5% critical difference (CD) values were 0.1115 (main plot), 0.2665 (subplot), and 0.4617 (interaction), whereas the 1% values were 0.1849, 0.3651, and 0.6326. These small CD values show that even slight treatment mean variations are statistically observable, demonstrating the experiment's sensitivity and robustness. Error (a) (0.2874%) and error (b) (0.7855%) had low coefficients of variation (CV), indicating low experimental variability and excellent data consistency. Low CV values indicate good experimental precision and reliability.

Table 3: Descriptive statistics for Main plot, subplot and Main plot-subplot interaction

Statistic	Mainplot	Subplot	MainplotxSubplot
SEm	0.0284	0.0897	0.1554
SEd	0.0402	0.1269	0.2198
CD (LSD) 5%	0.1115	0.2665	0.4617
CD (LSD) 1%	0.1849	0.3651	0.6326
C.V. (a)	0.2874	CV (b)	0.7855

The Tukey grouping showed that M3 (37.21 q ha⁻¹; group 'a') was significantly superior to all other treatments M1 (35.12 q ha⁻¹; group 'b') was significantly superior to M2, but inferior to M3. M2 (30.47 q ha⁻¹; group 'c') recorded the lowest yield. Since each treatment falls into a separate group (a, b, c), it confirms that all pairwise differences among main plot treatments are statistically significant under Tukey's HSD criterion. S4 (38.84 q ha⁻¹; group 'a') was significantly superior to all other treatments S3 (35.48 q ha⁻¹; group 'b') was inferior

to S4 but superior to S2 and S1 S2 (33.03 q ha⁻¹; group 'c') showed moderate performance S1 (29.71 q ha⁻¹; group 'd') recorded the lowest BEY The presence of four distinct groups (a, b, c, d) clearly indicates that each subplot treatment differs significantly from the others, highlighting a strong treatment effect. Tukey's HSD test (5%) revealed highly significant differences among all treatment combinations, with distinct groups (a-k) indicating complete separation. The highest Bajra Equivalent Yield (BEY) was recorded in s4 × m3 (42.09 q ha⁻¹; 'a'), which was significantly superior to all treatments, followed by s4 × m1 (39.91; 'b') and s3 × m3 (38.70; 'c'). Intermediate combinations showed gradual declines, while the lowest BEY was observed in s2 × m2 (29.53; 'k'). The absence of overlapping groups confirms that all interaction treatments differ significantly. Low SE (0.37-0.64) indicates high precision. The results clearly show that M3 × S4 is the best-performing combination, confirming that integrated moisture and nutrient management practices maximize Bajra Equivalent Yield.

Table 4: Tukey's HSD test for main plot Bajra equivalent yield(Q/Ha)

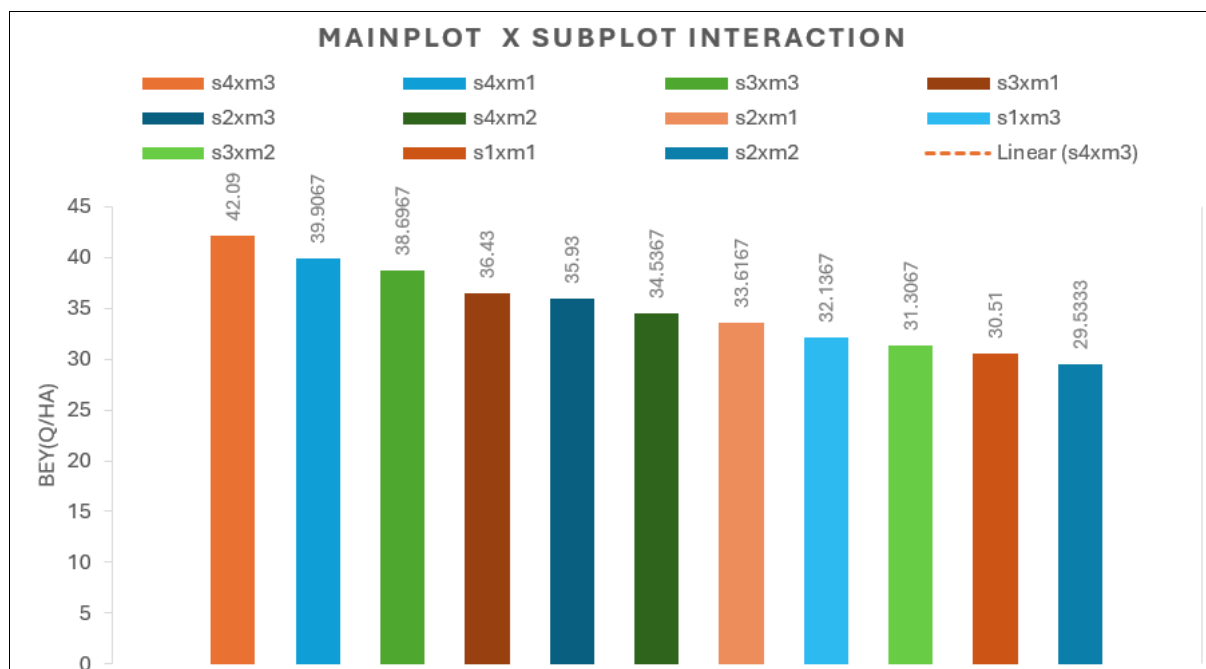
Main plot	BEY(Q/Ha)	Standard Error	Standard Dev	Group
M3(Sub-soiler at 1.8m)	37.2133	1.1217	3.8856	a
M1(Ridge& Furrow method)	35.1158	1.067	3.6961	b
M2 (Conventional ploughing)	30.4675	0.9021	3.1251	c

Table 5: Tukey's HSD test for subplot Bajra equivalent Yield (Q/Ha)

Subplots	BEY (Q/Ha)	Standard Error	Standard Dev	Group
S4:S2 + Supplemental Irrigation	38.8444	1.1569	3.4708	a
S3:S1 + Supplemental Irrigation	35.4778	1.1107	3.332	b
S2:RDF +1% KNO ₃ foliar nutrition at 25-30 DAS	33.0267	0.9783	2.935	c
S1: (RDF)	29.7133	0.8619	2.5856	d

Table 6: Tukey's HSD test for mainplot X subplot Bajra equivalent Yield (Q/Ha)

Main Plot x SubPlot	BEY(Q/Ha)	Standard Error	Standard Dev	Group
s4xm3 (sub soiler at 1.8m X s2 + supplemental irrigation)	42.09	0.4866	0.8429	a
s4xm1 (Sub soiler at 1.8m X ridge & furrow)	39.9067	0.6064	1.0504	b
s3xm3(Subsoiler at 1.8m X s1 + supplemental Irrigation)	38.6967	0.4372	0.7572	c
s3xm1 (ridge & furrow X s1 + supplemental Irrigation)	36.43	0.3703	0.6413	d
s2xm3 (RDF + 1% KNO ₃ foliar nutrition at 25-30 DAS)	35.93	0.6384	1.1057	e
s4xm2 (S2 + supplemental Irrigation) X conventional Ploughing	34.5367	0.5897	1.0214	f
s2xm1 (RDF +1% KNO ₃ foliar nutrition at 25-30 DAS) X (ridge & furrow)	33.6167	0.5538	0.9592	g
s1xm3 (RDF X Sub soiler at 1.8m)	32.1367	0.3776	0.6539	h
s3xm2 (s1 + Supplemental Irrigation) X (conventional Ploughing)	31.3067	0.376	0.6513	i
s1xm1 RDF X (ridge & furrow)	30.51	0.4041	0.7	j
s2xm2 RDF + 1% KNO ₃ foliar nutrition at 25-30 DAS.	29.5333	0.5298	0.9177	k

**Fig 2:** Bajra equivalent yield (Q/Ha) Mainplot X Subplot interaction.

Conclusion

The research indicated that the main plot, subplot, and their interaction effects were extremely significant ($p < 0.01$), affirming a substantial treatment impact on Bajra Equivalent Yield (BEY). The M3 treatment (optimal moisture conservation approach, subsoiler at 1.8m) and S4 treatment (S2 + supplemental irrigation) each demonstrated exceptional performance. Their interaction, M3 × S4, yielded the highest BEY, dramatically surpassing all other treatments. The minimal error variance and coefficient of variation values signified elevated experimental precision and dependability. Tukey's HSD test further corroborated the total distinction among treatments, affirming the reliability of the data. The findings indicate that the integration of effective moisture conservation (M3) and improved nutrient management (S4) is the optimal strategy for enhancing productivity in rainfed circumstances.

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