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Optimizing indigenous pest management practices for sustainable cereal crop production in tribal regions: Insights from Koraput District, Odisha

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ABSTRACT

Cereals are globally essential staples, supplying over 60% of calorie intake for populations in the developing world. Traditionally, cereal cultivation has relied on indigenous technical knowledge, with natural and locally accepted pest control methods. However, widespread use of chemical fertilizers and pesticides in modern agriculture, along with climate change, erratic weather, and shifting cropping systems, has led to increased pest pressure and severe crop losses. This study, conducted in Koraput district, Odisha (covering the blocks of Koraput, Jeypore, Kundra, and Boipariguda) from July to December 2023, assesses insect pest incidence on three major cereal crops—paddy, finger millet, and maize—across 16 sampling sites totaling 32 hectares. Tribal farming communities, characterized by socio-economic vulnerability, were engaged through Participatory Rural Appraisal (PRA) methods, with 134 male and 56 female participants interviewed using structured questionnaires. Pest types, developmental stage-specific damage, and traditional pest control practices (including neem kernel and leaf extracts, fermented cow dung and cow urine, ash, and fire) were documented. Insect species identified spanned five orders, 12 families, and 21 species. T-tests indicated reduced pest incidence following the application of natural formulations, while two-way ANOVA revealed significant differences in crop yields across three cultivation types: no pest control, neem-based applications, and a combination of natural and minimal chemical formulations within safe limits. Findings underscore the effectiveness of optimized traditional pest control in sustaining cereal production under marginal farming conditions.

Keywords: Cereal crops; Indigenous pest control; Sustainable agriculture; Tribal farming practices; Natural formulations; Climate resilience

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INTRODUCTION

Cereal crops hold immense importance globally, serving as staple foods for a substantial portion of the world's population (Jakhar A *et al*., 2020). Both developing and developed countries rely on cereals as a primary food source due to their provision of essential dietary requirements, including proteins, fibers, carbohydrates, and vitamins (like vitamin E and B), as well as micronutrients like magnesium and zinc (Kumar H, Jakhar A 2018). With the global population projected to increase by 33% by 2050, potentially reaching 9.6 billion (Godfray HCJ *et al.* 2010), there is a pressing need to enhance food grain production to meet this demand. Crop growth and productivity, however, are influenced by various factors, with insect pests being a significant limiting factor (Jakhar A *et al.* 2020.) Among cereals, rice stands out as a staple food for over 50% of the global population, cultivated across 150 million hectares in 114 countries, yielding an annual production of 525 million tons Rai M 2006. Cereal production is also affected by erratic weather conditions, water stress, and global warming, which contribute to the rising diversity of insect pests. Global crop losses from pests are estimated between 20–40% annually, with the economic impact of plant diseases and pest infestations costing around $220 billion and $70 billion, respectively IPPC Secretariat 2021. Consequently, crop protection has become a central component of agricultural practices, with pesticides historically playing a pivotal role (Popp *et al.,* 2013). In recent years, pesticide use has increased substantially, with the European Union reporting approximately 370 million kilograms used in (2018), comprising fungicides (46%), herbicides (35%), and insecticides (11%) Eurostat (2020a).

The advent of the Green Revolution introduced technologies and chemical inputs like fertilizers and pesticides, significantly boosting crop production and contributing to food security Cooper (Dobson, 2007). However, due to the adverse environmental and health impacts of pesticides, many countries are now prioritizing pesticide reduction in policy formulation (Barzman and Dachbrodt-Saaydeh, 2011). Pesticides harm biodiversity, often killing non-target organisms, contaminating soil and water, and posing risks to human health through residues found in food and air (IPBES 2016; Pietrzak Kania *et al.,* 2019; Fantke, *et al*., 2012; Panseri *et al*., 2019). Before pesticides were widely available, farmers relied on indigenous knowledge and traditional pest control methods to safeguard their crops (George *et al.*, 2000).

Several studies have documented the effectiveness of cow urine and other organic materials as pest control agents. For example, cow urine can repel various pests (Sadwarte and Sarode, 1997; Ukey and Sarode, 2001; Gupta, 2005). Fermented mixtures of cow dung and urine provide plant nourishment and deter pests (Prakash and Rao, 1997), while cow urine combined with plant extracts has shown effectiveness against pests like stem borers in rice. Indigenous pest control strategies such as using neem extracts, ash, and buttermilk have demonstrated promising results in managing insect populations without harming beneficial organisms (Bissdorf, 2008; Kumari and Chandla, 2010; Oparaeke *et al.,* 2006). These methods offer environmentally sustainable alternatives to chemical pesticides, particularly beneficial in rural areas with limited access to commercial inputs.

The Koraput district of Odisha, India, where tribal communities primarily rely on agriculture for their livelihood, faces unique challenges. Tribal farmers cultivate essential crops such as ragi, rice, and maize, yet any crop loss due to pests can compromise food security, economic stability, and nutritional well-being. Although these communities historically relied on indigenous or traditional pest control methods, the introduction of high-yield varieties and chemical inputs has inadvertently increased pest diversity and associated crop losses. This situation underscores the urgent need for a return to sustainable practices that align with local environmental conditions and economic realities. Many tribal farmers favor indigenous pest control techniques due to their affordability and reduced impact on the environment. This study aims to document and explore the traditional pest control knowledge and practices of tribal communities in Koraput, assessing their effectiveness in managing pest populations while sustaining crop productivity. Additionally, there is a pressing need to optimize these traditional practices for broader agricultural applicability, offering a more sustainable alternative to chemical-based pest management. The significance of this research lies in its potential to preserve and enhance sustainable, local agricultural practices that minimize reliance on chemical inputs. By emphasizing indigenous pest control techniques, this study aligns with modern agricultural policies that advocate for reducing pesticide use due to its adverse effects on the environment and human health. Promoting these methods could play a critical role in protecting local biodiversity and improving food security by empowering farmers with eco-friendly, effective tools for crop protection. Furthermore, this study may lay the foundation for future research focused on refining and scaling indigenous pest control practices for use in similar agricultural regions. The findings have the potential to inform policy development that supports traditional agriculture and fosters the integration of indigenous knowledge into mainstream practices. By demonstrating the value of these methods, this research could contribute to the establishment of sustainable, community-cantered pest management systems that enhance long-term food security and resilience in vulnerable farming communities.

MATERIALS AND METHODS

Research site

This study was conducted in various locations within the Koraput district of Odisha. Koraput is situated at a latitude of 18°49'12.00" N and longitude of 82°43'12.00" E, with an elevation of 602 meters above Mean Sea Level (MSL). The district lies within the Eastern Ghats highlands and falls under the southern ghat agro-climatic zone. Koraput receives an average annual rainfall ranging from 1521 mm to 1710 mm, and the soil is typically a mix of red and red-yellow, enriched with organic matter. The study covered four blocks in Koraput district: Koraput, Jeypore, Kundra, and Boipariguda. Within these blocks, eight Gram Panchayats (GPs) were selected as sampling sites to observe insect pest infestations and existing pest control practices. Sixteen plots were randomly chosen for observation within these eight GPs, with two sites in each GP. A total of 32 hectares of cultivated land was included, comprising 1 hectare of rice, 0.5 hectares of finger millet, and 0.5 hectares of maize at each of the 16 sites. The three major cereal crops—rice, maize, and finger millet (ragi) were selected to analyze pest diversity and infestation rates across these fields (Fig 1).

Methods of Data Collection

In this study, a total of 134 male and 56 female participants who were actively involved in the cultivation of cereals, including rice, maize, and finger millet, were interviewed using Participatory Rural Appraisal (PRA) tools and a pre-structured questionnaire. The data collected encompassed various aspects such as cultivated varieties, production levels, pest incidences, and both indigenous or traditional and modern pest control methods. The quantity of production was also documented. To ensure the accuracy and comprehensiveness of the data, responses were cross-verified by posing questions to different groups engaged in cereal cultivation. This approach significantly contributed to generating robust data for the study.

Statistical Analysis

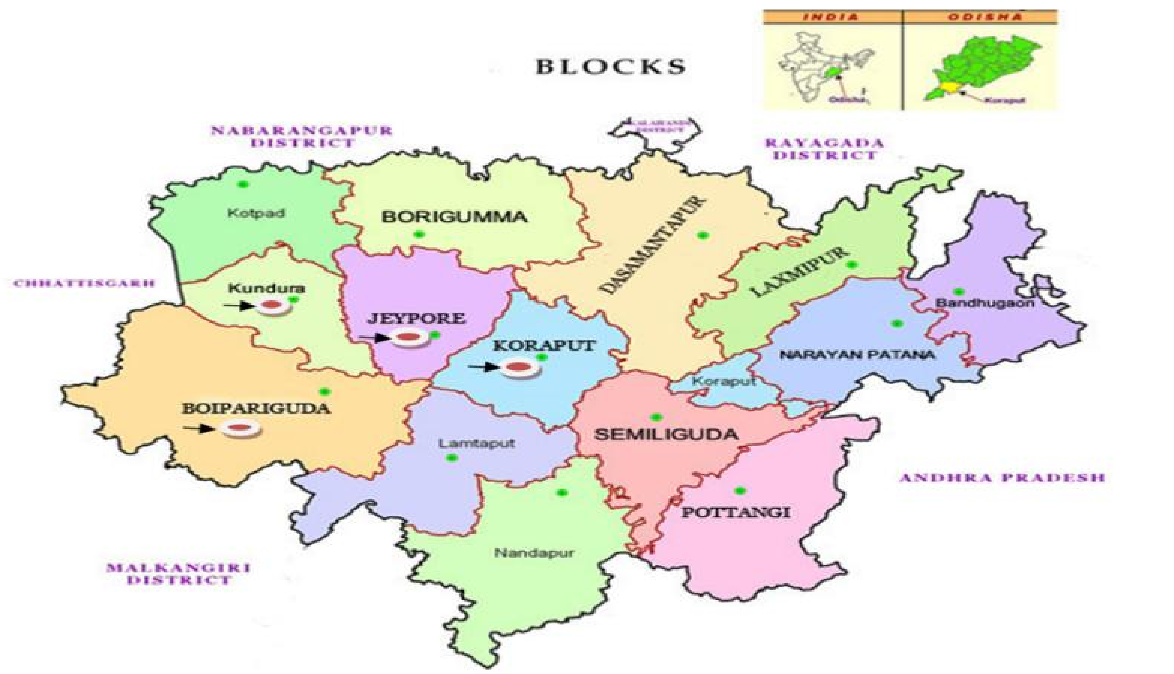
The data collected from the sample population regarding pest incidence, pest control and management practices, and production across eight different Gram Panchayats (GPs) in four distinct blocks were organized in Excel spreadsheets. A list of pests was compiled, and the various pests affecting rice, maize, and finger millet across different sites in the blocks were compared. Paired t-tests were utilized to assess differences in pest populations under different pest management techniques. Two datasets were prepared: one before and one after the application of pest control measures. These datasets were then compared using two-way ANOVA in SPSS to determine the significance of the various pest control methods concerning the production of the three crops: rice, maize, and finger millet.

RESULTS AND DISCUSSION

Insect Pest Diversity and Incidence

In total, insect pests belonging to five orders, twelve families, and twenty-one species were identified from the fields in the selected areas. Among these, four orders were found in rice, while three orders were present in both maize and finger millet. The families of insect pests identified were seven for rice, six for maize, and five for finger millet. Additionally, the number of species recorded was ten in rice, seven in maize, and six in finger millet (Fig. 2).

Among the identified species, some were found to be invasive. In rice, severe infestations were noted for the yellow stem borer, Asian rice gall midge, and green leafhopper. Moderate infestations were observed for the brown plant hopper, leaf folder, and armyworm, while very low levels of infestation were recorded for the swarming caterpillar, white-backed plant hopper, rice hispa, and Gundhi bug. In maize, the most invasive pests identified included the maize stem borer, pink stem borer, and aphids, with moderate infestation levels observed for earworms and leafhoppers. Low levels of infestation were recorded for the maize shoot fly and maize shoot bug. In finger millet, the pink stem borer, ear head caterpillar, and grasshopper exhibited the highest incidence, while root aphids were found at moderate intensity. Flea beetles and leaf aphids were noted as less common pests in finger millet.



Block	Gp	Villages
Koraput	Umari (Site I)	Machhara, Khiloput
	Mastiput (Site II)	Bagaraguda, Dongri maliguda
Jeypore	Dangorchucha (Site III)	Bisoiput, Bodapar
	Patraput (Site IV)	Kanjai, Maliguda
Kundra	Kundra (Site V)	Chendia jhilligam, Kaudiaguda
	Lima (Site VI)	Kusumguda, Pradhaniguda
Boipariguda	Bodaput (Site VII)	Kasiguda, Bhejaguda
	Mahuli (Site VIII)	Baliguda, Rauliguda

Fig. 1. Studied areas in Koraput district depicting the various blocks, Gram Panchayats (GPs), and villages within Koraput district.

Incidence of Insect Pest Diversity, Pest Control, and Management Practices Observed in the Area

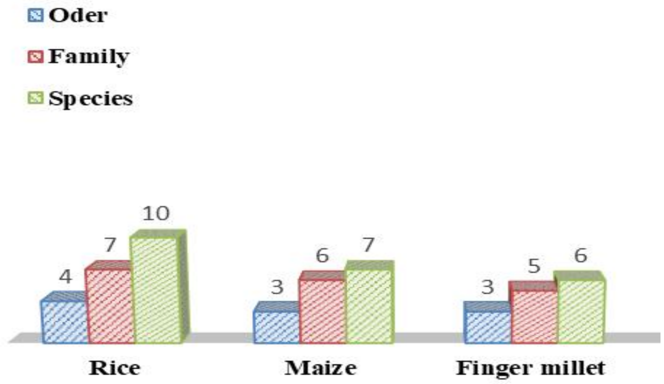
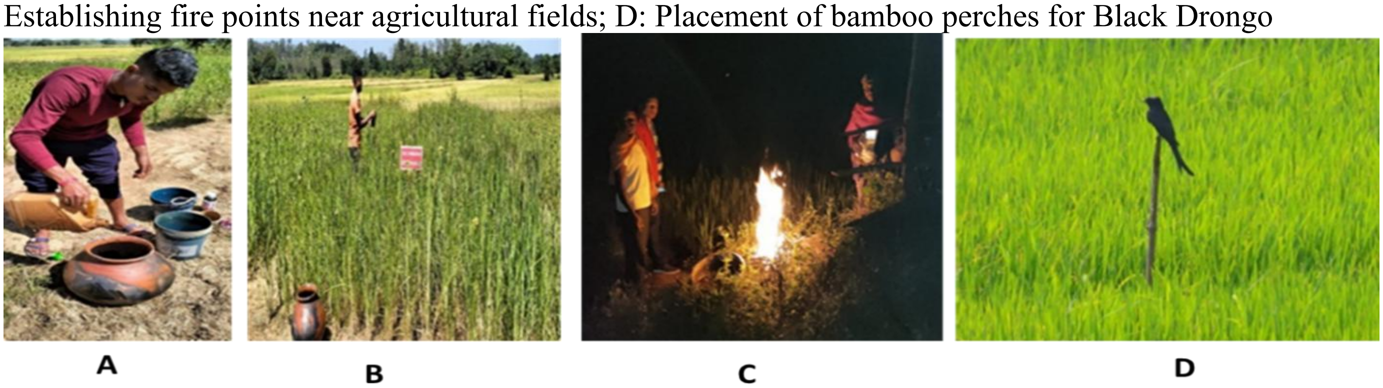


Fig. 2 Numbers of Insect Orders, Families, and Species Identified in the Study Area.

Traditional to New Practices

The most common pest control practices employed for managing cereal pests include the use of fermented mixtures of cow dung and cow urine, neem leaf and kernel extracts, ashes, fire, and bamboo sticks for attracting black drongos (Fig. 3). In sampling plots I, III, and IV, the pest control strategy primarily involved applying cow urine and cow dung fermentation mixtures at ten-day intervals, alongside the application of neem kernel extract. In contrast, sampling plots II, V, VI, VII, and VIII utilized a 6% neem kernel extract applied to the rice fields (Tables 1). This fermentation process produced a solution that was applied at a rate of eight liters per hectare.

Fig 3. A. Preparation of neem extracts; B: Application of cow dung and cow urine ferments in fields; C: Establishing fire points near agricultural fields; D: Placement of bamboo perches for Black Drongo



The results were impressive; in rice, the infestation of the yellow stem borer decreased from severe to moderate intensity in sampling plots I, III, and IV. A similar reduction in the incidence of the Asian rice gall midge was observed in these plots, indicating that the cow dung and cow urine ferments significantly influenced the populations of these two pests. In sampling plots II, V, VI, VII, and VIII, where neem kernel and neem leaf extracts were additionally used in conjunction with the fermented mixture, the populations of both the yellow stem borer and the Asian gall midge fell to very low levels.

In maize, the application of both neem extracts and ferments resulted in a notable reduction in the populations of maize stem borer and pink stem borer. The earworm population also decreased from moderate to low levels due to these formulations. Similarly, in finger millet, the infestations of the pink stem borer and earhead caterpillar were reduced across all locations, with neem seed and neem kernel extracts exhibiting enhanced efficacy in pest population reduction, particularly in plots II, V, VI, VII, and VIII.

The population of natural predators has been shown to significantly influence pest incidence in several observed crop fields, with pest levels decreasing from severe to moderate during the investigation. It was found that 82% of respondents used cow dung and cow urine ferments, while 79% applied neem leaf and neem kernel extracts for pest control. Additionally, 45% of farmers utilized plant twigs and bamboo in their fields to create perches for black drongos or king crows (Fig. 4). This practice encourages these birds to inhabit the area, thereby helping to

Table 1. Incidence levels of various pests across different crops and field sites. Incidence scale: 3 indicates severe pest incidence, 2 indicates moderate incidence, and 1 indicates low incidence in rice.

Sl. No.	Pest name	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	Site VIII
1	Yellow stem borer	***	***	***	***	***	***	***	***
2	Swarming Caterpillar	*	*	*	*	*	*	*	*
3	Asian rice gall midge	***	***	***	***	***	***	***	***
4	Brown plant hopper	**	**	**	**	**	**	**	**
5	White backed plant hopper	*	*	*	*	*	*	*	*
6	Leaf folder	**	**	**	**	**	**	**	**
7	Rice hispa	*	*	*	*	*	*	*	*
8	Gundhi bug	*	*	*	*	*	*	*	*
9	Green leaf hopper	***	***	***	***	***	***	***	***
10	Armyworm(Ear cutting caterpillar)	**	**	**	**	**	**	**	**
Incidence levels of various pests in maize.									
1	Maize stem borer	***	***	***	***	***	***	***	***
2	Pink stem borer	***	***	***	***	***	***	***	***
3	Aphids	***	***	***	***	***	***	***	***
4	Maize soot fly	*	*	*	*	*	*	*	*
5	Ear worm	**	**	**	**	**	**	**	**
6	Leaf hopper	**	**	**	**	**	**	**	**
7	Shoot bug	*	*	*	*	*	*	*	*
Incidence levels of various pests in Millet									
1	Pink stem borer	***	***	***	***	***	***	***	***
2	Root Aphid	**	**	**	**	**	**	**	**
3	Ear head caterpillar	***	***	***	***	***	***	***	***
4	Flea beetle	*	*	*	*	*	*	*	*
5	Leaf aphid	*	*	*	*	*	*	*	*
6	Grass hopper	***	***	***	***	***	***	***	***

Table 2. Incidence of Pests in Rice, Maize and Finger Millet fields after the application of neem extracts and fermented mixture. Incidence scale: 3 indicates severe pest incidence, 2 indicates moderate incidence, and 1 indicates low incidence.

Incidence of Pests in Rice fields after the application of neem extracts and fermented mixture.									
Sl. No.	**Pest name**	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII	Site VIII
1	Yellow stem borer(YSB)	**	*	**	**	*	*	*	*
2	Swarming Caterpillar(SC)	*	*	*	*	*	*	*	*
3	Asian rice gall midge(ARGM)	**	*	**	**	*	*	*	*
4	Brown plant hopper(BPH)	**	**	**	**	**	**	**	**
5	White baked plant hopper(WBPH)	*	*	*	*	*	*	*	*
6	Leaf folder(LF)	**	**	**	**	**	**	**	**

7	Rice hispa (RH)	*	*	*	*	*	*	*	*
8	Gundhi bug(GB)	*	*	*	*	*	*	*	*
9	Green leaf hopper(GLH)	***	***	***	***	***	***	***	***
10	Armyworm(Ear cutting caterpillar)	**	**	**	**	**	**	**	**
Pests incidents in Maize fields after the application of neem extracts and fermented mixture.									
1	Maize stem borer	**	*	**	**	*	*	*	*
2	Pink stem borer	**	*	**	**	*	*	*	*
3	Aphids	*	*	*	*	*	*	*	*
4	Maize soot fly	**	**	**	**	**	**	**	**
5	Ear worm(EW)	*	*	*	*	*	*	*	*
6	Leaf hopper(LH)	**	**	**	**	**	**	**	**
7	Shoot bug(SB)	*	*	*	*	*	*	*	*
Pests incidents in Finger Millet fields after the application of neem extracts and fermented mixture.									
1	Pink stem borer	***	***	***	***	***	***	***	***
2	Root Aphid	**	**	**	**	**	**	**	**
3	Ear head caterpillar	***	***	***	***	***	***	***	***
4	Flea beetle	*	*	*	*	*	*	*	*
5	Leaf aphid	*	*	*	*	*	*	*	*
6	Grass hopper	***	***	***	***	***	***	***	***

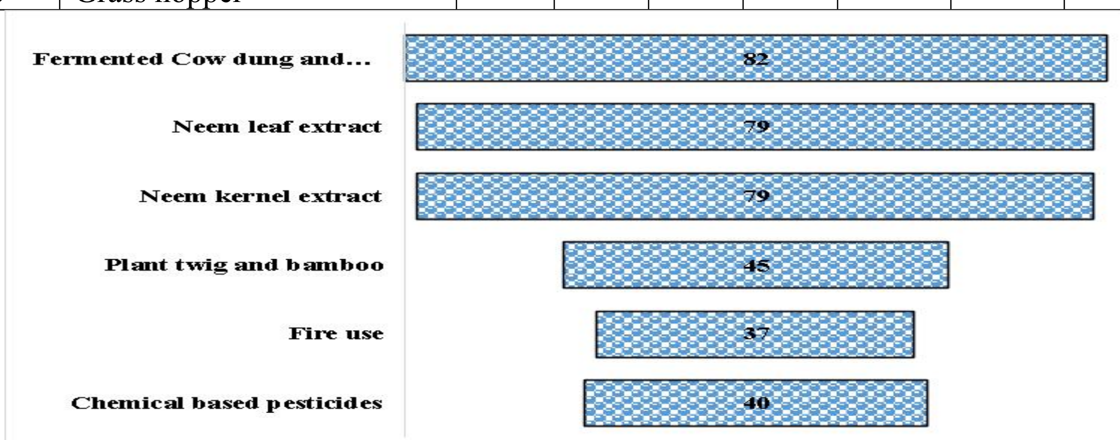


Fig. 4. Percentage of farmers using different indigenous methods and chemical methods

manage insect pest populations through their predation. Furthermore, approximately 37% of farmers reported using fire near their fields to attract insects for elimination. Interestingly, about 40% of respondents also employed chemical fertilizers in their agricultural practices, indicating a blend of traditional and modern pest management strategies. Rice production under zero pest control measures was recorded at 1.7 tons per hectare, while the application of indigenous pest management techniques increased the yield to 2.53 tons per hectare.

Table 3. Analysis of Variance Table

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.244			
Factor A-crops	2	8.717	4.359	301.440	0.00000
Factor B-methods	2	3.076	1.538	106.371	0.00000
Interaction A X B	4	0.242	0.060	4.183	0.01659
Error	16	0.231	0.014		
Total	26	12.511			

When both indigenous methods and limited chemical formulations were used together, production further improved to approximately 2.75 tons per hectare. Similarly, maize yields under these three conditions were 1.41 tons, 1.82 tons, and 2.15 tons per hectare, respectively. For finger millet, the production figures were 0.62 tons, 0.94 tons, and 1.28 tons per hectare (Fig. 5). Data related to cereal production per hectare were analyzed statistically using a two-way ANOVA test, with results summarized in Table 3. The analysis revealed that mean cereal production without any pest control method was 1.70 tons for rice, 1.41 tons for maize, and 0.62 tons for finger millet. In comparison, the mean production for the indigenous techniques was 2.53, 1.82 and 0.94 tons for rice, maize, and finger millet respectively. Notably, the mean production for rice, maize, and finger millet increased to 2.75 tons, 2.15 tons, and 1.28 tons per hectare, respectively, when combining indigenous techniques with chemical methods.

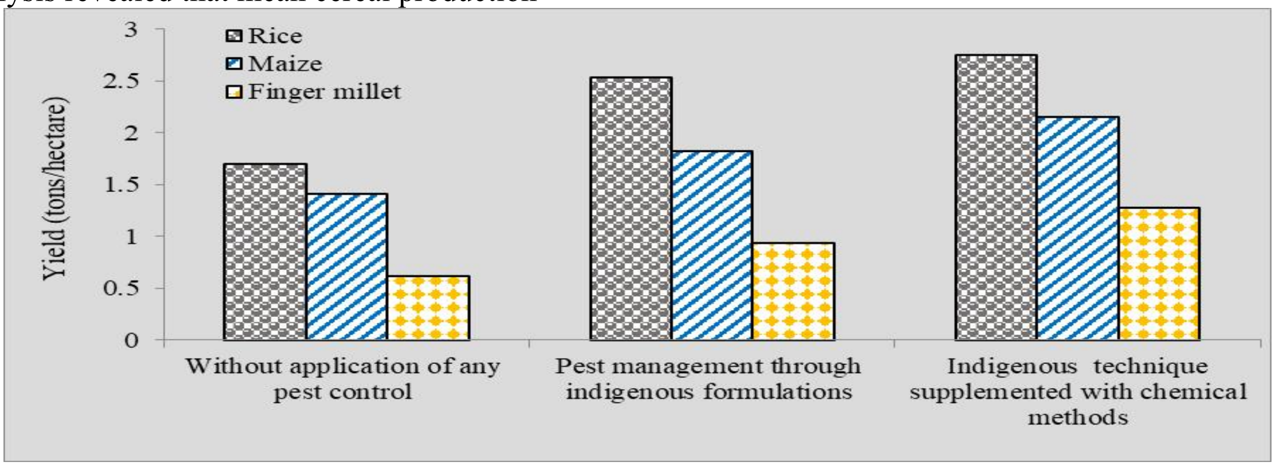


Fig 5. Rice, maize and finger millet production with and without any control methods

The ANOVA results indicated significant differences in mean production across the three pest control methods. The DMRT test further confirmed that the combination of indigenous techniques supplemented with chemical methods yielded higher cereal production compared to the other two methods.

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AUTHOR'S CONTRIBUTION

Samir collect the data from field site and compilation of data, collection of photograph. Nirmal Biswal Co-author guided for preparation of the manuscript. Kartik Charan Lenka Edited the final draft and supervise the data collection, Photography along with Samir.

AUTHOR'S DECLARATION

We, the authors of this research paper, declare that we have no conflicts of interest to disclose regarding the research, its findings and integrity of the work.

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