STCR BASED IPNS-MODULES FOR ENHANCING PRODUCTIVITY AND PROFITABILITY OF MAIZE-CHICKPEA CROPPING SYSTEM IN VERTISOLS

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Long-term field experiments are essential to study the complex interactions between plants, soil, and management practices and their effects on crop productivity and soil properties (Singh and Wanjari, 2012). These studies offer valuable insights into crop yield trends, soil health, and sustainable production practices (Meena et al., 2019). In the Vertisols of central India, the imbalanced use of chemical fertilizers has led to deficiencies in nitrogen (N), phosphorus (P), sulfur (S), and zinc (Zn), resulting in reduced crop yields and declining soil fertility (Subbarao et al., 1998). Organic manure applications, which increase soil organic carbon (SOC) and nutrient availability, have been recognized as an effective strategy to improve soil fertility and crop productivity (Meena et al., 2019).

To develop a cleaner and sustainable crop production technology for the maize-chickpea cropping system the ICAR-Indian Institute of Soil Science, Bhopal conducted a long-term study from 2012 to 2022 (Figure 1).

The field experiment aimed to assess Soil Test Crop Response (STCR)-based IPNS modules followed a Randomized Complete Block Design with 12 treatments, replicated three times. Maize was grown as the rainfed crop and chickpea in the winter season. For the control (farmer's practice), applied N 120 kg ha^{-1}, P 60 kg ha^{-1}, and K 30 kg ha^{-1} to maize and N 20 kg ha^{-1}, P 60 kg ha^{-1} and K 20 kg ha^{-1} to chickpea. STCR-based fertilizers were applied at a rate of N 142 kg ha^{-1}, P 57.5 kg ha^{-1}, and K 50 kg ha^{-1} for maize for the yield target of 5 Mg ha^{-1}.

Organic amendments incorporated into different IPNS modules were farmyard manure (FYM 5 Mg ha^{-1}), poultry manure (PM 1 Mg ha^{-1}), urban compost (UC 5 Mg ha^{-1}), maize residue mulch (MRM 5 Mg ha^{-1}), and *Gliricidia Sepium* mulch (GLM 2 Mg ha^{-1}).

Economic performance was assessed through gross and net returns, and benefit-to-cost ratio (BCR). Also, energy use efficiency (EUE), energy productivity (EP), and energy profitability (EPF) were calculated. The environmental impact was measured by analyzing the carbon footprint (CF) in terms of greenhouse gas emissions, expressed as CO_2 equivalents (CO_2-e). N_2O emissions were estimated based on FAO emission factors (2015) for each nutrient source.

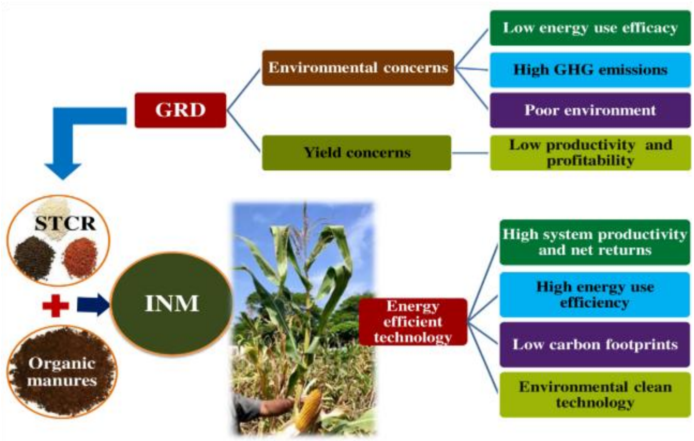

Figure 1. Conceptual framework of the study

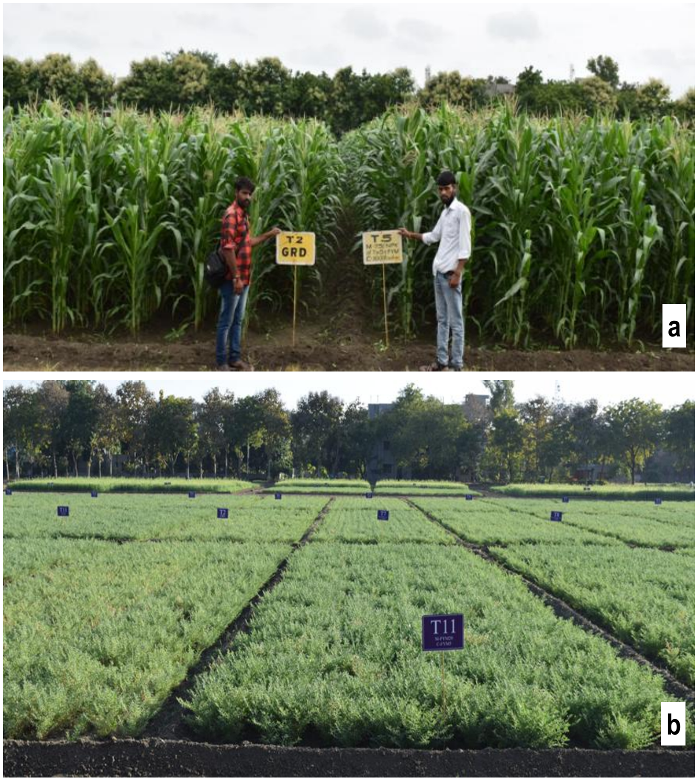

Figure 2. A view of the (a) maize and (b) chickpea crops in the experimental fields of ICAR-IISS Bhopal

TECHNOLOGY AND ITS IMPACT

The STCR-based IPNS module resulted in approximately a 20% increase in maize grain yield and 13% in chickpea grain yield over the farmer's practice. Overall, it increased system productivity (maize-chickpea) by 17.0% compared to the farmer's practice. The STCR-based IPNS module also enhanced energy use efficiency (EUE), energy productivity (EP), and energy profitability (EPF) by 28.5%, 31.5%, and 31.8%, respectively, compared to the farmer's practice. Following this IPNS module, GHG emissions from fertilizers and manures were 17.4% lower, and total CO_2-e emissions were 11.2% less compared to organic module. A significant improvement was observed in various soil health indicators (physical, chemical, biological) under the STCR-based IPNS module compared to the farmer's practice. The STCR-based IPNS module also increased carbon efficiency (CE) by 19.3% and the carbon sustainability index (CSI) by 21% compared to the GRD. About 11% and 16% higher gross returns and net returns were recorded under the STCR-based IPNS module than GRD, respectively. The highest B:C ratio (3.85) was observed for the IPNS module. Adoption of the STCR-based IPNS module (FYM + 75% NPK of STCR) improved system productivity by 17.0% while minimizing the energy requirement by 14% compared to GRD.

SOCIO-ECONOMIC BENEFITS

The STCR-based IPNS module in maize resulted in a 20% increase in grain yield over the GRD (farmer's practices). Maize is cultivated on 15.0 lakh hectares in central India (Madhya Pradesh and Chhattisgarh), which would generate an additional income of Rs.1964 crores, benefiting around 137 lakh farm holdings. Similarly, the STCR-based IPNS module in chickpea has the potential to increase farmers' income in central India by Rs. 2312 crore. Overall, the technology would provide an additional income of Rs.4276 crores from this system. Hence, it is evident that the STCR-based IPNS technology is an innovative approach for achieving targeted yields compared to farmer practices in cereal-legume system.

However, in-depth study on the efficiency of the developed IPNS module in terms of crop productivity, environmental impact, and socio-economic benefits need farmers participatory field demonstrations based on on-farm organic resources.

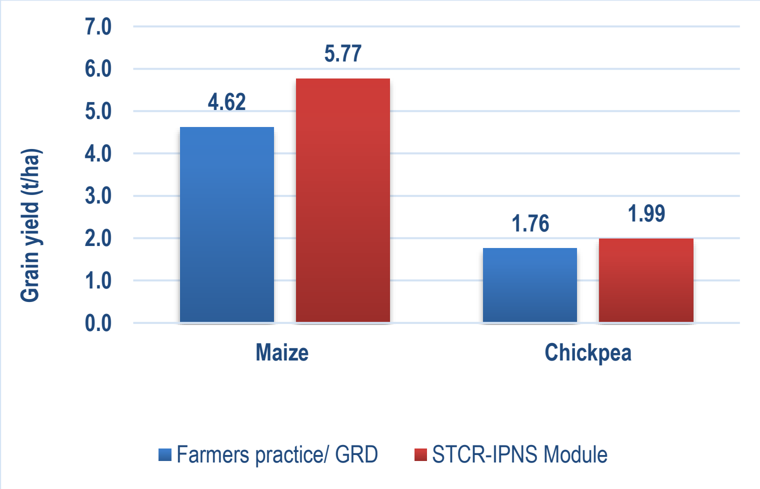

Figure 2. Average crop yields from the maize-chickpea system under the STCR-based IPNS module

Table 1. System productivity, Economic, and Environmental Sustainability of the Maize-Chickpea System under the STCR-based IPNS module

Treatment	System Productivity (t ha^{-1})	Benefit: Cost ratio	EUE (%)	Carbon footprint (CO_2-e kg Mg^{-1})	Carbon Sustainability Index (CSI)
Farmers Practice	9.31^{de}	3.12^{cde}	9.62^{cd}	242.7^{ab}	9.9^{cde}
STCR-IPNS Module	10.89^{a}	3.85^{a}	12.37^{a}	201.3^{e}	12.0^{a}

CONCLUSION

The STCR-based IPNS module, consisting of 75% NPK of STCR + 5 t/ha FYM in maize, performed significantly better compared to farmer practices. It has great potential to increase farm income while reducing carbon footprints and production costs in the cereal–legume cropping system.

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Article Received on: 14 June 2025