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Research Paper

Dry Matter Accumulation, Yield and Economics of Maize Cultivation as Influenced by Mixed Stands of Maize + Vegetable Legumes

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ABSTRACT

Maize (*Zea mays* L.), the queen of cereals, has a versatile use as food, feed, and industrial purpose, and the area under maize has been increasing in India in recent times. As a widely spaced crop, it offers the provision of adoption for the intercropping system without reducing the optimum plant stand in additive series. Based on the above facts, a field experiment was conducted during the summer of 2021 on intercropping maize with vegetable legumes at the Experimental Farm of Centurion University of Technology and Management, Paralakhemundi, Odisha. The experiment was carried out in Randomized Block Design (RBD) comprising nine treatments and replicated thrice. The results of the research revealed that the dry matter accumulation (g m^{-2}) of maize and legumes was significantly affected at different growth stages. In the case of biological yield, a higher value was obtained in sole maize. It was statistically at par with maize + cluster bean (2:3). In Terms of Land Equivalent Ratio (LER) and Area Time Equivalent Ratio (ATER), the values obtained in all the intercropped treatments were more significant than unity, and this clearly showed that intercropping was advantageous. The economics of the intercropping systems showed that the highest cost of cultivation was recorded in maize + cluster bean (2:3). However, in the case of a gross return, the net return, and B:C ratio, the higher value was noted in 2:3 row proportion of maize intercropped with cowpea followed by sole cowpea and maize + cluster bean (2:3). The study indicated that intercropping 2:3 row proportion of maize + vegetable legumes was advantageous over a pure stand of maize in terms of biomass production and economic importance.

HIGHLIGHTS

- In wide maize, legumes can easily be incorporated as intercrops in an additive series of intercropping systems without reducing the plant stand of maize compared to its pure cultivation.
- Intercropping legumes in maize showed higher productivity, greater resource utilization, and higher economic return than a monoculture of maize.

Keywords: Maize, intercropping system, biomass production, competitive indices, economics

Agriculture is facing a tremendous problem in the context of climate change and increased demand for food, feed, and industrial raw materials (Zaman *et al*. 2017; Gaikwad *et al*. 2022). The rapid increase in population creates a more significant gap between the demand and supply chain, and the day-to-day decrease in agricultural land even worsens the conditions. In this regard, the latest innovations, climate-resilient crop production, and agronomic adaptations are the suitable options to meet the growing demands (Das *et al*. 2021; Moulick *et al*. 2023; Mwakidoshi *et al*. 2023).

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Cereals are considered as the principal source of food and dietary energy in the world. After rice and wheat, maize (*Zea mays* L.) attains the third position that fits various agro climatic regions in different growing seasons, has versatile uses, and has numerous ecological purposes (Maitra *et al*. 2019). Due to its high feeding value and as a carbohydrate source worldwide, it is used as human food and animal feed (Undie *et al*. 2012). Maize is a C_4 plant that can assimilate high amounts of carbon dioxide from the atmosphere and can efficiently utilize the radiant energy that increases its yield potential. In the global level, maize was cultivated in a total area of 201.98 m ha with a production of 1162.3 m tonnes and productivity of 5.75 t/ha. The world's maize production forecast has increased from 11 million tonnes in 2020-21 to 12.1 million tonnes in 2021-22 (ICAR – IIMR, 2022). India is the fourth largest producer of maize in the world in terms of total maize output with an area of 9.89 m ha, production of 31.65 m tonnes, and productivity of 3199 kg/ha (ICAR – IIMR, 2022). The change in climatic conditions, deterioration of soil health due to excessive use of chemical fertilizers, pesticides, etc., and monoculture also results in the possibility of crop failure. Under such consequences, intercropping became very popular among small and marginal farmers (Sarkar *et al*. 2000; Gitari *et al*. 2020; Maitra *et al*. 2020). Intercropping is considered the practice of growing two or more preferably different crops simultaneously on the same piece of land with different row arrangements (Manasa *et al*. 2020; Panda *et al*. 2021).

Intercropping is beneficial over monocropping as it brings more productivity by efficiently utilizing the water, nutrients, labor, and land and reducing pests, diseases, and weed infestation (Maitra and Ray, 2019; Chappa *et al*. 2022; Panda *et al*. 2022). An additive series of intercropping utilizes the space left between the main crop to grow another crop which covers the land and reduces the growth of weeds and pests. The selection of compatible crops, the density of the population, and the planting geometry are the factors that determine the success of an intercropping system (Jena *et al*. 2022). An intercropping system harnesses multifaceted benefits such as stable or more yield (Maitra, 2020), crop diversification, greater ecosystem services and a healthy environment (Maitra and Gitari, 2020), natural insurance against aberrant weather conditions (Maitra *et al*. 2019; Maitra *et al*. 2020), livelihood and food security for smallholders (Maitra, 2018), soil quality improvement (Jena *et al*. 2022) and higher resource use efficiency. In the semi-arid tropics, cowpea (*Vigna unguiculata* L.) plays a vital role because of its high tolerance to drought and adverse weather conditions. Cowpea is considered a preferable intercrop with taller crops as it performs well in partial shade. The crop itself fulfils a major portion of the nitrogen requirement due to its nitrogen-fixing capacity, which also makes it compatible for intercropping systems (Parimaladevi *et al*. 2019). However, for both arid and semi-arid conditions, cluster bean (*Cyamopsis tetragonoloba* L.) is also considered one of the important commercial crops. Cluster bean has a deep tap-root system which makes them suitable to sustain during drought, and that helps in escaping the water stress situation (Bhatt *et al*. 2016). Based on the above facts, the present investigation was conducted to assess the effect of maize and vegetable legumes intercropping system on dry matter accumulation, productivity, and competitive relationship of the systems.

MATERIALS AND METHODS

A field experiment was conducted at Experimental Farm (23˚39′ N latitude and 87˚42′ E Longitude) of Centurion University of Technology and Management, Odisha, during the summer season of 2021-2022. During the crop growing period, the weather data was recorded at the Meteorological Observatory of the university from 22 February 2021 to 15 June 2021 and was presented in Table 1. The weekly maximum and minimum mean temperatures during the crop period ranged between 30° and 37°C, and 20° and 25°C, respectively. The weekly mean relative humidity ranged from 29.4 % to 87.1%, and rainfall of 167.5 mm was received during the crop-growing. The physical and chemical characteristics of the composite soil samples were estimated using standard procedures. The results showed that the experimental soil was sandy loam in texture with a pH of 6.3 and organic carbon of 0.34%. The available soil nutrients such as nitrogen, phosphorus, and potassium of initial soil were 172, 15, and 198 kg/ ha, respectively.

Table 1: Meteorological observation during the crop period

Week	Standard week	Temperature (°C) Max	Temperature (°C) Min	Relative Humidity (%)	Rainfall (mm)	Sunshine (hrs. day^{-1})
February 2021						
1	8th	35	26	90	0	7
2	9th	37	28	91	0	9
March 2021						
3	10th	36	26	88	0	9
4	11th	34	26	89	10.7	8
5	12th	30	25	91	0	8
6	13th	34	25	89	0	8
April 2021						
7	14th	32	25	88	0	7.5
8	15th	34	25	83	0	8
9	16th	34	25	85	13.2	8
10	17th	33	25	90	0	8
11	18th	33	20	89	5.4	8
May 2021						
12	19th	35	26	90	19.6	9
13	20th	34	25	92	38.9	8
14	21st	33	25	91	18.3	8
15	22nd	33	25	90	6.6	8
June 2021						
16	23rd	36	27	86	45.2	9
17	24th	33	27	86	9.6	9

The experiment was carried out in Randomized Block Design (RBD) comprising of nine treatments, namely, T_1: maize sole, T_2: cowpea sole, T_3: cluster bean sole, T_4: maize + cowpea (2:1), T_5: maize + cowpea (2:2), T_6: maize + cowpea (2:3), T_7: maize + cluster bean (2:1), T_8: maize + cluster bean (2:2) and T_9: maize + cluster bean (2:3), with 3 replications. The plots were of 4.8 m × 5.0 m each. Maize hybrid 'Sharp' cowpea variety 'Ankur-Gomati (VU-89)' and cluster bean variety 'Nylon-66' were considered for the experimentation with a duration of 120, 90, and 90 days, respectively. Paired row sowing of maize was adopted with a spacing of 30 cm/90 cm × 25 cm, and in between two pairs of maize rows, legumes were sown as per the treatment specifications.

However, in sole cowpea and cluster bean, row to row distance was 30 cm, while plant to plant distance was maintained at 10 cm apart. The field was ploughed twice with a tractor before the commencement of the experiment to bring the soil to a fine tilth and then leveled after the weeds were removed. Irrigation channels were made and the division of the subplots was done as per plan. The fertilizers, namely, nitrogen, phosphate and potash (N, P_2O_5 and K_2O) were applied as per recommended dose to maize and legumes (cowpea and cluster bean), and the doses of N-P_2O_5-K_2O were for sole maize was 100-50-50 kg ha^{-1}, sole cowpea 20-40-20 kg ha^{-1} and sole cluster bean 20-40-20 kg ha^{-1}, while maize + legume mixed stands were provided with 100-50-50 kg ha^{-1}. In additive series of intercropping, 66,667 maize plants ha^{-1} were accommodated in the sole and intercropped treatments; however, sole legumes were comprised of 333333 plants ha^{-1}, and 1, 2, and 3 rows of legumes in between paired rows of maize consisted of 66667, 133333 and 200000 plants ha^{-1}, respectively. The recorded data were statistically analyzed using analysis of variance (ANOVA), standard error of means (S. Em.), and critical difference (C.D., P=0.05) at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Dry matter accumulation

In the case of dry matter accumulation, it was observed that at 30 DAS, sole maize recorded significantly higher dry matter content (112 g/m^2) than intercropped treatments except for maize + cluster bean in 2:3 row proportion (Table 2). However, maize + cluster bean (2:3) was statistically at par with the rest of the intercropped treatments. At 60 DAS, a similar trend was observed in which pure stand of maize and it was significantly superior to maize + cowpea (2:1), maize + cowpea (2:2), maize + cowpea (2:3), maize + cluster bean (2:1) and maize + cluster bean (2:2). However, sole maize was statistically on par with maize + cluster bean (2:3). At 90 DAS and at harvest, significantly more dry matter production (1365 g/m^2 and 1475 g/m^2, respectively) was obtained in sole maize and it was statistically at par with maize + cowpea (2:3), maize + cluster bean (2:2) and maize + cluster bean (2:3). Among the intercropped treatments, maize + cluster bean (2:3) resulted in significantly more dry matter accumulation at 90 DAS and harvest and the treatment was statistically at par with maize +

Table 2: Effect of maize + vegetable legume intercropping system on dry matter accumulation (g/m^2)

Treatments	Dry matter accumulation (g/m^2)								
	30 DAS			60 DAS			Harvest		
	Maize	Legume	Total	Maize	Legume	Total	Maize	Legume	Total
Sole maize	112	—	112	968	—	968	1475	—	1475
Cowpea	—	287	287	—	1597	1597	—	2007	2007
Cluster bean	—	247	247	—	1287	1287	—	1780	1780
Maize + Cowpea (2:1)	86	54	140	770	299	1069	1290	396	1686
Maize + Cowpea (2:2)	91	104	195	795	565	1360	1325	781	2106
Maize + Cowpea (2:3)	94	160	254	849	810	1659	1379	1128	2507
Maize + Cluster bean (2:1)	83	48	131	821	247	1068	1383	339	1722
Maize + Cluster bean (2:2)	94	91	185	827	528	1355	1395	699	2094
Maize + Cluster bean (2:3)	98	150	248	899	824	1723	1424	1052	2476
S. Em. (±)	6	NA	16	38	NA	54	35	NA	101
C. D. (at 5%)	18		49	115		162	107		404

NA= Not analysed (as the two legumes had different morphological characters, hence, the statistical analysis was not done).

cowpea (2:2), maize + cowpea (2:3), maize + cluster bean (2:1) and maize + cluster bean (2:2). Such results were obtained due to efficient utilization and uptake of nutrients under pure stand of maize without any interspecies competition (Khan *et al*., 2018; Raza *et al*. 2019).

In terms of legumes at 30 days periodic intervals, the data on dry matter accumulation of legumes (g/m^{-2}) was measured and presented in Table 2. The recorded data revealed that there was a gradual increase in dry matter content at different crop stages with the progression of crop age. The highest dry matter accumulation of cowpea and cluster bean was obtained at their harvest stage. Further, sole cowpea produced more dry matter than intercropped cowpea at all the growth stages. However, at 30 DAS intercropped cluster beans in maize with a row proportion of maize + cluster bean (2:3) resulted in the more dry matter than sole cluster bean This might be due to the partial shade provided by the paired maize crops during the summer season, which created a favorable microclimate for legumes and allowed them for utilization of nutrients efficiently as elongation of internodes which resulted in higher cell division and enlargement of the stem. At later growth stages, i.e., 60 DAS and harvest, the sole cluster bean yielded more dry matter than intercropped cluster bean. The results conform with the findings of Üstündağ and Ünay (2016) and Iderawumi (2014).

Further, the combined dry matter production of maize in the mixed stand was more than sole maize at different growth stages. At 30 DAS, sole maize produced less dry matter from the unit area than mixed stands because legumes in mixed culture added value. Sole maize remained significantly inferior to maize + cowpea (2:2), maize + cowpea (2:3), maize + cluster bean (2:2), and maize + cluster bean (2:3). A similar trend was recorded at 60 DAS and harvest in total dry matter accumulation. Legumes have a more remarkable ability to produce more dry matter than maize. In the additive series of experiments, legumes added extra biomass spatially; hence, a significant enhancement in dry matter production was recorded in mixed stands where 2 and 3 rows of legumes were added. The results corroborate the findings of Manasa *et al*. (2021).

Yield

The grain yield of maize differed significantly among the treatments, and it showed that pure stand of maize recorded significantly higher grain yield (6756 kg/ha) and it remained statistically at par with maize + cowpea (2:3) and maize + cluster bean (2:3). However, sole maize was significantly superior to maize + cowpea (2:1), maize + cowpea (2:2), maize + cluster bean (2:1) and maize + cluster bean (2:2). Among the intercropped treatments, all were statistically at par with each other. In the case of stover yield, the significantly higher value (8168 kg/ha) was recorded in maize intercropped with cluster bean (2:2). It remained at par with sole maize, maize + cowpea (2:2), maize + cowpea (2:3), maize + cluster bean (2:1), maize + cluster bean (2:3). The treatment maize + cowpea (2:1) resulted in the lowest stover yield (6810 kg/ha). It was on par with maize + cowpea (2:2) and maize + cowpea (2:3). The results are similar with the previous findings of Prakash *et al*. (2019), Choudhary and Choudhury (2016) and Manasa *et al*. (2020).

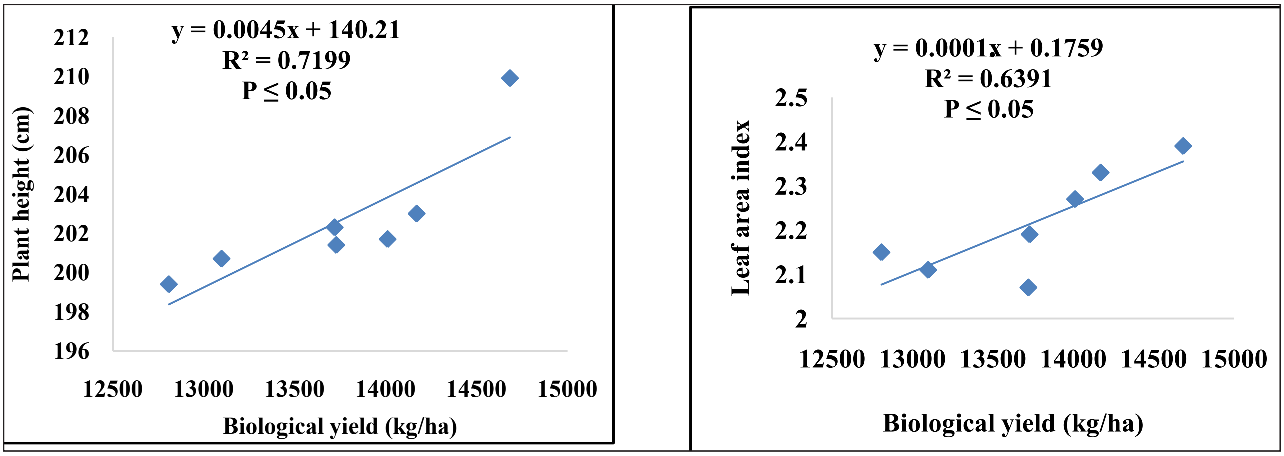
Impact of growth parameters on biological yield of maize

Growth attributes like plant height and leaf area significantly influenced total biological yield. The plant height and leaf area index of maize taken at harvest were plotted against the biological yield. The linear equation reflected that there was a close relation between plant height and leaf area on the biological yield of maize. The R^2 values of the regression graph plotted against plant height (0.7199) and leaf area index (0.6391) over biological yield are presented in Fig. 2. The graphical analysis further predicted a linear increase in biological yield with an increase in plant height and leaf area index of maize. An increase in plant height and leaf area was converted into higher biomass production, resulting in greater biomass yields (Ginwal *et al*. 2019).

Competition functions

LER is defined as the proportionate land area needed under sole crop to generate the same yield as achieved under the intercropping system by adopting same management practices. The total LER was obtained by adding the individual LER of maize and legume (Fig. 2). In case of total LER, it was recorded that maize + cluster bean (2:3) registered the greater LER of 1.89 which was followed by maize + cowpea (2:3) with 1.87, maize + maize + cluster bean (2:2) with 1.84, maize + cowpea (2:1) with 1.83, maize + cowpea (2:2) with 1.82 and maize + cluster bean (2:1) with 1.81. The higher individual LER values of maize and legumes (cowpea and cluster bean) are primarily responsible for enhancing the total LER. All the intercropped treatments recorded LER value more than unity which showed that they were more advantageous than sole cropping. Similar findings are observed by Jan *et al*. (2016).

The value for Area Time Equivalent Ratio (ATER) was computed and presented in Fig. 3. ATER considers the land use during the period for which the crops were present in the field. The data revealed that all the intercropped treatments recorded value more than unity which showed they all were advantageous and they used the land and time efficiently. The treatment maize + cluster bean (2:3) registered the highest ATER value of 1.40, and it was closely followed by maize + cowpea (2:3) with 1.39. The lowest and even same value of ATER was observed in 2:1 row proportion of maize + cowpea and maize + cluster bean of 1.01, which was slightly higher than unity indicated marginal yield benefit. The treatments with a 2:2 row proportion of maize



(A) (B)

Fig. 2: Relation between plant height and LAI on biological yield of maize

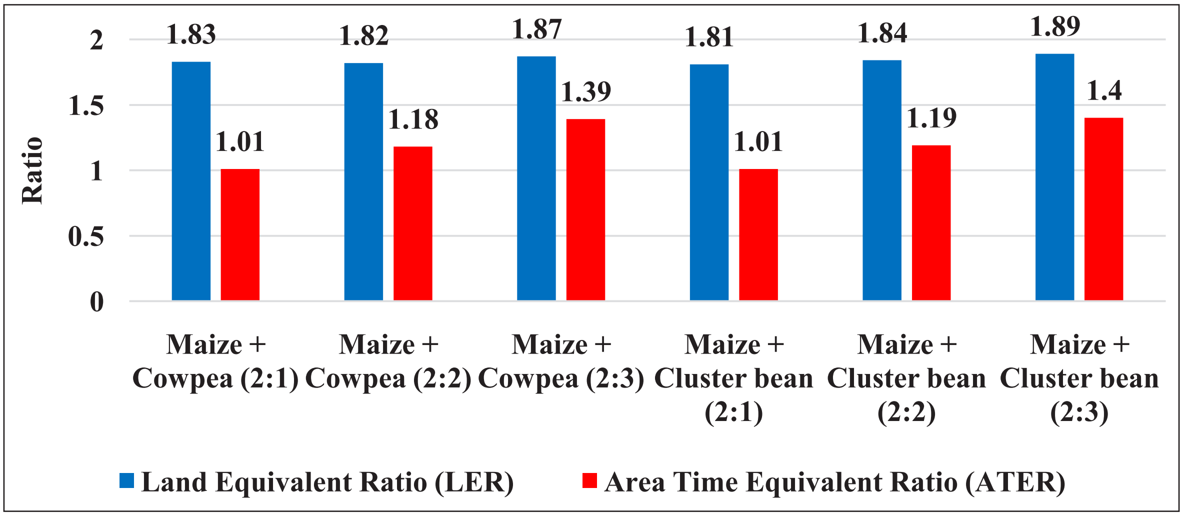


Fig. 3: Effect of maize-legume intercropping on Land Equivalent Ratio (LER) and Area Time Equivalent Ratio (ATER)

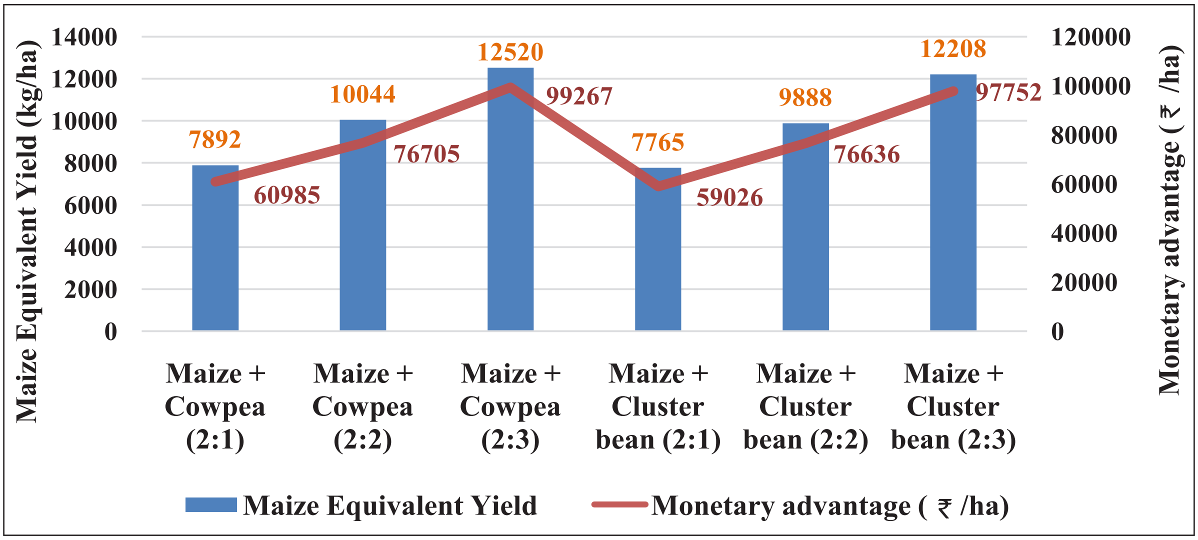


Fig. 4: Effect of maize-legume intercropping on Maize Equivalent Yield (MEY) and Monetary Advantage (MA)

with cowpea and cluster bean also record close proximity in values that is 1.18 and 1.19, respectively (Panda *et al*. 2021).

The Maize Equivalent Yield (MEY) and monetary advantage (MA) was calculated and presented in Fig. 4. The Maize Equivalent Yield (MEY) was recorded highest in 2:3 row proportion of maize intercropped with cowpea and it was followed by maize + cluster bean (2:3). However, the lowest maize equivalent yield was obtained in 2:1 row proportion of maize intercropped with cowpea and cluster bean. The MA also followed a similar trend as MEY. The monetary advantage was highest in the 2:3 row proportion of maize intercropped with cowpea, followed by maize + cluster bean (2:3).

Economics

The cost required for the cultivation was calculated for both pure and their respective mixed stand and was presented in Table 3. The highest cost incurred to grow the crop was registered in maize intercropped with cluster beans in 2:3 row proportion. The second highest was recorded in a pure stand of cluster bean (₹ 68258/ ha), and it was closely followed by maize + cluster bean (2:2) (₹ 67673/ ha) and maize + cowpea (2:3) (₹ 67113/ ha). The gross return was generally the price obtained after selling the produce. The data revealed that maize intercropped with cowpea in a 2:3 row ratio recorded the maximum return for the produce (₹ 222584/ ha), and it was closely followed by a 2:3

Table 3: Effect of maize-legume intercropping on economics and B:C ratio

Treatments	Economics (₹/ha)			B:C ratio
	Cost of cultivation	Gross return	Net return	
Sole maize	47973	118816	70843	1.48
Sole cowpea	61658	197635	135977	2.21
Sole cluster bean	68258	183588	115330	1.69
Maize + Cowpea (2:1)	62153	139864	77711	1.25
Maize + Cowpea (2:2)	64633	178696	114063	1.76
Maize + Cowpea (2:3)	67113	222584	155470	2.32
Maize + Cluster bean (2:1)	63673	137708	74035	1.16
Maize + Cluster bean (2:2)	67673	175740	108066	1.60
Maize + Cluster bean (2:3)	71673	217012	145339	2.03

row proportion of maize+ cluster bean (₹ 217012/ ha). Sole maize noted the lowest gross return among all the treatments; this might be because of the higher pod price of cowpea and cluster bean. Net return was calculated by subtracting the cost of cultivation from gross return. It is generally the profit obtained. The maximum net return was registered with maize + cowpea (2:3), that is, ₹ 155470/ ha, and it was closely followed by 2:3 row proportion of maize intercropped with cluster bean (₹ 145339/ ha). The least profit was recorded in a pure stand of maize (₹ 70843/ ha). Benefit: cost ratio of different intercropping systems depicts the ratio of the profit obtained to the cost required to produce the yield. The data showed that the highest benefit: cost ratio (2.32) was registered in maize + cowpea (2:3) followed by sole cowpea and maize intercropped with cluster bean (2:3) with a value of 2.21 and 2.03, respectively. The results conform with the previous findings of Yogesh *et al*. (2014) and Manasa *et al*. (2020).

CONCLUSION

The study concluded that intercropping vegetable legumes, namely, cowpea and cluster bean in hybrid maize, were more productive in terms of greater resource use and profitability than a pure stand of maize. However, based on economic benefit, it can be recommended that maize + cowpea and maize + cluster bean in a 2:3 ratio can be recommended for cultivation under south Odisha conditions during the summer season.

REFERENCES

Bhatt, R.K., Juklani, A.K. and Roy, M.M. 2016. Cluster bean (*Cyamopsis tetragonoloba*), an important industrial arid legume: A review. *Legume Res.*, **40**: 207-214

Chappa, L.R., Mugwe, J., Maitra, S., Gitari, H.I. 2022. Current status, and prospects of improving sunflower production in Tanzania through intercropping with Sunnhemp. *Int. J. Biores. Sci.*, **9**: 1-8.

Choudhary, V.K. and Choudhury, B.U. 2016. A staggered maize–legume intercrop arrangement influences yield, weed smothering and nutrient balance in the eastern Himalayan region of India. *Exp. Agric.*, **47**: 1-20.

Das, P., Pramanick, B., Goswami, S., B., Maitra, S., Ibrahim, S. M., Laing, A.M., Hossain, A. 2021. Innovative land arrangement in combination with irrigation methods improves the crop and water productivity of rice (*Oryza sativa* L.) grown with okra (*Abelmoschus esculentus* L.) under raised and sunken bed systems. *Agron.*, **11**(10): 2087.

Gaikwad, D.J., Ubale, N.B., Pal, A., Singh, S., Ali, M.A., Maitra, S. 2022. Abiotic stresses impact on major cereals and adaptation options- A review. *Res. Crops*, **23**(4): 896-915.

Ginwal, D.S., Kumar, R., Ram, H., Dutta, S., Arjun, M. and Hindoriya, P.S. 2019. Fodder productivity and profitability of different maize and legume intercropping systems. *Ind. J. Agric. Sci.*, **89**(9): 1451-5.

Gitari, H.I., Nyawade, S.O., Kamau, S., Karanja, N.N., Gachene, C.K., Raza, M.A., Maitra, S. and Schulte-Geldermann, E. 2020. Revisiting intercropping indices with respect to potato-legume intercropping systems. *Field Crop Res.*, **258**: 107957.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedure for agricultural research. 2nd Edn. International Rice Research Institute. Los Banos, Philippines. John Willy and Sons. New York, pp. 324.

ICAR – IIMR. 2022. Director's report: ICAR – Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab, India.

Iderawumi, A.M. 2014. Effect of cowpea on growth and yield parameter in a maize-cowpea intercrop. *J. Manage. Sci.*, **4**(1): 37-42.

Jan, R., Saxena, A., Jan, R., Khanday, M. and Jan, R. 2016. Intercropping indices and yield attributes of maize and black cowpea under various planting pattern. *The Bioscan.*, **11**(3): 1781-1785.

Jena, J., Maitra, S., Hossain, A., Pramanick, B., Gitari, H.I., Praharaj, S., Shankar, T., Palai, J.B., Rathore, A., Mandal, T.K. and Jatav, H.S. 2022. Role of legumes in cropping system for soil ecosystem improvement, *In:* Jatav H.S. *et al*. (Eds.) *Ecosystem services: types, management and benefits*. Nova Science Publishers, Inc, New York, pp.1-21.

Khan, M.A.H., Sultana, N., Akter, N., Zaman, M.S. and Islam, M.R. 2018. Intercropping gardenpea (*Pisium sativum*) with Maize (*Zea mays*) at farmers' field. *Ban. J. Agric. Res.*, **43**(4): 691-702.

Maitra, S. and Ray, D.P. 2019. Enrichment of Biodiversity, Influence in Microbial Population Dynamics of Soil and Nutrient Utilization in Cereal-Legume Intercropping Systems: A Review. *Int. J. Biores. Sci.*, **6**(1): 11-19.

Maitra, S. 2018. Role of Intercropping System in Agricultural Sustainability. *Centurion J. Multidisc. Res*., **8**(1): 77-90.

Maitra, S. 2020. Intercropping of small millets for agricultural sustainability in dry lands: A review. *Crop Res.*, **55**: 162-71.

Maitra, S. and Gitari, H.I. 2020. Scope for adoption of intercropping system in organic agriculture. *Ind. J. Nat. Sci.*, **11**: 28624-8631.

Maitra, S., Palai, J.B., Manasa, P. and Kumar, D.P. 2019. Potential of intercropping system in sustaining crop productivity. *Int. J. Environ. Agric. Biotechnol.*, **12**: 39–45.

Maitra, S., Shankar, T. and Banerjee, P. 2020. Potential and advantages of maize- legume intercropping system, *In:* Maize -production and use; Hossain, A., Ed.; Intech open, London, United Kingdom.doi:10.5772/intechopen.91722.

Maitra, S., Shankar, T., Manasa, P. and Sairam, M. 2019. Present status and future prospects of maize cultivation in South Odisha. *Int. J. Biores. Sci*., **6**:27-33.

Manasa, P., Maitra, S. and Barman, S. 2020. Yield Attributes, yield, competitive ability and economics of summer maize-legume intercropping system. *Int. J. Agric. Environ. Biotechnol.*, **13**(1): 33-38.

Manasa, P., Sairam, M. and Maitra, S. 2021. Influence of Maize-Legume Intercropping System on Growth and Productivity of Crops, *Int. J. Biores. Sci.*, **8**(1): 47-60.

Moulick, D., Bhutia, K.L., Sarkar, S., Roy, A., Mishra, U.N., Pramanick, B., Maitra, S., Shankar, T., Hazra, S., Skalicky, M., Brestic, M., Barek, V. and Hossain, A. 2023. The intertwining of Zn-finger motifs andabiotic stress tolerance in plants: Current status and future prospects. *Front. Plant Sci*. **13**: 1083960.

Mwakidoshi, E.R., Gitari, H.H., Muindi, E.M., Wamukota, A., Seleiman, M.F. and Maitra, S., Smallholder farmers' knowledge of the use of bioslurry as a soil fertility amendment for potato production in Kenya. *Land Degradation & Development*. Wiley Online, https://doi.org/10.1002/ldr.4601

Panda, S.K., Maitra, S., Panda, P., Shankar, T., Pal, A., Sairam, M. and Praharaj, S. 2021. Productivity and competitive ability of rabi maize and legumes intercropping system. *Crop Res.*, **56**: 98-104.

Panda, S.K., Sairam, M., Sahoo, U., Shankar, T. and Maitra, S. 2022. Growth, productivity and economics of maize as influenced by maize-legume intercropping system. *Farm. Manage.*, **7**(2): 61-66.

Parimaladevi, C., Ramanathan, S. P., Kumar, N. S. and Suresh, S. 2019. Evaluation of maize based intercropping systems in Thamirabarani basin of Tamil Nadu. *J. Pharmacogn Phytochem.*, **8**(3): 4051-4056.

Prakash, V., Manimaran, S., Elankavi, S. and Venkatakrishnan, D. 2019. Evaluation of growth attributes and yield of maize + pulse intercropping system. *Plant Arch.*, **19**(2): 3522-3524.

Raza, M.A., Bin Khalid, M.H., Zhang, X., Feng, L.Y., Khan, I., Hassan, M.J., Ahmed, M., Ansar, M., Chen, Y.K., Fan, Y. F. and Yang, F. 2019. Effect of planting patterns on yield, nutrient accumulation and distribution in maize and soybean under relay intercropping systems. *Scientific Rep.*, **9**(1):1-14.

Sarkar, R.K., Shit, D. and Maitra, S. 2000. Competition functions, productivity and economics of chickpea (*Cicer arietinum*)-based intercropping system under rainfed conditions of Bihar plateau, *Ind. J. Agron*., **45**(4): 681-686.

Undie, U.L., Uwah, D.F. and Attoe, E.E. 2012. Effect of intercropping and crop arrangement on yield and productivity of late season Maize/soybean mixtures in the humid environment of South Southern Nigeria. *J. Agric. Sci.*, **4**(4):37-50.

Üstündağ, İ.Y. and Ünay, A.Y.D.I.N. 2016. Effect of maize/legume intercropping on crop productivity and soil compaction. *Anadolu Tarım Bilimleri Dergisi*, **31**(2): 268-274.

Yogesh, S., Halikatti, S.I., Hiremath, S.M., Potdar, M.P., Harlapur, S. I. and Venkatesh, H. 2014. Light use efficiency, productivity and profitability of maize and soybean intercropping as influenced by planting geometry and row proportion. *Karnataka J. Agric. Sci.*, **27**(1): 569-582.

Zaman, A., Zaman, P. and Maitra, S. 2017. Water resource development and management for agricultural sustainability, *J. Appl. Adv. Res.*, **2**(2): 73-77.