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# Cereal + legume intercropping: A sustainable approach for improving productivity and soil health

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*Cereal + legume intercropping is a promising strategy for sustainable agricultural intensification, enabling efficient utilisation of water, nutrients, light and space while reducing dependence on synthetic fertilisers. Legume-based diversification through intercropping enhances biological $N_2$ fixation, soil fertility, biodiversity and agroecosystem resilience, while improving system productivity and resource-use efficiency. Appropriate selection of component crops, planting geometry, population ratio, and complementary resource-use patterns is essential to minimise interspecific competition and maximise intercropping benefits. Different intercropping arrangements, including row, strip, mixed and relay systems, along with additive and replacement series, provide flexible options for enhancing productivity, resource conservation and environmental sustainability.*

**Keywords:** Biodiversity, Environmental sustainability, Resource conservation, Nitrogen fixation

ENSURING food security while sustaining the soil and environment health is a major agricultural challenge in current scenario. Crop productivity must be enhanced sustainably without compromising soil fertility, increasing greenhouse gas (GHG) emissions, or adversely affecting food quality. Enhancing plant diversity within agroecosystems is a key strategy for promoting resource-use efficiency, ecological resilience, and long-term agricultural sustainability Excessive use of synthetic N fertilisers can enhance crop productivity in the short term but may adversely affect soil health over the long term. Sustainable crop production therefore requires greater reliance on biological $N_2$ fixation by legumes, which can reduce synthetic N dependence, enhance soil fertility and biodiversity, and contribute to carbon sequestration. Integrating legumes through crop rotation and intercropping can thus improve N-use sustainability and reduce the carbon footprint of agricultural production.

Intercropping is the system of growing of two or more crops simultaneously on the same piece of land such that the period of overlap is long enough to include the vegetative stage. In intercropping, two or more crops are grown simultaneously on the same land with a definite row arrangement. It is the practical application of basic ecological principles viz. diversity, competition and facilitation for crop production. Intercropping enhances the complementary use of limiting resources such as water, nutrients and solar radiation, thereby improving overall crop productivity compared with sole cropping. Complementary root systems improve nutrient and water use, while better soil cover reduces moisture loss and weeds.

## Cereal + legume intercropping system

Cereal + legume intercropping is a promising strategy for achieving sustainable agricultural intensification by enhancing crop productivity while conserving soil and environmental resources. With the global population rise, projected to exceed 9 billion by 2050, increasing food production without accelerating soil degradation, biodiversity loss and GHG emissions is a major challenge. Cereal + legume combinations exploit complementary growth patterns and resource-use strategies, enabling more efficient utilisation of resources than sole cropping.

The complementary use of nitrogen and other resources can enhance overall nutrient cycling and system productivity. Increased plant diversity also improves soil cover, promotes biodiversity and may enhance agroecosystem resilience to environmental stresses. The cereal + legume intercropping systems has potential to offers multiple benefits, including higher productivity, improved soil fertility, enhanced biodiversity, reduced dependence on external N inputs and greater system resilience. Its integration into sustainable production systems can therefore contribute to food security while minimising the environmental footprint of agriculture.



Maize + groundnut intercropping (2:2)



Maize + soybean intercropping (2:2)



Maize + soybean intercropping (2:2)

Maize + legume intercropping systems at ICAR-IIAB, Ranchi

The intercropping of legumes like groundnut, soybean, cowpea etc. with cereals like maize, sorghum, pearlmillet provides great scope for minimising the adverse impact of moisture stress in less rainfall years as well as excess moisture during high rainfall years. Besides, these intercropping systems are able to exploit the edaphic and climatic conditions more efficiently as compared to maize cultivation as sole crops. The soybean, groundnut and cowpea being legumes and maize, being cereal complement each other in their intercropping systems minimising the competition for common growth factors. For successful cereal + legume intercropping, the following principles should be followed:

- Peak nutrient demand of component crops should occur at different growth stages to minimise competition for nutrients. For example, green gram peaks at ~35 days after sowing (DAS), whereas maize peaks at ~50 DAS, promoting complementary nutrient use in the intercrop.
- Component crops should differ in canopy architecture and light requirements to minimise interspecific competition for light. Ideally, taller, sun-loving cereals should be combined with shorter, shade-tolerant legumes, while greater cereal competition for soil N may promote greater reliance of legumes on biological $N_2$ fixation.
- Complementarity should exist between the component crops use of growth resources in both time and space. The most important relation between cereals and legumes is the N-use complementarity.
- There should be difference in maturity for component crops by at least 30 days for least completion in intercropping.

### Types of intercropping and change in crop geometry

***Additive series*:** This type of intercropping is mostly popular in developing countries like India where one component crop is grown with its 100% recommended population (same as sole crop or pure stand), known as the base crop. The associated intercrop grown within the base crop by changing the crop geometry of the base crop. Here, the population of the intercrop is less than its recommended population in pure stand. This series is highly efficient in terms of total system productivity and utilisation of available farm resources. There is always an advantage of Land Equivalent Ratio (LER) as compared to their pure stand.

***Replacement series*:** In replacement series, both the crops are called component crops or intercrops. None of the component crops were raised with their 100% recommended population in pure stand. By scarifying certain proportion of population of one intercrop, another intercrop is grown. It is mostly done for component crops of similar phenology. The gaining in yield from such intercropping is from a simple response due to 'reduced' population and complementary use of either space or time, or both. There was not any advantage in LER here. It is mostly done to produce diversified products as well to improve the forage quality.

### Nitrogen management in cereal + legume intercropping

Nitrogen (N) management is critical for optimising productivity and resource-use efficiency in cereal +



Soybean + maize intercropping (2:1)

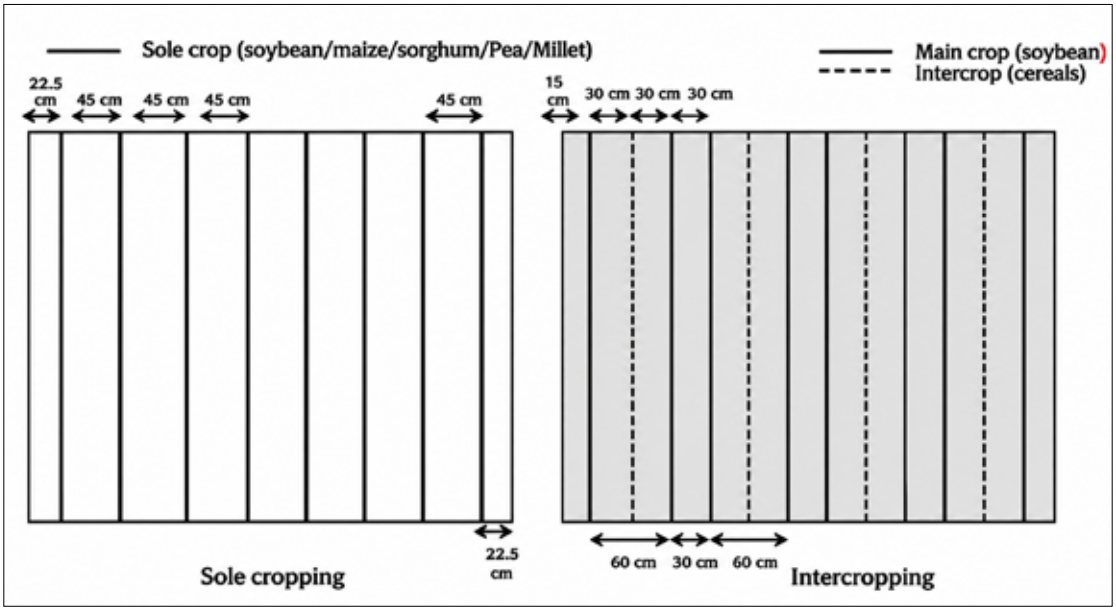


Soybean + maize intercropping (2:1)

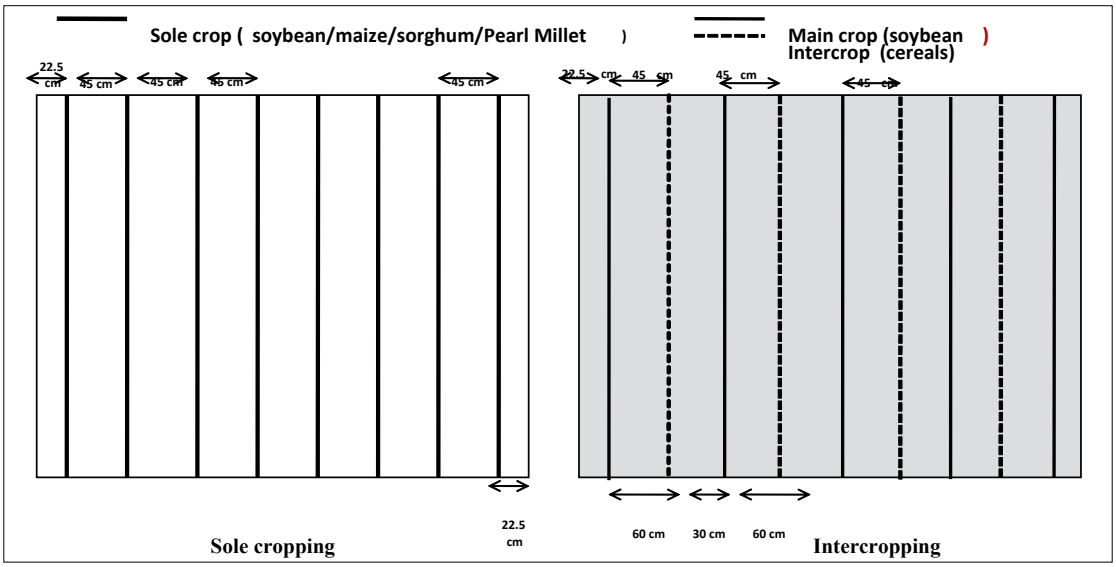


Soybean + pearlmillet intercropping (2:1)

Maize + legume intercropping systems at ICAR-IIAB, Ranchi




Planting geometry of sole crop and soybean + cereal (2:1) in additional series

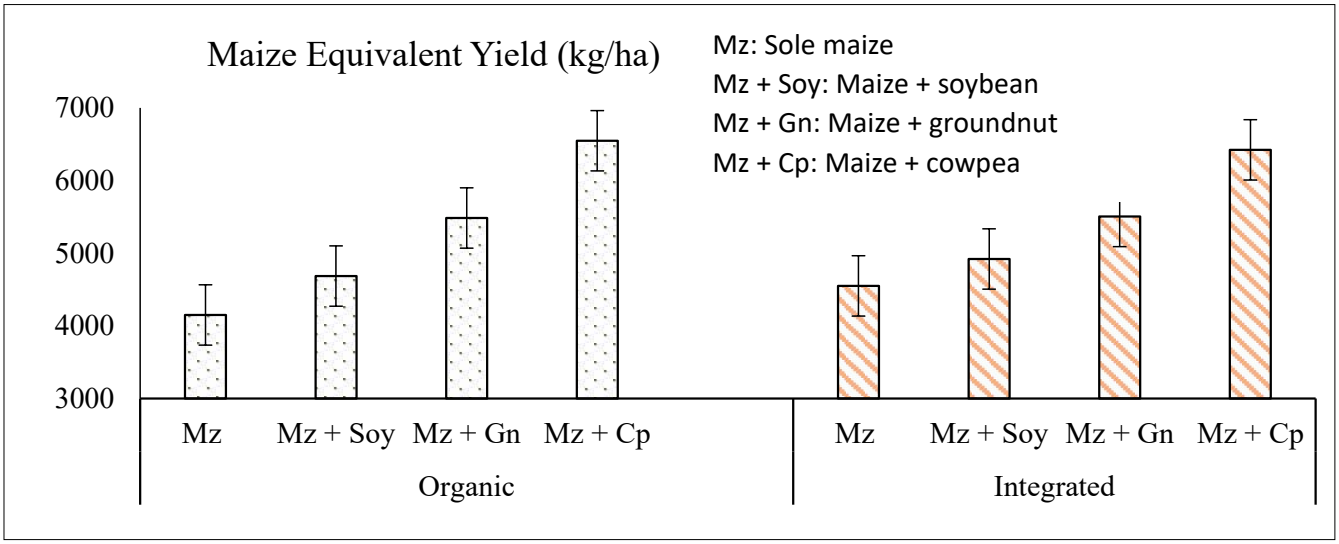



Planting geometry of sole crop and soybean + cereal intercropping (1:1) in replacement series.

legume intercropping systems. Legumes contribute biologically fixed $N_2$ through symbiotic associations, potentially reducing the dependence on synthetic N fertilizers and improving soil N availability. However, cereal crops generally exhibit a greater response to applied N than associated legumes, and excessive N application may intensify cereal competition and suppress legume growth and N fixation. Number of studies have reported improved cereal growth, yield, N uptake and cereal-equivalent yield with appropriate N fertilisation, although the optimum N requirement varies with crop combinations, planting ratios, soil fertility and agro-ecological conditions. Balanced fertiliser application, combined with effective legume inoculation and suitable crop geometry, can enhance complementarity between component crops. Therefore, site-specific N management is essential for maximising productivity, profitability and sustainability of intercropping systems.

## Productivity of maize based intercropping systems

The results of the field experiments conducted at ICAR- Indian Institute of Agricultural Biotechnology (IIAB), Ranchi reported that intercropping significantly enhanced maize productivity over sole maize under both organic and integrated nutrient management systems. Under organic nutrient management, maize yield increased by 13.3, 24.6 and 20.5% with soybean, groundnut and vegetable cowpea, respectively, whereas the corresponding increases under integrated nutrient management were 11.9, 16.4 and 11.0%. Groundnut was therefore the most effective intercrop for enhancing maize yield under both nutrient management systems. Integrated nutrient management increased maize yield over organic management by 9.6% in sole maize and by 8.3, 2.4 and 1.0% in soybean, groundnut and vegetable cowpea intercropping, respectively. In contrast, intercrop yield was lower under integrated nutrient management than under organic management by 8.0% for soybean,




Maize equivalent yield of intercropping systems at ICAR-IIAB, Ranchi

15.0% for groundnut and 17.3% for vegetable cowpea. Among the intercrops, vegetable cowpea recorded the highest intercrop productivity, exceeding soybean by 166% under organic and 140% under integrated nutrient management, and exceeding groundnut by 125 and 119%, respectively. The results indicate that groundnut was more advantageous for improving the maize component, while vegetable cowpea had greater potential for maximising intercrop production.

***System productivity*:** Maize + legume intercropping improved the overall productivity of the system compared with sole maize under both organic and integrated nutrient management. Among the tested combinations, maize + vegetable cowpea recorded the highest maize equivalent yield, reaching around 6,570 kg/ha under organic management and 6,420 kg/ha under integrated management. The inclusion of soybean, groundnut and cowpea consistently enhanced the combined economic yield of the system, demonstrating the advantage of utilising complementary crops for better use of available resources.

***Improvement in soil health*:** Maize + legume intercropping, combined with appropriate nutrient management, positively enhanced soil chemical properties compared with sole maize. After two years of cereal + legume intercropping, improvements in soil organic carbon (SOC), soil pH and available N were observed under both organic and integrated nutrient management systems. The increase in SOC may be attributed to greater root biomass, crop-residue addition and organic matter decomposition in diversified cropping systems. Similarly, improved soil N availability under legume-based systems could be associated with biological N fixation, enhanced root activity and mineralization of N-rich residues. Among the tested combinations, maize + cowpea generally recorded comparatively higher SOC, pH and available N under both nutrient management systems. These findings indicate that integrating legumes with maize can contribute to improved soil fertility, nutrient cycling and long-term soil quality while supporting sustainable crop production.

## SUMMARY

Maize + legume intercropping proved to be a promising approach for enhancing crop and system productivity while improving soil fertility under both organic and integrated nutrient management. Maize + groundnut showed greater potential for improving maize productivity, whereas maize + vegetable cowpea was more effective in enhancing overall system productivity. Legume integration also improved soil organic carbon, available nitrogen and soil pH, indicating better nutrient cycling and soil quality. Overall, suitable cereal + legume combinations can contribute to sustainable intensification, resource-use efficiency and resilient maize-based production systems.

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