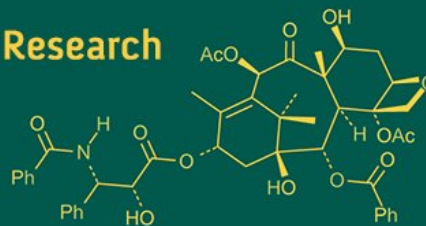
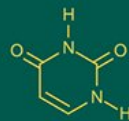
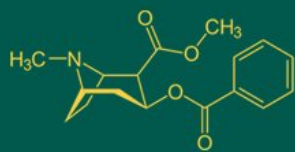


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(9): 1481-1485
www.biochemjournal.com
Received: 05-07-2026
Accepted: 09-08-2026

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Evaluation of maize (*Zea mays* L.) based intercropping system with small millets under rain-fed condition

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9Sr.10033>

Abstract

The Present investigation entitled “Evaluation of maize (*Zea mays* L.) based intercropping system with small millets under rain-fed condition” was conducted at the Research-cum-Instructional Farm of Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.), during the *kharif* season of 2025. The experiment was laid out in a Randomized Block Design (RBD) with 7 treatments viz., T1- Sole maize, T2- Sole kodo, T3- Sole kutki, T4- Sole ragi, T5- Maize + kodo (1:2), T6- Maize + kutki (1:2), T7- Maize + ragi (1:2). Observations on growth parameters including plant population, plant height, dry matter production, were recorded at different growth stages of the crop. Yield attributes such as number of cobs plant⁻¹, number of seed rows cob⁻¹, number of seeds cob⁻¹, seed index, grain yield, straw yield and harvest index were subjected to statistical analysis. The results indicated that maize intercropping with small millets significantly influence crop growth and yield of maize. Among all treatments, sole maize recorded the highest plant height, dry matter production, number of cob plant⁻¹, number of seed rows cob⁻¹, number of seeds cob⁻¹, test weight, grain yield and straw yield of maize. Among the intercropping treatments, maize + kodo (1:2) recorded maximum grain, straw yield of maize. Maximum LER and ATER were registered under maize + kodo (1:2) and highest MGEY was recorded in maize + ragi (1:2) as compared to other intercropping system.

Keywords: Maize, small millets, intercropping, LER, ATER, MGEY

1. Introduction

Maize (*Zea mays* L.), commonly known as corn, is third most important cereal crop after rice and wheat worldwide and is also known as the “Queen of cereals” due to its high genetic yield potential. It has a wide range of adaptation under various agro-climatic situation (Reddy *et al.*, 2004). It is one of the most important grain crops to ensure food security due to its higher production capacity than any other cereal crop, especially under favourable growing conditions. The economic importance of maize crop has been increasing because of its diversified agro-based industrial uses apart from its food, feed and fodder value and ethanol production. In India, about 25 per cent of the maize produced is used for human consumption, 49 per cent in poultry, 12 per cent as cattle feed and 12 per cent in food processing industries mainly as starch and one per cent in brewery and seed industry (Jat *et al.* 2009) [6].

Globally, more than 170 countries collectively produce about 1147.7 million metric tons of maize in an area of 193.7 million hectares, with an average productivity of 5.75 tons ha⁻¹ (Anon., 2020). India is the 5th largest producer of maize about 120.17 lakh ha area was covered under maize and production is at 422.81 lakh tonnes with productivity of 3518 kg ha⁻¹ (Anon., 2024). Chhattisgarh contributes 217.1 area in thousand ha which have production 635.83 thousand MT and productivity 2929 kg ha⁻¹ in *kharif* in the year 2023-24 (Anon., 2023-24).

Small millets like kodo millet, little millet and finger millet are traditional rainfed crops grown under limited agricultural inputs on marginal and degraded lands where other cereals cannot perform well. Its fast-growing ability, weed suppressive nature, lower water requirement makes them suitable for conservation of natural resource.

Intercropping is an old age practice in India, especially under rainfed conditions, which aims to increase total productivity per unit area through equitable and judicious use of land resource and farming inputs including labours. Intercropping is a kind of assurance against

weather irregularities however intercropping may not practicable to all basic crops mainly due to problems of crop competition for sunlight, nutrients, incidence of diseases and pests, etc. Intercropping of crops with rainfed maize is a sustainable farming practice that offers numerous benefits, including increased productivity, enhanced resource utilization and greater resilience to drought and other environmental stresses. Maize offers a suitable base for intercropping due to its extensive root system and ability to utilize available soil nutrients efficiently. When maize intercropped with small millets (kodo millet, little millet and finger millet) is an innovative and sustainable agricultural practice under rainfed condition of Chhattisgarh, that enhances productivity, improves resource use efficiency and supports environmental resilience. Maize intercropped with millets produced comparable maize yields with additional millet yield, resulting in higher total system productivity and diversification in marginal hill farming systems (Chapagain *et al.* 2018) [4]. Maize and millet can be intercropped as they have different growth habits and can use nutrients from different layer of the soil. Maize is a tall growing, widely spaced crop which can accommodate short and medium duration crops like kodo, kutki and ragi. The differences in rooting pattern, canopy and growth duration minimize direct competition and promote complimentary use of light, water and nutrients. This approach may increase the possibility to generate the yield recovery of such system. Additionally, intercropping maize with millet can help to increase overall crop yield per unit area. Therefore, the present investigation was undertaken to Evaluation of maize (*Zea mays* L.) based intercropping system with small millets under rain-fed condition.

2. Materials and methods

2.1 Experimental site and Location

A field experiment was conducted during the *Kharif* season of 2025 at the Instructional-cum-Research Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur, Chhattisgarh, India. The experimental farm is situated at 22.09° N latitude and 82.15° E longitude in the Chhattisgarh Plains Agro-climatic Zone. The region experiences a sub-tropical climate characterized by hot summers and monsoon rainfall.

2.2 Soil characteristics

Before sowing, composite soil samples were collected from a depth of 0-15 cm and analysed using standard laboratory procedures. The experimental soil was neutral in reaction, low in available nitrogen, medium in available phosphorus, and available potassium, making it suitable for evaluating the response of maize to different maize based intercropping system.

2.3 Experimental design and treatments

The experiment was laid out in a Randomized Block Design (RBD) with Seven treatments and three replications. The treatments comprised different intercropping treatments viz., T1- Sole maize, T2- Sole kodo, T3- Sole kutki, T4- Sole ragi, T5- Maize + kodo (1:2), T6- Maize + kutki (1:2), T7- Maize + ragi (1:2).

2.4 Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for the Randomized Block Design as described by Gomez and Gomez (1984). The significance of treatment effects was tested using the F-test,

and treatment means were compared using the Critical Difference (CD) test at the 5% probability level.

Table 1: Details of treatment combinations

S. No.	Treatments
T1	Sole maize
T2	Sole kodo
T3	Sole kutki
T4	Sole ragi
T5	Maize + kodo (1:2)
T6	Maize + kutki (1:2)
T7	Maize + ragi (1:2)

3. Results and Discussion 3.1 Growth Parameters

3.1.1 Plant population (m^{-1}) row length

Plant population at 30 DAS was not significantly influenced by different maize based intercropping system with small millets. The non-significant variation indicating a uniform plant stand under various maize based intercropping treatments.

3.1.2 Plant height (cm)

Plant height of maize was not significantly influenced by the treatments at 30 DAS, whereas significant differences were observed at 60, 90 DAS and at harvest. At 30 DAS, higher plant height was recorded under T1- sole maize (45.39 cm). At 60, 90 DAS and at harvest, T1- sole maize recorded significantly higher plant height (155.72, 183.89 and 194.49 cm, respectively), and it was significantly superior over T5- maize + kodo (1:2), T6- maize + kutki (1:2) and T7- maize + ragi (1:2) intercropping system. However, among intercropping, the maximum plant height of maize was noted under T5- maize + kodo (1:2) intercropping system and lowest plant height was noted in T7-maize + ragi (1:2) intercropping system but plant height of maize in all intercropping system are comparable. At all the growth stages, sole maize recorded the highest plant height than intercropped maize and it is probably due to no competition faced by sole maize, whereas intercropped maize treatments were in association with small millets and competed for resources favorable for growth. Considerably higher plant height of maize under sole maize as compared to different intercropping treatments was also reported by Patel *et al.* (2018) and Mauriya *et al.* (2024) [3, 8].

3.1.3 Dry matter production ($g\ plant^{-1}$)

Dry matter production of maize was significantly influenced by different maize based intercropping system with small millets at all growth stages, except at 30. At 30 DAS, the maximum dry matter production ($15.10\ g\ plant^{-1}$) was recorded under T1- sole maize followed by T5- maize + kodo (1:2), T6- maize + kutki (1:2) and T7- maize + ragi (1:2) intercropping system. At 60, 90 DAS and at harvest T1- sole maize (91.94 , 219.07 and $248.73\ g\ plant^{-1}$, respectively) recorded the maximum dry matter production, which was significantly superior over T5- maize + kodo (1:2), T6- maize + kutki (1:2) and T7- maize + ragi (1:2) intercropping system. However, among intercropping systems, the maximum dry matter production was noted under T5- maize + kodo (1:2) intercropping system and lowest dry matter production was noted in T7- maize + ragi (1:2) intercropping system but the difference was non-significant. The constantly higher dry matter production in sole maize may be attributed to the absence of interspecific competition for light water, nutrient,

moisture and specially for growing space. Similar findings were reported by Patel *et al.* (2018) and Mauriya *et al.* (2024) [3, 8].

3.2 Yield parameters 3.2.1 Number of cob plant⁻¹

The number of cobs plant⁻¹ in maize was not significantly influenced by intercropping with small millets. However, numerically the highest value was recorded under T1- sole maize (1.40), while the lowest value was observed in T7- maize + ragi (1:2) (1.13). The relatively higher number of cobs under sole maize may be attributed to reduced interspecific competition for growth resources, thereby favouring better ear development and retention.

3.2.2 Number of seed rows cob⁻¹

Maize based intercropping system with small millets significantly influenced the number of seed rows cob⁻¹. The significantly maximum number of seed rows cob⁻¹ was noticed at sole maize (T1) (15.87) compared to all intercropping treatments.

3.2.3 Number of seeds cob⁻¹

Maize + small millets intercropping significantly influenced the number of seeds cob⁻¹. The maximum number of seeds cob⁻¹ (507.28) was noticed at sole maize (T1) and which was significantly superior over T5- maize + kodo (1:2), T6- maize + kutki (1:2) and T7- maize + ragi (1:2) intercropping system. However intercropped maize with different small millets (kodo, kutki and ragi) did not show any significant difference in respect to number of seeds per cob.

3.2.4 Test weight (g)

The test weight of maize was significantly influenced by sole maize and its intercropping with small millets. The highest value of test weight (291.96 g) was observed in T1- sole maize and statistically superior over T5- maize + kodo (1:2), T6- maize + kutki (1:2), T7- maize + ragi (1:2). The lowest value of test weight was observed at T7- maize + ragi (1:2) (233.28 g).

3.2.5 Grain yield (kg ha⁻¹)

Grain yield of maize was significantly influenced by different intercropping systems. The highest grain yield was obtained with T1- sole maize (4695.53 kg ha⁻¹), which was significantly superior over intercropping of maize with small millets *i.e.* T5- maize + kodo (1:2) (3806.42 kg ha⁻¹), T6- maize + kutki (1:2) (3657.13 kg ha⁻¹), T7- maize + ragi (1:2) (3487.45 kg ha⁻¹). Among the intercropping treatments, T5- maize + kodo (1:2) recorded comparatively higher grain yield, while the lowest grain yield was observed in T7- maize + ragi (1:2). In absence of interspecific competition for different growth resources like solar radiation, essential elements, moisture and space favoured better crop growth, cob development, kernel formation and grain filling resulted higher grain yield in sole maize. Similar finding was also reported by Mandal *et al.* (2014) and Prakash *et al.* (2024) [10, 13].

3.2.6 Straw yield (kg ha⁻¹)

Grain yield of maize was significantly influenced by different maize based intercropping systems. T1- sole maize (6332.24 kg ha⁻¹) recorded the highest straw yield which was significantly superior to all intercropping systems. Among the intercropping systems, T5- maize + kodo (1:2) (5186.77

kg ha⁻¹) produced higher straw yield, lower straw yield of maize was noticed T7 when it was intercropped with ragi (4840.37 kg ha⁻¹), which might be due to higher competition offered by the intercrop for natural resources like space, nutrients and moisture. These results are in agreement with the findings of Flavia *et al.* (2023) and Prakash *et al.* (2024) [10, 14].

3.2.7 Harvest index (%)

Harvest index was not significantly influenced by different maize base intercropping system with small millets. Although numerical differences were observed among the treatments, the highest harvest index (42.46%) was recorded under T1- Sole maize, followed by T5- maize + kodo (1:2) and T6- maize + kutki (1:2). The lowest harvest index (42.26%) was recorded under T7- maize + ragi (1:2), very small difference in harvest index of maize in sole and intercropping with small millets indicating that partitioning of total biomass towards grain production.

3.3 Intercropping indices

3.3.1 Land Equivalent Ratio (LER)

Land equivalent ratio was influenced by different maize based intercropping systems with small millets. Higher land equivalent ratio was recorded with the intercropping system of T5- maize + kodo (1:2) (1.68) followed by T6- maize + kutki (1:2) (1.66), and T7- maize + ragi (1:2) (1.65) which were comparable with each other. Higher land equivalent ratio with T7- maize + kodo (1:2) might be due to higher land utilization and extra yield obtained from intercrop which makes the combination more advantageous over other intercropping systems. These results corroborated with Choudhary *et al.* (2012) and Sharmili *et al.* (2018) [5, 11].

3.3.2 Area Time Equivalent Ratio (ATER)

Area time equivalent ratio was also higher than unity in each intercropping system of maize with small millets then the sole crops. The higher ATER (1.60) was recorded under T5- maize + kodo (1:2), followed by T7- maize + ragi (1:2) (1.59) and T6- maize + kutki (1:2) (1.58). The ATER values greater than unity indicate that the intercropping systems were more efficient than sole cropping in terms of both land and time utilization. These findings are in close conformity with Kumar *et al.* (2008) and Padhi *et al.* (2010) [7, 9].

3.3.3 Aggressivity

Aggressivity was found non-significant among the treatments of different intercropping systems. The aggressivity value of maize based small millets intercropping revealed that maize was the dominant (more aggressive) component in T5- maize + kodo (1:2) (1.16) and T6- maize + kutki (1:2) (1.09) intercropping system. In T7- maize + ragi (1:2) recorded an aggressivity value below unity (0.93), the lower among the three intercrops, suggestive a more balanced competitive relationship between maize and ragi, with ragi being relatively less suppressed and contributing more equitably to the combined yield.

3.3.4 Maize Grain Equivalent Yield (MGEY)

Maize grain equivalent yield (MGEY) was significantly influenced by different maize based intercropping system. Among the treatments, T7- maize + ragi (1:2) recorded the highest MGEY *i.e.* 6064.42 kg ha⁻¹. This was significantly higher than T1- sole maize (4695.53 kg ha⁻¹), T5- maize +

kodo (1:2) (4914.73 kg ha⁻¹) and T6-maize + kutki (1:2) (4715.21 kg ha⁻¹), while the sole millet crops (kodo, kutki and ragi) recorded the lowest MGEY. Highest maize grain equivalent yield by maize + ragi intercropping system might be due to efficient utilization of the resources by the

component crops in the system, which led to higher yields of both maize as well as ragi with additional advantage of better market price of ragi. These results are in close conformity with those of Choudhary *et al.* (2012) and Sharmili *et al.* (2018) [5, 12].

Table 2: Plant population (m⁻¹) row length of maize as influence by intercropping with small millets

Treatments	Plant population (m ⁻¹) row length
	30 DAS
T1- Sole maize	5.44
T5- Maize + kodo (1:2)	5.33
T6- Maize + kutki (1:2)	5.22
T7 -Maize + ragi (1:2)	5.22
S.Em. (±)	0.15
CD (5%)	NS

Table 3: Plant height (cm) of maize as influence by intercropping with small millets

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T1- Sole maize	45.39	155.72	183.89	194.49
T5- Maize + kodo (1:2)	38.86	129.15	152.36	161.33
T6- Maize + kutki (1:2)	37.38	125.18	147.28	155.41
T7- Maize + ragi (1:2)	34.43	117.16	136.94	144.66
S.Em. (±)	2.41	7.65	9.07	9.52
C.D. (5%)	NS	26.47	31.38	32.95

Table 4: Dry matter production (g plant⁻¹) of maize as influence by intercropping with small millets

Treatments	Dry matter production (g plant ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest
T1- Sole maize	15.10	91.94	219.07	248.73
T5- Maize + kodo (1:2)	12.98	75.42	180.09	204.18
T6- Maize + kutki (1:2)	11.51	73.32	175.12	198.72
T7- Maize + ragi (1:2)	11.16	69.46	165.75	188.32
S.Em. (±)	0.86	4.54	10.75	12.16
C.D. (5%)	NS	15.71	37.20	42.09

Table 5: Yield attributes of maize as influence by intercropping with small millets

Treatments	No. of cobs plant ⁻¹	No. of seed rows cob ⁻¹	No. of seeds cob ⁻¹	Test weight (g)
T1- Sole maize	1.40	15.87	507.28	291.96
T5- Maize + kodo (1:2)	1.33	13.56	433.11	248.83
T6- Maize + kutki (1:2)	1.27	13.29	419.96	242.11
T7- Maize + ragi (1:2)	1.13	12.56	403.96	233.28
S.Em. (±)	0.06	0.65	20.87	11.90
C.D. (5%)	NS	2.24	72.21	41.18

Table 6: Grain yield, straw yield and harvest index of maize as influence by intercropping with small millets

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
T1- Sole maize	4695.53	6332.24	42.46
T5- Maize + kodo (1:2)	3806.42	5186.77	42.44
T6- Maize + kutki (1:2)	3657.13	4995.90	42.34
T7- Maize + ragi (1:2)	3487.45	4840.37	42.26
S.Em. (±)	240.53	310.28	-
C.D. (5%)	832.35	1073.72	-

Table 7: Land equivalent ratio, Area time equivalent ratio, Aggressivity and Maize grain equivalent yield as influenced by different maize based intercropping system with small millets

Treatments	LER	ATER	Aggressivity	MGEY
T1 - Sole maize	1.00	1.00	-	4695.53
T2 - Sole kodo	1.00	1.00	-	1288.71
T3 - Sole kutki	1.00	1.00	-	1230.28
T4 - Sole ragi	1.00	1.00	-	2914.98
T5 - Maize + kodo (1:2)	1.68	1.60	1.16	4914.73
T6 - Maize + kutki (1:2)	1.66	1.58	1.09	4715.21
T7 - Maize + ragi (1:2)	1.65	1.59	0.93	6064.42
S.Em. (±)	0.05	0.05	-	229.05
C.D (5%)	0.16	0.15	-	705.78

4. Conclusion

The present study demonstrated that different maize based intercropping system with small millets significantly influenced the growth and yield of maize. Sole maize (T1) was recorded higher plant population, plant height and dry matter production, number of seed rows cob⁻¹, number of seeds cob⁻¹, grain and straw yield than the intercropped maize treatments. Among the intercropping systems, T5- maize + kodo (1:2) perform better than the other intercrops, T6- maize + kutki (1:2), T7- maize + ragi (1:2). The LER, ATER and Aggressivity recorded higher in T5- maize + kodo (1:2) and highest MGEY was recorded in the treatment T7- maize + ragi (1:2) and the lowest was observed in T3- sole kutki.

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