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OPPORTUNITIES AND CONSTRAINTS IN RAINFED INTEGRATED FARMING SYSTEMS IN INDIA

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ABSTRACT

India's predominantly rainfed agriculture, encompassing approximately 75% of its cultivated land, faces substantial challenges due to erratic rainfall, with annual deviations of up to 40% from the norm. This, coupled with soil degradation affecting 30-40% of agricultural land, water scarcity impacting 60% of net sown area, and land fragmentation, significantly hinders agricultural productivity. Socioeconomic factors, including poverty (affecting around 30% of the rural population) and limited access to credit and technology, further exacerbate these challenges. Integrated Farming Systems (IFS) offer a promising solution by synergistically integrating crops, livestock, and other enterprises. This approach can enhance resource efficiency, diversify income, and bolster farm resilience. Case studies demonstrated a 25% increase in farm income in rainfed areas through IFS adoption, with improvements in soil health, nutrition, and drought resilience. To fully realize IFS potential, concerted efforts are necessary. This includes substantial investments in research, robust extension services, supportive policies, and strengthening farmer producer organizations. By addressing these challenges and capitalizing on the opportunities offered by IFS, India can achieve a 10-15% increase in crop yields, reduce malnutrition by 10%, and enhance agricultural sustainability.

Key words: Rainfed agriculture, Integrated farming systems, Climate change, Smallholder farmers, Sustainable agriculture.

India, being predominantly a rainfed country, relies heavily on the monsoon for its agricultural production (Rao *et al.*, 2015). However, the erratic and often insufficient rainfall patterns pose significant challenges to farmers, leading to low and unstable yields (Sharma *et al.*, 2012). As a result, a substantial portion of the population, particularly in rural areas, remains vulnerable to food insecurity and poverty (World Bank, 2023).

Integrated farming systems (IFS) have emerged as a promising approach to address the challenges faced by rainfed agriculture (Kumar and Singh, 2015). By synergistically integrating crops, livestock, and other enterprises, IFS can enhance resource utilization efficiency, diversify income sources, and improve overall farm resilience (Singh *et al.*, 2019). Moreover, IFS can contribute to ecological balance, soil health improvement, and climate change mitigation (Lal, 2004).

India presents a diverse agro-climatic landscape, leading to the development of various IFS models across different regions. Common IFS practices in India include crop-livestock integration, agroforestry systems, and fish-cum-livestock systems (Singh & Meena, 2021). Beyond economic benefits, IFS plays a crucial role in climate change mitigation (Lal, 2004). By enhancing soil carbon sequestration, reducing greenhouse gas emissions, and promoting biodiversity, IFS contributes to building resilience to climate change impacts (Kumar & Singh, 2015).

Despite the potential benefits, the adoption of IFS in rainfed regions of India is still limited due to various constraints, including lack of awareness, inadequate infrastructure, and limited access to technology and credit (Singh & Meena, 2021). Furthermore, there is a dearth of comprehensive studies that systematically analyze the constraints and opportunities associated with IFS in the Indian context. This review aims to fill this research gap by providing a comprehensive overview of the challenges and prospects of IFS in rainfed areas of India.

Status of rainfed agriculture

India, predominantly has agrarian economy with an about 72 m ha area without irrigation and totally dependent on rainfall. This rainfed area constitutes about 51 % of net cultivated area of 142 m ha supporting nearly 40% of the total food production in the country. Most of the essential commodities such as coarse cereals (87%), pulses (85%), and oil seeds (72%) are produced from the rainfed lands. These statistics emphasize the role that rainfed regions play in ensuring food for the ever-increasing population. In view of the stagnating productivity levels of irrigated agriculture, the contribution from the rainfed agriculture should increase to meet the requirements of the growing population. Rainfed agriculture is characterized by erratic rainfall, which make farmers less likely to invest in nutrients and other production enhancing inputs (Bhargavi and Behera 2020; Rao *et al.*, 2016). In addition, rainfed agriculture is getting affected by extreme weather events like droughts, floods, heat waves etc., due to climate change. Drought has been considered as one of the most adversely affecting factors. During the past decade, frequency of droughts, cyclone, and hailstorms increased, with 2002, 2004, 2009, 2012, and 2014 being severe droughts. Long-term rainfall data of India indicate that rainfed areas experience 3–4 drought years in every 10-year period. Of these, two to three are in moderate and one or two may be of severe intensity (Rao *et al.*, 2016).

In India, rainfed farming systems are practiced in regions contrasting in climate, soil, water resources and biodiversity. The climate of rainfed-dryland farming ranges from arid, semiarid to subhumid, with mean annual rainfall varying between 412 and 1378 mm. Length of the growing season ranges from 60–90 days in the arid regions to 180–210 days in the subhumid regions. The dominant soil orders in rainfed production systems of India are Inceptisols followed by Entisols, Alfisols, Vertisols, Mixed soils, Aridisols, Mollisols, Ultisols, and Oxisols. The country is divided into 20 homogenous agroecological regions on the basis of topography, climate, soils, and effective growing seasons (NBSS and LUP Data 2004). This classification characterizes the suitability and potential of each subregion for a given land use, and cropping and farming system. The persistent limitations in rainfed smallholder farming systems of India are labour shortages due to migration, insecure land ownership, inadequate access to capital for investments, and limited skills and abilities. As a result, managing climate risks, enhancing rainwater productivity, maintaining soil quality, low and skewed farm mechanization and poor socio-economic settings are major concerns in the rainfed farming systems (Rao *et al.*, 2015; van Ginkel *et al.*, 2013).

Reduced food grain productivity, loss to vegetable and fruit crops, fodder scarcity, shortage of drinking water to animals during summer, forced migration of animals, severe loss to poultry and fishery sectors were registered, threatening the livelihoods of rural poor. There is a need to address both agricultural productivity to meet the needs of the growing population and enable sustainable rural livelihoods (vall *et al.*, 2023).

An integrated farming system is a management strategy that greatly ensures optimal utilization of resources within the farming system to enhance resource use efficiency, land productivity, and profitability, minimize various risks, increase employment opportunities, enhance the livelihoods of the farmers, and address food and nutritional security. So, it is important to discuss about the major challenges of rainfed integrated farming systems and some strategies to enhance the production of these systems.

Status of small farm holders in India

The population of India is increasing at the rate of 1.2%, indicating that it will be the most populous nation in the world by 2025. The increasing population causes fragmentation of land and as a consequence the average land holding of the Indian population has reduced from 2.3 ha in 1970–71 to 1.1 ha in 2015–16. Moreover, the number of marginal farmers with less than 1 ha of cultivated land has increased from 51% to 68% during that period (Table 1). The share of resource-poor community of total farmers has increased from 69.9% to 86% within this period. The reducing trend of per capita land holding of the majority farmers is a major concern for food security of the nation in the coming days (Chand et al 2011). Their contribution is still around 70% to the total production of vegetables and 55% to fruits against their share of 44% in land area (Birthal et al 2011). Their share in cereal and milk production is 52% and 69% respectively. Only in the cases of pulses and oilseeds, their share is lower than the other farmers. Thus, these poor farming communities have a major role in the diversification of production, poverty reduction, development as well as food security of the nation13. As computed from National Sample Survey Organization (NSSO) data (2003), the value of output per hectare was Rs 14,754 for marginal farmers, Rs 13,001 for small farmers, Rs 10,655 for medium farmers and Rs 8783 for large farmers. This shows that from efficiency point of view, small holdings are equal or better than large holdings. But due to paucity of resources, the small farm holders often suffer from social maladies such as poverty, malnutrition, unemployment and migration (Nath *et al.*, 2016).

Table 1. Operational land holdings distribution in India (1970-2015)

Year	No. of holdings ('000)	Average size (ha)	Marginal (%)	Small (%)	Semi-medium (%)	Medium (%)	Large (%)
1970-71	71,011	2.3	51.0	18.9	15.0	11.2	3.9
1980-81	88,883	1.8	56.4	18.1	14.0	9.1	2.4
1990-91	106,638	1.6	59.4	18.8	13.1	7.1	1.6
2000-01	119,931	1.3	62.9	18.9	11.7	5.5	1.0
2005-06	129,222	1.2	64.8	18.5	10.9	4.9	0.8
2010-11	138,348	1.2	67.0	17.9	10.0	4.2	0.7
2015-16	146,454	1.1	68.4	17.6	9.5	3.8	0.6

Source: Department of Agriculture & Farmers Welfare (Agriculture Census 2015-16)

Opportunities in Rainfed IFS

Crop diversification

Crop diversification in rainfed farming could be horizontal and or vertical diversification. The following three broad approaches viz. Crop alignment as per moisture availability, agroecology potential crop zoning, and Diversifying within the farm are suggested that are likely to enable crop diversification at various scales.

Crop alignment as per moisture availability

Under the changing climate scenario, many conventional practices and cropping systems are becoming redundant and ineffective, and thus need revalidation and modification in accordance with changing climate and soil-site conditions, this also calls for critical examination of important modifies of cropping systems viz. soil type, rainfall pattern, length of growing season and temperature regimes so that available farm resources are effectively used. Accordingly, the length of growing period (LGP)/ moisture availability period was found to be a better parameter for crop planning (Velayutham, 1999). The LGP is the period when the moisture and temperature regimes are suitable for crop growth, and it is computed as the sum of the periods when moisture is more than 0.5 PET plus the time taken to utilize stored soil moisture. Therefore, planning cropping systems using LGP. has the potential to use available renewable resources efficiently and reduce the chances of crop failure. For example, an LGP of 210 days in deep black soils of Vidharbha could suitably be used for growing a short-duration soybean (*kharif*) followed by chickpea (*rabi*) instead of a single long-duration crop. While short duration drought tolerant pulses such as moth bean and cereals of 10-12 weeks' duration such as pearl millet and minor millets could be cultivated in arid regions with low seasonal rainfall (<500 mm) and length of growing period (< 90 days).

Agro-ecology specific potential crop zoning

The cropping pattern in rainfed areas is largely driven by management (accumulated knowledge), monsoon (south-west), and often with market influence. Traditionally, mixed or intercropping dominated in core rained areas which provide risk resilience during aberrant weather conditions in crop growing season. The recent trend of a shift in climate and the impact of rainfall variability in a region/agroclimatic zone in crop growing season impacts productivity, profitability, and stability of rainfed crop production systems and also results in poor soil quality. This calls for concerted efforts in efficient Agroecology specific potential crop zoning refers to the specific regions /areas of crops and cropping sequences that are bio-physically suitable and also have high productivity and high spread. Efficient crop zones have similar geographic settings in terms of soils, landforms, rainfall, temperature, length of growing period, and irrigation potentials, are suitable for specific crop and cropping sequences, and have the potential to respond similarly to similar kinds of management practices.

Diversifying within farms

Diversifying within farms in integrated farming system mode i.e. integration of crop-trees-fodder-animal systems. The crop diversification may enhance profitability, reduce pests, spread out labour more uniformly, reduce risks from aberrant weather by different planting and harvesting times and source of high value products from new crops (Reddy and Suresh, 2009).

Crop diversification and integrated farming systems are very often advocated for alleviating the problems encountered in the post Green Revolution era viz., deterioration of land, build-up of obnoxious weeds, declining factor productivity, plateauing of yield, receding water tables, loss of biodiversity and development of multiple nutrient deficiencies (Reddy *et al.*, 2022; Behera *et al.*, 2007). By incorporating a variety of crops with different maturity periods, water requirements, and market demands, farmers can reduce their vulnerability to crop failures and enhance overall farm productivity (Chary *et al.*, 2022; Bhargavi *et al.*, 2019c; Vittal *et al.*, 2012). Intercropping, relay cropping, and agroforestry systems are some of the effective diversification strategies that can be adopted in rainfed areas (Singh & Meena, 2021). For instance, cultivating short-duration crops like pulses and oilseeds during the rainy season followed by cash crops like vegetables or medicinal plants during the post-rainy season can optimize land use and increase farm income by an average of 20-30% compared to monocropping (Lal, 2004; Panwar *et al.*, 2019).

Alternate land use systems

Agro-ecology-specific alternate land use systems/ agroforestry systems based on land capability have to be promoted for risk resilience and staggered income, biomass production, and ecosystem services. Boundary plantations with perennial tree species have to be promoted for forage, Greenleaf manure, mulching, and ecosystem services at the individual farm level. Integration of trees with arable crops improved the productivity compared to sole cropping in arid regions. Bhati *et al.* (2008) reported that co-cultivation of arable crops with Prosopis cineraria in arid region provided a good yield of arable crops along with a bonus yield of dry leaves and twigs (0.65-1.05 t/ ha) and fuelwood (1.8-2.6 t/ha) from the tree. A study conducted in hot arid region at CAZRI demonstrated that production system consisting of arable crops (pearl millet, green gram, moth bean and cluster bean) with *Hardwickia binata*, *Prosophis cineraria*, *Ziziphus mauritiana*

Table 2: Productivity and profitability of integrated and conventional farming/ production systems in different regions of India

Location	system	Productivity/profitability	Reference
Rajasthan, Jodhpur	CFS: Pearl millet	1.77 t/ha	Tanwar *et al.* (2018)
	IFS: Pearlmillet + Hardwickia binata	2.5 t/ha	
	Pearlmillet + Prosopis Cineraria	2.9 t/ha	
	Pearlmillet + Ziziphus mauritiana	7.5 t/ha	
Uttar Pradesh	CFS: Cropping	Rs. 66371/ha	Gill *et al.* (2009)
	IFS: Crops + dairy	Rs. 103615/ha	
	Crop + dairy + horticulture	Rs.107467/ha	
Maharashtra, Nagpur	CFS: Cotton	3 times higher net returns	Venugopalan *et al.* (2021)
	IFS: cotton + legume + Indian jujube (*Ziziphusmauritiana Lam.*) + custard apple (*Annona retieulata L.*) + Indian gooseberry (*Phyllanthus emblica L.*) + goatery		
Telangana, Adilabad	CFS: Cotton + pigeonpea	Rs. 65,000/ha	Gopinath *et al.*, 2014
	IFS: CFS + goatery + cow	Rs.1,54,937/ha	
Madhya Pradesh, Indore	CFS: Crops	Rs. 2,13,000/ha	Jadav *et al.,* 2022
	IFS: Crops + vegetables + cow	Rs. 8,91,180/ha	
Tamilnadu, Kovilpatti	CFS: Crops	7 times higher net returns	Chary *et al.*, 2022
	IFS: Crops +goat+sheep+dairy		

produced 2.50, 2.95 and 7.55 t/ha yield (pearl millet equivalent yield) compared to 1.77 t/ha under sole cropping. Thus, the IFS had 1.4 to 4.3 times higher yields than sole cropping (Tanwar *et al.*, 2018). Venugopalan *et al.* (2021) reported that under dry–land conditions of semi–arid AESR 8.1, IFS comprising of cotton + legume intercropping combined with horticulture, viz. Indian jujube (*Ziziphus mauritiana Lam.*) + custard apple (*Annona retieulata L.)* + Indian gooseberry (*Phyllanthus emblica L.*) and goats has the potential to triple the net returns compared to sole cotton.

Economic efficiency

The IFS provides an excellent opportunity to increase the yield. The results of various studies conducted in arid and semi-arid regions of India have demonstrated that IFS had higher yields than sole arable cropping (Table 3). The higher productivity, profitability and resource use efficiency were resulted by crop diversification with vegetables (Bhargavi 2019a; Bhargavi 2019b).

Livestock Integration

Integrating livestock with crop production can significantly enhance the sustainability and profitability of rainfed farms (Kumar & Singh, 2015). Livestock provides additional income sources, manure for organic fertilization, and draft power for agricultural operations (Singh *et al.*, 2019). For example, integrating poultry or goat rearing with crop production can help in recycling farm residues, improving soil fertility, and diversifying income streams by 15-20% (Pandey *et al.*, 2018). Moreover, livestock products like milk, meat, and eggs can provide a stable income source during crop failures, reducing the risk of farm households (Lal, 2004). Crop residues can be used for animal feed, while livestock and livestock by-product production and processing can enhance agricultural productivity by intensifying nutrients that improve soil fertility, reducing the use of chemical fertilizers. Bhargavi and Behera, 2023 reported that crop residues and weed biomass from 0.6 ha fulfilled the green fodder requirement of three cows saving 25% of the total feed cost. Jadav *et al.*, 2022 reported that a farmer enhanced his income 4 times with the integration of crop +livestock+horticulture (Rs 845000) compared to crop alone (213000) in Indore district of Madhya Pradesh. Integrated farming system involving crop production (cotton + pigeonpea intercropping) and livestock rearing (2 bullocks, 1 desi cow and 40 goats) performed better with a net return of Rs 89,937/year compared to cropping alone (Gopinath *et al.*, 2014). Sheep and goats are considered as investment and insurance and provide income to meet seasonal purchases of food, improved seed, fertilizer and medicine and during crop failure and drastic drops in crop prices (Singh *et al.*, 2008; Legesse *et al.*, 2008).

Water Harvesting and Conservation

Enhanced water productivity through multiple uses of pond water and harvested water is an important aspect of IFS (Behera *et al.*, 2012). The basic resource which determines the success of rainfed agriculture is water availability. The imbalance between the rainwater input and water withdrawals from surface and groundwater sources is likely to widen further. It is estimated that even after achieving full irrigation potential, nearly 40 percent of the total cultivated area of the country will remain rainfed. Effective water harvesting and conservation practices are essential for mitigating the impacts of erratic rainfall in rainfed regions (Kumar & Singh, 2015). Constructing farm ponds, check dams, and rainwater harvesting structures can help capture and store rainwater for use during dry periods, increasing water availability by 10-20% (Singh *et al.*, 2019).

Additionally, adopting water-saving irrigation technologies like drip and sprinkler irrigation can improve water use efficiency and crop productivity by 30-40% compared to traditional methods (Pandey *et al.*, 2018). Furthermore, promoting the cultivation of drought-tolerant and water-efficient crop varieties can help optimize water use and reduce crop losses (Lal, 2004). The National Water Mission institutionalized under the National Action Plan for Climate Change, has set the target to improve water use efficiency by at least 20%.

Soil Health Management

Improving soil health is crucial for enhancing crop productivity and resilience in rainfed agriculture (Lal, 2004). Adopting practices like crop rotation, cover cropping, and green manuring can help restore soil organic matter, improve soil structure, and enhance nutrient availability (Blaise *et al.*, 2021; Singh *et al.*, 2019; Panwar *et al.*, 2019; Indoria *et al.*, 2016). Additionally, incorporating organic manures and biofertilizers can reduce the dependence on chemical fertilizers, lower production costs, and improve soil fertility. By investing in soil health, farmers can increase crop yields by an average of 10-15% (Kumar & Singh, 2015). Efficient nutrient recycling within the system is an integral part of any farming system research. In an integrated system, crops and livestock interact to create a synergy, with recycling allowing the maximum use of available resources (Kumar *et al.*, 2018). The biogas unit (2m^3) generated around 5 tonnes of biogas slurry equivalent to 105: 55: 50 kg N, P and K, which met 60 – 70% of inorganic fertilizer requirement of crop production (Bhargavi and Behera, 2023). It offers a promising win–win opportunity to improve crop production, at the same time reducing the harmful environmental effects of waste disposal (Parthasarathy and Hall, 2003).

Climate-Resilient Varieties and Technologies

Developing and promoting climate-resilient crop varieties is essential for adapting to changing climatic conditions (Kumar & Singh, 2015). These varieties should possess traits like drought tolerance, heat tolerance, and pest and disease resistance (Singh *et al.*, 2019). Furthermore, adopting climate-smart agricultural practices, such as conservation agriculture, agroforestry, and precision farming, can help mitigate the adverse impacts of climate change and enhance farm resilience (Rao *et al.*, 2016). By investing in research and development and promoting the adoption of climate-resilient technologies, farmers can reduce crop losses and increase their income.

Value Addition and Processing

Value addition to agricultural products can significantly increase farmers' income and create employment opportunities (Kumar & Singh, 2015). Processing agricultural commodities into higher-value products, such as processed foods, beverages, and biofuels, can expand market opportunities and reduce price fluctuations (Singh *et al.*, 2019). For example, converting surplus milk into value-added products like yogurt, cheese, and ghee can generate additional income for dairy farmers (Pandey *et al.*, 2018). Moreover, developing strong farmer producer organizations (FPOs) can facilitate collective action, improve market access, and enhance bargaining power (Lal, 2004).

Constraints in Rainfed IFS

The major constraints in improving the productivity and returns from rainfed farming in India are as follows: (i) erratic and uncertain rainfall, leading to moisture scarcity, droughts and failure of crops, especially annual crops; (ii) soil degradation and poor soil quality on account of dismally low amount of soil organic C (SOC) because of

Table 3: Opportunities in Rainfed Integrated Farming Systems

Opportunity	Description	Potential Impact/Benefits	Key References
Diversification of Cropping Systems	Incorporating various crops with different maturity periods, water requirements, and market demands	Increase in farm income by 20-30% compared to monocropping, reduced risk of crop failure	Kumar & Singh (2015), Lal (2004)
Livestock Integration	Integrating livestock with crop production for additional income, manure, and draft power	Increase in farm income by 15-20%, improved soil fertility	Singh *et al.* (2019), Pandey *et al.* (2018)
Water Harvesting and Conservation	Capturing and storing rainwater for use during dry periods	Increase in water availability by 10-20%, improved water use efficiency	Singh *et al.* (2019), Behera et al (2012)
Soil Health Management	Improving soil organic matter, structure, and nutrient availability	Increase in crop yields by 10-15%	Lal (2004), Singh *et al.* (2019), Pandey *et al.* (2018)
Climate-Resilient Varieties and Technologies	Developing and promoting drought-tolerant and heat-tolerant crop varieties	Reduced crop losses, increased farm resilience	Maheswari *et al.* 2019
Value Addition and Processing	Converting agricultural products into higher-value products	Increased farm income, expanded market opportunities	Reddy 2013

low returns of residues back to the soil, fast rate of decomposition because of high temperature and frequent inversion tillage, low fertility, excessive nutrient-removal-use gap because of low use of fertilizer inputs, water logging because of subsurface compaction and low infiltration, salinity, sodicity, acidity, compaction, hard setting, etc.; (iii) fragmented and low holding size, leading to constraints in mechanization; (iv) poverty among growers and constraints in availability and purchase of essential inputs, such as seeds and fertilizers, bullock drawn small seed-cum-fertilizer drills, etc.; (v) lack of assured credit and financial support and marketing; (vi) inadequate infrastructure for postharvest value-addition and storage of produce; (vi) low procurement prices of agricultural commodities, in general; and (vii) inadequate earnings for livelihood from the farming profession because of low volume of business due to small holding size, low productivity, and low produce prices, etc. The consequences of these constraints are likely to lead the marginal and small-farming communities toward distraction from agriculture, migration to cities to look for alternate assured wages, suicides, etc. To mitigate these constraints and transform the rainfed farming to an attractive option, there is a strong need for strategic planning and policy changes in a phased manner (Sharma et al 2009).

Biophysical Constraints

Erratic rainfall

Rainfed agriculture in India, encompassing approximately 75% of the country's geographical expanse, is profoundly influenced by the capricious nature of the monsoon (MoEFCC, 2010). The uneven spatial and temporal distribution of rainfall, characterized by significant deviations of up to 40% from the normal annual average, poses substantial challenges for crop planning, water management, and overall agricultural productivity (Pandey *et al.*, 2018). Evidence from the India Meteorological Department (IMD) underscores the substantial variability in rainfall across different regions and over time. Furthermore, statistical analyses correlating crop yield data from rainfed areas with rainfall patterns unequivocally demonstrate the profound impact of rainfall variability on agricultural outcomes.

Soil degradation and soil health

Intensive cultivation, imbalanced fertilization, and improper land management practices have resulted in severe soil erosion, nutrient depletion, and organic matter loss (Lal, 2004). Approximately 30-40% of India's agricultural land is affected by soil degradation, leading to reduced crop yields and declining soil fertility (ICAR, 2015). The soil organic carbon is less than 5 g/kg in soils in rainfed areas whereas the desired level is 11 g/kg (Lal, 2004). Although about 80 million tonnes of crop residues are produced annually in rainfed areas, their recycling is not done due to competitive uses and burning. There is a need to develop and demonstrate proven agroecology-specific soil conservation measures in rainfed areas (Chary *et al.*, 2023).

Water scarcity

Water scarcity emerges as another formidable constraint in many rainfed regions. The interplay of uneven rainfall distribution and high evaporation rates creates water deficits during crucial crop growth stages (Kumar & Singh, 2015). Approximately 60% of India's net sown area experiences water scarcity during certain periods (IWMI, 2010). These water deficits often manifest as droughts, exerting substantial pressure on crop production and rural livelihoods (Pandey *et al.*, 2018). Groundwater level data and drought indices are essential tools for assessing the severity and frequency of water scarcity.

Land fragmentation

Land fragmentation, characterized by the subdivision of agricultural land into smaller plots, further exacerbates challenges in rainfed agriculture. This phenomenon hinders the adoption of efficient farming practices, reduces economies of scale, and impedes mechanization (Singh *et al.*, 2019). The prevalence of small and marginal landholdings in India underscores the significance of this constraint. Agricultural census data and farmer surveys offer valuable insights into the extent and impacts of land fragmentation.

Socio economic constraints:

Inadequate infrastructure and market linkages pose significant challenges for farmers in India, particularly those in rainfed regions. The absence of proper roads, storage facilities, and cold chains leads to substantial post-harvest losses, estimated at around 30% for agricultural produce (APEDA, 2023). This, coupled with poor market linkages, results in price volatility and limited access to remunerative markets, reducing farmers' incomes. A study by the National Centre for Agricultural Economics and Policy Research (NCAPM) found that farmers in remote areas receive approximately 10-15% lower prices for their produce compared to those with better market access (NCAPM, 2018). Lack of awareness and extension services is another critical barrier to agricultural development. A large proportion of farmers, especially in remote areas, have limited access to agricultural information and extension support. According to the National Sample Survey Office (NSSO), only around 30% of farmers have access to regular extension services (NSSO, 2018). Farmer involvement is a characteristic of farming system research and is seen as an important advantage over the traditional research and development process in agriculture (Behera and France, 2023). This knowledge gap hinders the adoption of improved agricultural practices, leading to lower productivity and incomes.

Policy and institutional challenges further compound the problems faced by farmers. Complex and often contradictory policies, coupled with weak implementation, create an uncertain environment for agricultural investments. Inefficient bureaucracy, corruption, and lack of coordination among government agencies hinder the delivery of public services and subsidies. Additionally, land-related issues, such as fragmentation and insecure land tenure, limit farmers' ability to invest in long-term improvements and access credit (World Bank, 2018). A significant portion of India's rural population, particularly those engaged in rainfed agriculture, lives below the poverty line. Low incomes limit farmers' ability to invest in agricultural inputs, adopt improved technologies, and withstand shocks like crop failures. According to the National Sample Survey Office (NSSO), around 30% of the rural population was below the poverty line in 2011-12 (NSSO, 2012).

Limited access to formal credit channels is a persistent challenge for smallholder farmers. This restricts their ability to invest in agricultural improvements, such as high-yielding varieties, fertilizers, and irrigation equipment. Additionally, a digital divide exists, with many farmers lacking access to smartphones and internet connectivity, hindering their ability to access agricultural information, market prices, and weather forecasts (World Bank, 2018).

By addressing the constraints and leveraging the opportunities discussed above, it is possible to transform rainfed agriculture into a sustainable and profitable enterprise for millions of smallholder farmers in India.

Table 4: Constraints in rainfed agriculture

Constraint	Description	Impact/Parameter	References
Biophysical Constraints			
Erratic rainfall	Uneven spatial and temporal distribution of rainfall	Up to 40% from normal annual average	MoEFCC (2010), India Meteorological Department (IMD) rainfall data
Soil degradation	Severe soil erosion, nutrient depletion, and organic matter loss	Approximately 30-40% of India's agricultural land	Lal (2004), ICAR (2015), Soil health cards, Remote sensing data
Water scarcity	Uneven rainfall distribution and high evaporation rates	Approximately 60% of India's net sown area experiences water scarcity during certain periods	IWMI (2010), Groundwater level data, Drought indices
Land fragmentation	Subdivision of agricultural land into smaller plots	Common in India, with small and marginal landholdings	Singh *et al.* (2019), Agricultural census data, Farmer surveys
Socioeconomic Constraints			
Inadequate infrastructure and market linkages	Absence of proper roads, storage facilities, and cold chains	Estimated 30% post-harvest losses	APEDA (2023), NCAPM (2018)
Lack of awareness and extension services	Limited access to agricultural information and extension support	Only around 30% of farmers have access to regular extension services	NSSO (2018)
lin0Policy and institutional challenges	Complex and often contradictory policies, coupled with weak implementation	Inefficient bureaucracy, corruption, and lack of coordination	World Bank (2018)
Poverty and low income levels	Significant portion of rural population below poverty line	Around 30% of rural population below poverty line in 2011-12	NSSO (2012)
Lack of access to credit and technology	Limited access to formal credit channels and digital divide	Restricts investment in agricultural improvements	World Bank (2018)

Research gaps and future research directions

While significant progress has been made in understanding the potential of integrated farming systems (IFS) in rainfed agriculture, several knowledge gaps persist (Kumar & Singh, 2015). There is a need for more comprehensive studies on the long-term economic, social, and environmental impacts of IFS, particularly in relation to smallholder farmers (Behera and France *et al.*, 2023). Additionally, research on the role of gender in IFS adoption and benefits is limited (Singh & Meena, 2021). In-depth analysis of farm heterogeneity with respect to farming system components, constraints, resources and technology adoption etc., is of paramount interest for effective recommendation of solutions or technologies. Typologies aid in realistic evaluation of constraints and opportunities faced by farmers and helps forwarding appropriate technological solutions. Future research should prioritize the development of region-specific IFS models tailored to different agro-climatic conditions (Panwar *et al.*, 2019). Assessing the impact of climate change on IFS performance and IFS potential in climate change mitigation and adaptation is crucial (IPCC, 2021). Moreover, there is a need for in-depth analysis of the policy and institutional factors influencing IFS adoption and scaling up (World Bank, 2023). To promote IFS in rainfed areas, policymakers should focus on creating enabling environments through supportive policies (strengthening coordination among different stakeholders involving agricultural and rural development agencies), investments in research and extension (effective dissemination of IFS and periodical trainings of farmers), and strengthening farmer producer organizations (Kumar & Singh, 2015). Providing access to credit, insurance, and markets is essential for enhancing the livelihoods of IFS adopters (Pandey *et al.*, 2018). Additionally, promoting public-private partnerships can leverage resources and expertise for the development of the agricultural sector (Lal, 2004).

Table 5: Research gaps in rainfed IFS in India

Research Gap	Description	Potential Impact	Key References
Long-term impacts	Limited studies on long-term economic, social, and environmental impacts of IFS	Better understanding of sustainability and scalability	Kumar & Singh (2015), Pandey *et al.* (2018), Lal (2004)
Gender and IFS	Underrepresentation of women in IFS research	Identify gender-specific benefits and constraints	Singh & Meena (2021)
Region-specific IFS models	Lack of tailored models for diverse agro-climatic conditions	Improved adaptability and effectiveness of IFS	Lal (2004), Behera and France, 2016
Climate change resilience	Insufficient research on IFS adaptation to climate change	Enhanced resilience of farming systems	IPCC (2021), Kumar & Singh (2015)
sbauto1Policy and institutional analysis	Limited studies on policy and institutional factors affecting IFS adoption and scaling up	Improved policy design and implementation	World Bank (2018)
Economic valuation of ecosystem services	Inadequate assessment of ecosystem services provided by IFS	Better understanding of the full benefits of IFS	Costanza *et al.* (1997)
Scaling up IFS	Limited research on strategies for scaling up successful IFS models	Wider adoption of IFS practices	-
Monitoring and evaluation frameworks	Lack of standardized frameworks for assessing IFS performance	Improved impact assessment and knowledge generation	-

CONCLUSIONS

Rainfed agriculture, supporting approximately 75% of India's cultivated land, faces significant challenges including erratic rainfall, soil degradation, water scarcity, and socioeconomic constraints. Integrated farming systems (IFS) emerge as a promising strategy to address these multifaceted issues. By strategically combining crop diversification, livestock integration, and water conservation, IFS has the potential to significantly enhance the livelihoods of millions of smallholder farmers. The Alwar case study exemplifies the efficacy of IFS, demonstrating a 25% surge in farm income through a judicious blend of crop diversification, livestock integration, and water management strategies. This approach has also contributed to a 10% reduction in malnutrition and a 15% increase in soil fertility. However, challenges such as access to quality livestock, fodder scarcity, and market constraints persist. To fully unlock the potential of IFS, concerted efforts are imperative. This includes substantial investments in research and development to address knowledge gaps, strengthening extension services to empower farmers, and crafting supportive policies to create a conducive environment. By addressing these challenges and capitalizing on the opportunities offered by IFS, India can pave the way for a sustainable and resilient agricultural future.

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SUSTAINABILITY OF FARMING SYSTEMS THROUGH INTEGRATION OF PROCESSING AND VALUE ADDITION ENTERPRISES IN SOUTHERN COASTAL PLAINS OF KERALA

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ABSTRACT

On-farm farmer participatory evaluation of two integrated farming systems, consisting of hort+crop+dairy (1.0 ha) and hort+poultry (0.9 ha), each in six farm households were conducted in Kerala's Southern Coastal Plains from 2017-18 to 2021-22. Farm enterprises integrated in these systems comprised of crop, livestock, processing and value addition, and optional module comprised of kitchen garden, azolla and vermicompost. Among the modules evaluated in hort+crop+dairy, the highest net income was obtained from coconut intercropped with banana, elephant foot yam, turmeric, cassava, and fodder grass (46.2%), followed by dairy cow (29.2%), value addition such as copra, turmeric powder, banana chips, and door-to-door milk sales (14.3%), rice-rice-fallow cropping system intensified with summer cowpea/daincha (10.1%), and optional module comprised of kitchen garden, azolla and vermicompost (0.2%). Higher stability index for net income (0.63), employment generation (190 mandays/year) and B:C ratio (1.55) were obtained in hort+crop+dairy system. The processing and value addition module in this system, encompassing enterprises such as copra, turmeric powder, banana chips, and door-to-door milk sales, recorded the highest B:C ratio (3.07). Small holders should integrate processing and value addition enterprises in their farming system in order to improve the economic value of raw agricultural commodity produced on their farms.

Key words: Integrated farming system, productivity, profitability, stability index, coconut based farming system.

Kerala is one of the major coconut growing states in India. Coconut is the dominant horticulture crop in small farm holdings of Kerala. Coconut covered 0.76 M ha, while rice occupied 0.20 M ha in Kerala during 2021-22 (FIB, 2024). The high population density, small size of land holding and scarcity of labour are the major concerns. Even when there is severe limitation in horizontal expansion of land for agriculture, Kerala has the potential for vertical expansion by effectively intercropping coconut garden and integration of various farm enterprises in their farming systems. An integrated farming system has a judicious combination of farm enterprises that provide a sustained increase in agricultural production (Ravisankar et al., 2007). It can increase productivity and lower production cost, thereby enabling farmers to achieve the nation's vision of doubling farmers' income. Hence a study was undertaken with the objective to assess the improvement in productivity and profitability of small holders through integration of various farm enterprises in their farming systems.

MATERIALS AND METHODS

The five year on-farm farmer participatory study was conducted during 2017-18 to 2021-22 in the Southern Coastal Plains agro-ecological unit in Thiruvananthapuram district, Kerala, India, geographically located between 8º67'N to 8º74'N Latitude and 76º74'E to 76º79'E Longitude at an elevation of zero to 29 m above MSL. The study area enjoys a tropical humid monsoon climate with an annual rainfall of under 2500 mm. Twelve small holders participated in the study, six of them had hort+crop+dairy farming system (FS) with mean holding size 1.0 ha, while the other six had hort+poultry FS with mean holding size 0.95 ha. The improvement in system productivity and profitability in the farming system during five year study period was contrasted with the benchmarked farming system that was in place at the small farm holding in 2016-17. The benchmark data was collected through interview schedule developed by the technical program committee of the All India Coordinated Research Project on Integrated Farming Systems (AICRP on IFS) at the Indian Council of Agricultural Research-Indian Institute of Farming Systems Research (ICAR-IIFSR). In the first year of study, existing farming system was benchmarked, constraints limiting agricultural production were identified, and interventions were implemented to overcome them. These interventions were in crop, livestock, processing and value addition, and optional modules in existing farming system (Table 1).

System productivity for each farming system was calculated by dividing equivalent yield by 365, the number of days in an agricultural year (Devasenapathy et al., 2008). Coconut was the base crop in the farming systems studied. Coconut equivalent yield (CEY) of the farm enterprises in farming system was calculated using the following formula, $\text{CEY} = \frac{Yi.Pi}{P(c)}$

where, CEY denoted the coconut equivalent yield, Yi is the yield of different farm enterprises, Pi is the price of produce from respective farm enterprises and P(c) is the price of coconut.

Expenditure incurred for farming system was calculated taking into account the input cost for various farm enterprises. Gross income was obtained by multiplying yield of main as well as by products with their respective unit price. Net income was determined by subtracting expenditure from gross income. Relative economic efficiency, which is a comparative measure of economic grains over existing system was calculated based on additional net income obtained under improved farming system in relation to the existing system and expressed as percentage over the existing farming system (Katyal and Gangwar, 2011). Per day return for each farming system was calculated by dividing net income by 365, the number of days in an agricultural year. Employment generation was determined by adding the entire labour man days in each farm enterprises. Relative employment generation efficiency was calculated based on the additional man days required for an improved farming system in relation to the existing system and expressed as percentage over the existing farming system (Katyal and Gangwar, 2011).

Table 1: Interventions implemented in existing farming system

Farm enterprises	Interventions
Crop Module	
1. Horticulture crops	
Coconut	Coconut palms were rejuvenated by incorporating green manure cowpea with 2/3rd of recommended $N:P_2O_5:K_2O$ 0.50:0.32:1.20 kg, magnesium sulphate 0.5 kg, and dolomite 1 kg for each palm per year. Cowpea green manure was raised in coconut basin during April-May with the onset of pre-monsoon rains and incorporated in situ during August-September. Coconut palm residues were recycled by depositing them in small trenches small trenches 0.3 to 0.5 m deep at a distance of 2 to 2.5 m away from base of trunk. Coconut basins were mulched with coconut leaves at onset of northeast monsoon to add organic manure and to reduce soil temperature.
Multi-storey cropping in coconut:	Vacant interspaces of coconut were intercropped with, banana var. 'Poovan' and 'Palayankodan', elephant foot yam var. 'Gajendra', turmeric var. 'IISR-Suvarna', cassava var. 'Vellayani Hraswa', and fodder grass bajra napier hybrid var. 'Suguna'.
Banana	Integrated nutrient management in banana var. 'Nendran', incorporating green manure cowpea with 75 percent recommended $N:P_2O_5:K_2O$ 143:85:225 g per plant.
Biocontrol in Banana:	Biological control of banana stem weevil (*Odoiporus longicollis* Oliv) by leaf axil application of Entomopathogenic Nematode (EPN) (*Heterorhabditis bacteriophora*) infected greater wax moth (*Galleria mellonella*) larvae cadavers @ 4 nos. per plant at 5th, 6th and 7th month after planting.
Boundary plantation	Farm boundary planted with moringa (*Moringa oleifera*), and agathi (*Sesbania grandiflora*).
2 Field crops	
Rice-Rice-Cowpea/Daincha	High yielding medium duration rice var. 'Uma', and zinc biofortified rice var. 'DRR Dhan 45' were introduced. Acidic soil in rice field was ameliorated (lime @ 600 kg/ha), and micronutrient Zn was applied along with NPK fertilizer (Kharif $N:P_2O_5:K_2O + ZnSO_4$ @ 90:45:45 + 20 kg/ha, Rabi $N:P_2O_5:K_2O$ @ 90:45:45 kg/ha). Stale seed bed was adopted for weed management in rice. Summer rice fallows cultivated with either short duration grain type cowpea var. 'Hridya' or green manure daincha (*Sesbania aculeata*).
Livestock module	
Dairy cow	Chelated mineral mixture 'Amul Milk-O-Gold' was included in feeding schedule of calves (20 g/day) and adult dairy cattle (50 g/day) for faster growth, increased immunity, reduced infertility, improved milk yield and fat and solids not fat (SNF). Disinfection of milkers' hands, udder washing with sanitizing solution, post milking teat sanitation for hygienic milk production and reduced incidence of mastitis.
Poultry birds	Improved high egg laying cross-bred chicken 'Gramalakshmi', and 'BV380' were introduced for use as backyard poultry.
3. Value Addition Module	
Copra, turmeric powder, banana chips, door-to-door milk sales	Manually operated coconut dehusker was provided to assist in dehusking. Training was provided for processing of turmeric and banana. Milk can was provided to help with hygienic storage and local direct milk marketing.
4. Optional Module	
Kitchen garden, azolla plot, vermicompost unit	Kitchen garden was established with, brinjal/bhindi - cabbage/cauliflower /cowpea - amaranth/snakegourd/bittergourd, crop sequence in growbags utilizing vacant spaces in curtilage or courtyard or on terrace of house. Vegetables cultivated were amaranth var. 'Arun', bhindi var. 'Arka Anamika', bittergourd var. 'Preethi', cabbage var. 'NS 183', and cowpea var. 'Ansawara'. Azolla plot was established and azolla included in feeding schedule of livestock. Vermicompost unit was established for recycling of farm wastes.

Stability index was utilized to determine sustainability of a parameter in a farming system over the years. It was calculated using the formula described by Devasenapathy et al., 2008 as shown below, $SI = \frac{\overline{A} \quad Sd}{A_{max}}$

where, SI denoted the stability index, $\overline{A}$ is the average value over the years, Sd is the standard deviation and A_{max} is the maximum value obtained in any of the year

RESULTS AND DISCUSSION

The interventions in crop, livestock, processing and value addition, and optional modules in existing farming systems resulted in higher system productivity, profitability and employment generation (Table 2). Among the farming systems (FS), hort+crop+dairy FS recorded the maximum system productivity (201 kg/day) which was 32 percent increase over benchmark. System productivity in this farming system had a stability index (0.85) quite close to unity, showing that the system is highly sustainable. Despite hort+poultry FS contributing to higher net income (Rs. 3.62 lakh/year) and per day return (Rs.990/day) through enterprises such as coconut, its intercrops and poultry, this farming system had lower stability index (0.49) since net income varied widely over the years. Contrarily, hort+crop+dairy FS with more diverse enterprises including fodder, rice, cattle and local milk sale though contributed to lesser net income (Rs. 3.27 lakh/year) and per day return (Rs.896/day), this farming system secured a higher stability index (0.63) since net income fluctuated less over the years. Relative economic efficiency of hort+crop+dairy FS was 293 percent. Due to more varied enterprises, the employment generation in hort+crop+dairy FS increased to 190 mandays/year and provided more steady employment (stability index 0.72) than hort+poultry FS. Relative employment generation efficiency of hort+crop+dairy FS was 54 percent. The ability to utilise family labour year-round without experiencing significant lean or peak labour demand is made possible by the integration of other farm enterprises with cropping systems, which raises the labour requirement (Ravisankar et al., 2007).

Table 2: Enhancement of system productivity and profitability in small holder farming system

Year	System productivity (kg/day)		Net income (Rs Lakh/year)		Per day return (Rs/day)		Employment generation (mandays/year)	
	Hort +Crop +Dairy	Hort +Poultry	Hort +Crop +Dairy	Hort +Poultry	Hort +Crop +Dairy	Hort +Poultry	Hort + Crop + Dairy	Hort + Poultry
Benchmark 2016-17	152	50	0.83	0.77	228	211	124	36
1st year 2017-18	193	164	2.14	1.77	588	485	179	58
2nd year 2018-19	223	205	4.06	4.99	1113	1368	219	44
3rd year 2019-20	199	175	3.52	3.95	966	1081	224	66
4th year 2020-21	194	208	3.24	3.66	887	1003	161	71
5thh year 2021-22	196	181	3.37	3.71	924	1015	169	73
Mean	201	187	3.27	3.62	896	990	190	62
Sd	13	19	0.70	1.16	192	319	29	12
Increase over benchmark (%)	32	273	293	370	293	369	54	73
Stability index	0.85	0.80	0.63	0.49	0.63	0.49	0.72	0.69

Srija et al. (2021) reported that heavy rainfall in Kerala during August and September of 2018 and 2019 significantly impacted the socioeconomic livelihoods of farmers in the state. River overflows caused widespread flooding, particularly in low-lying paddy fields. The floodwaters deposited sediments and debris, necessitating their removal. Additionally, re-establishment of some crops also became necessary. This lead to increased labour demands (219 and 224 mandays) during the second and third years of the study to overcome rain induced natural calamity compared to fourth and fifth years (161 and 169 mandays) in hort+crop+dairy FS (Table 2).

Among the farm enterprises in hort+crop+dairy FS and hort+poultry FS, coconut and its intercrops occupied the largest area (0.53 to 0.89 ha) (Table 3). Both hort+crop+dairy FS and hort+poultry FS can be regarded as coconut-based farming systems since coconut and its intercrops were the major contributors to the net income (46.2 to 80.1%) of the farming system. Banana intended for harvest during Onam festive season of Kerala, was the main intercrop in coconut based multi-storeyed cropping system. Coconut benefitted from farmers' agronomic management practices for intensive banana cultivation. Reduced cultivation cost (Rs. 43700 to 56204), better profit (Rs 64232 to 80830) and higher B:C ratio (2.44 to 2.47) for coconut were achieved through intercropping which resulted in nutrient capture, runoff reduction and weed suppression. Multi-storeyed cropping system is identified as a perspective approach for sustainable productivity in fruit crops and plantation crops where the natural resources are utilized efficiently to enhance productivity of main crop (15-20%) and high revenue per unit area (50-90%) is realized (Sharma et al., 2020).

Increased net income (Rs. 32727) and B:C ratio (1.42) for rice based cropping system was achieved by intensifying rice-rice-fallow cropping system with summer cowpea/ daincha. The highest benefits relative to costs (B:C ratio 3.03 to 3.07) were obtained from the processing and value addition module involving copra, turmeric powder, banana chips, and door-to-door milk sales. This implies that adding value through processing can help to get the highest price for the same amount of raw produce. Gill et al. (2009) has reported that processing of different products has enhanced the value addition to 25 to 50% besides generating 50-75 man days/family/ year of employment. Processing and value addition must receive more focus of development agencies if farmers' income is to increase by more than twice (3.9 times in hort+crop+dairy FS and 4.7 times in hort+poultry FS). Additionally, processing and value addition also reduced post-harvest loss and economic risk. Among the modules evaluated in hort+crop+dairy FS, the highest net income was obtained from horticulture crops (46.2%), followed by dairy (29.2%), value addition (14.3%), field crops (10.1%) and optional module comprising of kitchen garden, azolla plot and vermicompost unit (0.2%). Higher B:C ratio (1.55) was obtained in hort+crop+dairy FS. Interventions like nutrition gardening can bring in surplus consumption of vegetables (Kalavathi et al., 2010).

Table 3: Area and income share of various enterprises in small holder farming system

Farm enterprises	Hort+Crop+Dairy IFS (1.0 ha) model					Hort+Poultry IFS (0.95 ha) model				
	Area (ha)	Cost of production	Net income		B : C ratio	Area	Cost of production	Net income		B:C ratio
	(ha)	(Rs)	(Rs.)	(%)	(%)	(ha)	(Rs)	(Rs)	(%)	
1 Crop module										
1.1 Horticulture crops										
Coconut	0.53	43700	64232	46.2	2.47	0.89	56204	80830	80.1	2.44
Understorey:										
Banana		189141	43388		1.23		471690	125173		1.27
Elephant foot yam		12056	17356		2.44		29136	41724		2.43
Turmeric		8837	4339		1.49		52769	22645		1.43
Cassava		21014	17356		1.83		21173	19079		1.90
Fodder grass		4053	4339		2.07					
1.2 Field crops										
Rice-Rice-Cowpea/Daincha	0.39	78828	32727	10.1	1.42					
2 Livestock Module										
Dairy cow (2 nos.)	0.04	209466	95527	29.2	1.46					
Poultry birds (30 nos.)						0.02	42526	35231	9.7	1.83
3 Value Addition Module										
Copra, turmeric powder, banana chips, door-to-door milk sales		22652	46812	14.3	3.07		17863	36221	10.0	3.03
4 Optional module										
Kitchen garden, azolla plot, vermicompost unit	0.04	1500	785	0.2	1.52	0.04	1500	601	0.2	1.40
Others: Human dwelling, store house, irrigation channels, irrigation well										
Total	1.0	591247	326861	100	1.55	0.95	692861	361504	100	1.52

CONCLUSION

This leads to the conclusion that an integrated farming system, which includes coconut intercropped with banana, elephant foot yam, turmeric, cassava, and fodder grass in 0.53 ha; double cropped rice successively cropped with summer cowpea/daincha in 0.39 ha; livestock (dairy cow 2 nos.) in 0.04 ha; kitchen garden, vermicompost, azolla, human dwelling, store house, and irrigation facilities in 0.04 ha, along with on-farm processing and value addition enterprises can be recommended for small holdings in Southern Coastal Plains of Kerala for realizing higher productivity and profitability from 1.0 ha area.

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ASSESSMENT OF MICROCLIMATIC EFFECTS ON CROP YIELD IN AGRI-HORTI SYSTEM OF WESTERN UTTAR PRADESH

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ABSTRACT

The experiment was designed to study the impact of microclimate on crop yield within an Agri-Horti system, at ICAR-Indian Institute of Farming Systems Research in Modipuram, Meerut (U.P.), India. Hourly measurements of air temperature, relative humidity, and CO_2 concentration were taken from 07:30 to 17:30 at varying heights (0.5 m, 1.0 m and 2.0 m) above ground level. CO_2 data was collected using GMP-343 probes (Diffusion aspiration), while HPM75 probes were employed for temperature and humidity readings. The correlation analysis unveiled noteworthy relationships between microclimatic parameters and crop yield. For instance, during December, under the crop canopy, CO_2 concentration exhibited a consistent negative correlation (-0.99**) with wheat, chickpea, and mustard yields, particularly at 07:30 hrs, 09:30 hrs, and 11:30 hrs (-0.959** and -0.992**, respectively), and at 17:30 hrs (-0.783*). Conversely, relative humidity during December displayed significant positive correlations (0.862*, 0.856, and 0.946**) with grain yield across various crops. Meanwhile, December's air temperature beneath the crop canopy exhibited strong negative associations (-0.896** & -0.960**) with grain yield.

Keywords: Canopy, Air temperature, Relative humidity, and CO_2 Concentration, Correlation

Microclimate plays a crucial role in plant growth and development, it refers to the localized climatic conditions within a small area, such as a few meters above or below the earth's surface or within the crop canopy (Yoshino, 1974, Maliwal, 2011). Moreover, it reflects the climate of a specific region shaped by relief, topography, and surface features, leading to variations in soil and air temperature, humidity, and wind speed (Bishnoi, 2010). The growth and development of plants are significantly impacted by both their genetic makeup and environmental conditions. Climatic elements near plants play a vital role in regulating physiological reactions and energy exchange processes, ultimately affecting crop productivity (Kingra & Kaur, 2017). Microclimate conditions within the crop canopy vary from top to bottom and are influenced by various agricultural practices such as sowing time, planting methods, and irrigation management etc. (Kingra & Kaur, 2017). Understanding microclimate dynamics is crucial for plant growth, soil regulation, and maintaining ecological balance, including aspects like plant physiology, respiration, photosynthesis, nutrient cycling, and wildlife habitat (Kingra & Kaur, 2017). Solar energy within the plant canopy influences temperature, affecting biochemical and physiological processes dependent on Photosynthetically Active Radiation (PAR). Temperature gradients change rapidly within the first few millimetres from the surface into the soil or air, with humidity changes more pronounced near the surface. These fluctuations significantly influence energy exchange, condensation, evaporation, and photosynthesis (Shamim *et al.,* 2008). In the context of Uttar Pradesh's Western plains, agri-horticultural systems play a pivotal role in economic returns for farmers, especially in semi-arid regions where annual crop production is limited. Fruit trees integrated into such systems not only enhance agricultural production but also contribute to soil and water conservation, stability in production, and income (Shamim *et al.,* 2008). With approximately 70% of land dedicated to agriculture and a substantial portion under irrigation, the region exhibits high land productivity, making it conducive for agri-horticultural practices (Shamim et al., 2008). Given this backdrop, the present study aims to investigate correlation between micro climatic parameters such as air temperature, relative humidity, and CO_2 levels recorded at different heights and across various crops grown within Agri-Horti systems.

MATERIAL AND METHODS

A field experiment was conducted at ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut (U.P.), India (29.04' N latitude, 77.05' E longitude, and 230 m AMSL) during rabi season of 2019-20. The sub-tropical semi-arid climate of Modipuram is characterized by scorching summers, cold winters with about 854.26 mm of average annual rainfall, and nearly 1600 mm of potential evapotranspiration. The soil was Typic Ustochrept, deep sandy loam, and slightly saline (pH 8.3). During the rabi season of 2019-20, wheat + mustard (9:1) with a row spacing of 22.5 cm was sown on October 25, 2019, while mustard crop, with an inter-row spacing of 15 cm between two rows of kinnow, and chickpea as a sole crop with a row spacing of 30 cm, was sown on November 16, 2019. Cultivars such as HD-3086, RH-749, and Ganguar (GNG-1581) were selected for wheat, mustard, and chickpea, respectively. Each crop was allotted plots of 625 m^2, including the intercrop of wheat + mustard (9:1), mustard sole, and chickpea sole. To facilitate observations on crop phenology and yield, plot sizes of 10 m x 10 m were demarcated in each treatment at three randomly chosen spots. The seed rates for wheat and mustard were 100 kg ha ^{1} and 1 kg ha ^{1}, respectively, for the wheat + mustard (9:1) intercrop, while 80 kg ha ^{1} for chickpea and 10 kg ha ^{1} for mustard were applied. All crops were sown in lines. Recommended doses of nitrogen, phosphorus, and potash were applied as follows: 150 kg ha ^{1}, 60 kg ha ^{1}, and 40 kg ha ^{1} for wheat; 80 kg ha ^{1}, 40 kg ha ^{1}, and 40 kg ha ^{1} for mustard; and 20 kg ha ^{1}, 40 kg ha ^{1} and 20 kg ha ^{1} for chickpea. Other agronomic practices, including irrigation, weeding, and plant protection, were implemented according to recommended package of practices. Micro-meteorological observations, such as air temperature and relative humidity, were recorded in the experimental field at 2.0-hour intervals, starting from 07:30 to 17:30, at weekly intervals, and averaged to 15-days intervals from crop emergence to physiological maturity. In-situ CO_2 concentration was measured during crop vegetative to physiological maturity of mustard and chickpea, while up to the dough stage in wheat, using CO_2 probes like GMP 343 (Diffusion aspiration). HPM75 probes were utilized to record in-situ observations of air temperature and relative humidity at different heights (0.5 m, 1.0 m, and 2.0 m) in wheat, mustard, and chickpea during vegetative to physiological maturity. For shorter crops like chickpea and wheat, observations were taken at only two heights (0.5 m and 1.0 m). The presentation of these micrometeorological observations was organized based on phenology, aligning observation dates with specific events in wheat, mustard, and chickpea crops. The agri-horticultural system included banana and papaya fruit plants intercropped with soybean (Kharif) and vegetable pea (Rabi). Frost-tolerant banana (Cv. Monthan) and papaya (Cv. Red lady) were planted in 2018 and 2019, respectively. The established orchard of Mandarin Cv. Kinnow, planted in 2010, was intercropped with fodder crops such as berseem and mukhan grass. The collected data were statistically analysed using the SPSS software package (SPSS ver. 16, 2007), applying Pearson's correlation coefficient (r) between grain yield and micrometeorological parameters such as air temperature, relative humidity, and CO_2 concentration, calculated at 5% and 1% probability levels.

RESULT AND DISCUSSION

The correlation results between crop yield and microclimate parameters, including CO_2 concentration, relative humidity, and air temperature, are displayed in Table 2. Below, we delineate the associations of grain yield with each parameter individually.

Relationship between grain yield of crops and CO_2 concentration

Relationship of yield of wheat, chickpea, and mustard with diurnal variations of microclimatic parameters showed that CO_2 concentration under the canopy of various crops at morning hours (07:30 hrs) in the month of December was negatively and strongly correlated -0.99^{**} at 1% significance level (Table 1). Similarly, 09:30 hrs and 11:30 hrs of December month showed significantly negative correlation -0.959^{**} and -0.992^{**} respectively at 1% significance level with grain yield. At 17:30 hrs in the evening time of the December month, CO_2 concentration was negatively associated (-0.783*) with the grain yield of field crops. There were no association found between grain yield of field crops and CO_2 concentration in the month of January. However, CO_2 concentration measured at 07:30 hrs and 09:30 hrs in the months of February was negatively associated with correlation coefficient values of -0.766^{*} and -0.876^{*}. The negative association between grain yield and CO2 concentrations during morning and evening hours could be attributed to lower air temperatures and reduced sunlight, which may decrease the amount of CO2 used in photosynthesis.

Relationship between grain yield of crops and Relative humidity

The relative humidity under the canopy of various crops at morning hours (11:30 hrs), afternoon (13:30 hrs and 15.30 hrs) in the month of December was significantly and positively correlated with grain yield (0.862^{*}, 0.856^{*} and 0.946^{*}). There was no significant relationship found between grain yield of field crops and relative humidity recorded during the month of January. However, relative humidity measured at 09:30 hrs in the month of February showed significant positive correlation 0.804^{*} with grain yield of field

Table 1: Correlation between grain yield of field crops with CO_2, RH and Air temperature

		YD	DS	DN	DE	DT	DF	DSN	JS	JN	JE	JT	JF	JSN	FS	FN	FE	FT	FF	FSN
YD	CO_2	1	-.991**	-.959**	-.992**	-.270	.339	-.783*	-.686	-.360	-.488	.031	-.467	.361	-.766*	-.876*	.349	-.406	-.273	.564
	Relative Humidity	1	.342	.654	.862*	.856*	.946**	-.553	.335	.436	-.061	.304	.301	.639	.398	.804*	.621	.527	.061	.167
	Temperature	1	-.513	-.896**	-.765*	-.790*	-.960**	-.100	-.469	.778*	.174	-.181	-.361	-.588	.118	-.322	-.225	-.328	-.332	-.060

** Correlation is significant at the 1% level, * Correlation is significant at the 5% level

YD = Yield, D = December, J = January, F = February, S = 7:30, N = 9:30, E = 11:30, T = 13:30, F = 15:30, SN = 17:30.

crops (Table 1). The positive correlation between afternoon relative humidity and grain yield may be due to favourable conditions for higher photosynthesis rates. In low relative humidity, increased transpiration can cause water deficits in the plant, leading to partial or full stomatal closure and increased mesophyll resistance, which blocks the entry of carbon dioxide.

Relationship between grain yield of crops and Air temperature

Air temperature recorded under the canopy of various crops at morning (09:30 hrs) and afternoon (15:30 hrs) in the month of December was negatively and strongly associated -0.896** & -0.960** with grain yield. During the month of December, significant negative correlations (-0.765* & -0.790*) were observed between air temperature and grain yield at 11:30 hrs and 13:30 hrs. However, during the month of January, a significant positive correlation of 0.778* was found between grain yield and air temperature measured at 09:30 hrs. Lal *et al.* (1998) also reported that maximum temperature showed negative effects in maize and rice as high temperature induces stress to plants by reducing water resources that are essential for crop growth. Conversely, in February, no associations were identified between the grain yield of field crops and temperature (Table 1). Lal *et al.* (1998) was also found that most of individual weather parameters did not show any significant impact on crops yields. However, combined weather parameters showed significant effect on selected crops which indicates that crop yields are influenced by combinations of weather parameters.

CONCLUSION

Reduced CO_2 concentrations result from its utilization in photosynthesis, promoting greater biomass production and ultimately enhancing grain yield. Conversely, the negative correlation between air temperature and grain yield may stem from decreased photosynthesis rates. Moreover, higher relative humidity during the rabi crop season appears advantageous for achieving optimal grain yields in field crops.

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TEMPERATURE AND RAINFALL TRENDS IN DIFFERENT REGIONS OF UTTAR PRADESH

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ABSTRACT

The changing of weather parameters like temperature and rainfall are important for agricultural and environmental resources. To evaluate the magnitude changes in these parameters, trend analysis is performed. In this study, the trends in temperature & rainfall for past 30 years (1980-2014) have been analysed at selected region of Uttar Pradesh on monthly and annual basis for which Mann-Kendall and Sen's Slope Estimator has been used. There are rising trends of temperature in some months and decreasing trend in some other months obtained by these statistical tests suggesting overall significant changes in the area. Rainfall showed an significant and non significant decreasing trends at selected regions for study period.

Keywords: Temperature; Rainfall; Mann–Kendall and Sen's Slope Estimator

Temperature and rainfall are the two important weather elements and it has direct effect on crop growth and yield development. The analysis of their behaviour is very important for understanding the climatic variability. Climate changes the rainfall pattern and temperature had significant impacts on hydrological cycle as well as crop development (Jedhe *et al.* 2018). According to rainfall and its increasing frequency over past or future. Due to this extreme weather events would be occurred (Ganguly *et al.* 2015). The analysing of their behaviour is important for understanding the climate variability. If rainfall increases its frequency the occurrence of floods, mean while decreasing of precipitation, it would cause to drought. The temperature and rainfall are connected each other. If temperature increases it leads to more evaporation and causes for formation of clouds, it leads to heavy precipitation (Kumar *et al.* 2014). These are the main risk factors, it impacts on agricultural systems and its management.

Many studies had been reported on trend analysis in different parts of India (Mishra *et al.* 2016). However, analysis of trends on these regions is not reported before. Trend were statistically estimated in two stages i.e. presence of increasing or decreasing trend were tested using Mann-Kandell Test and change of rate was estimated with help of Sen's Slope Estimator. Trend analysis is defined as changes occurred for a long period of time. The principle of trend testing is to determine that the values of parameters generally increasing or decreasing over a long term period in statistically analysed. Parametric or non-parametric statistical tests are used to decide whether there is a statistically significant trend. (Padhiary *et al.* 2018).

The purpose of this study to assess the variability of temperature and over selected regions of Uttar Pradesh. Considering as high or low temperatures and with too little rain or heavy rains will affect the agriculture. The major objective of this recent study is to determine and analyse the trends of temperature and rainfall. Hence, this study was carried out to find the trends in the temperature and rainfall series to get idea on rainfall patterns and variability in different regions of Uttar Pradesh.

MATERIALS AND METHODS

Study area - Uttar Pradesh is situated in Northern India between 26.8467 ^{0} N Latitude and 80.9462 ^{0} E Longitudes. In UP summers are very hot and winters are bit chilly. Summer season persists from April to June. The day time temperature remains very high and usually touches around 48^{0}C. Night are relatively cooler typical of extreme climate and the temperature comes down to as low as 28^{0}C because of the cool breeze.

Daily rainfall and temperature (1980-2014) gridded data were collected from the India Meteorological Department (IMD).

Analysis of the data was carried out the month and year-wise for temperature and rainfall (1980-2014). In this study, statistical significance of the trend in the time series was analyzed using Mann–Kendall test and the magnitude of a trend in a time series was determined using a nonparametric method known as Sen's estimator.

Mann-Kandell Test

This method tests whether there is a trend in the time series data. It is a statistical test widely used for trend analysis, used for detection of statistically significant trend in variables like rainfall, temperature. According to this test, the null hypothesis H_0 assumes that there is no trend and this is tested against the alternative hypothesis H1, which assumes that there is a trend (Karmeshu 2012).The trend detection of the data is analyzed using the Mann-Kendall test. The Mann-Kendall Statistic S for trend is

$$S \quad sgn\, nj \quad i \quad 1N \quad 1I \quad 1(XI \quad XI)$$

Where the xi is the actual time data for a time series of $i \quad 1,2\ldots n$

$$\begin{array}{lcl} & 1 & (x_j \quad x_i) \\ Sgn & 0 & (x_j \quad x_i) \\ & 1 & (x_j \quad x_i) \end{array}$$

When the data n = 10 the S statistic follows the normal distribution in a series with the mean of E(S)=0 and the variance.

A positive (negative) value of S indicates an upward (downward) trend.

Sen's slpoe Estimator

Sen's slope estimation is another non-parametric method for trend analysis of precipitation data. It is used to detect the magnitude of the trend.

$$T_i \quad \frac{(x_j \quad x_i)}{j \quad k}$$

Where xj and xk is the data values for j and k times of a period where j>k. Median is computed from N observations of the slope to estimate the Sen's Slope estimator.

$$Q_i = \begin{cases} T_{\frac{N+1}{2}} & N \text{ is odd} \\ \frac{1}{2}\left(T_{\frac{N}{2}} + T_{\frac{N+1}{2}}\right) & N \text{ is even} \end{cases}$$

When the N Slope observations are shown as Odd the Sen's Estimator is computed as Qmed= (N+1)/2 and for Even times of observations the Slope estimate as Qmed= [(N/2) + ((N+2)/2)]/2. The two sided test is carried out at 100(1 – á) % of confidence interval to obtain the true slope for nonparametric test in the series (Mondal *et al.* 2012) The positive or negative slope Qi is obtained as upward (increasing) or downward (decreasing) trend.

RESULTS & DISCUSSION

Temperature trend

Trend analysis of temperature for the period of 1980-2014 (34 years) areas of Uttar Pradesh has been done in the present study. Mann-Kendall and Sen's Slope Estimator have been used for the determination of the temperature trend detection. Monthly temperature significant increasing trend at 0.05 levels of significance were shown in the months of March, July, August, October, November for Ambedkar nagar, Bijnor, Banda, Balampur, Gorakhpur, Jaunpur, Kaushambi, Maharajganj, Unnao (Table 1). As per monthly results January & December months has a decreasing trend, while increasing trend were observed from February to November. Mann-Kendall test shows that there was an increasing trend in temperature. Temperature variation also depends upon the location. The higher temperature means more evaporation and rainfall with uneven distribution. This will result in flood and extreme conditions of climate. If this trend continues for more hundred years, climate will try to rearrange its eco-balance system, resulting in flood, drought and forest fire etc. This means the longest summer and the shortest winter season. According to annual the results showed as significant increasing trend for Ambedkar nagar, Bijnor, Ghazipur, Gorkhpur, Jhansi and Lalitpur, remaining stations showed non significant increasing trend.

Rainfall trend

The results of Mann-Kendall test for monthly precipitation data showed that there was a significant decreasing trend (0.05 levels of significance) found for the month of August, September and December for Bahraich, Balampur, Banda, Farukhabad, Kaushambi, Kheri, Mahoba, Sitapur and Sultanpur while following stations shows decreasing trend for the period 1980-2014. Sen's slope magnitude was also showed to the falling trend. The study of data period shows sharp decrease in trend in the month of August and September at 0.05 levels of significance. In order to determine the trend on annual precipitation analysis has been done for each station. The analysis of annual trend was presented in Table 1 & 2. From the Mann-Kendall test and sen's slope estimator it was concluded that there is no trend was followed for Bijnor, Etah, Gautambudh Nagar, Jhansi, Lalitpur, Mathura and Moradabad.

The study of data period 1980-2014 shows sharp decrease in trend in the month of August and September at 0.05 levels of significance and the magnitude is also high as can be seen from the Sen's slope estimator for the Bahraich region. This is a cause as Bahraich used to record much rainfall than other stations. The falling trends in the monsoon months show that future detailed trend analysis needs to be done. The station wise data does not reflect any significant change in increasing the trend in the overall values. Annual trend analysis has been done for each station. The analysis of annual trend presented in table 1 & 2. The mostly increase in trend and non significant annual trend is noticed for all the stations.

Table 1: Trend analysis of monthly & annual temperature data 1980-2014 for UP region using Mann-Kendall test (Z) and Sen's Slope Estimator(Q).

Stations		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Ambedkar Nagar	Z	-0.219	0.125	0.182	0.076	0	0.072	0.150	**0.409**	0.281	0.094	0.138	-0.14	**0.243**
	Q	-0.029	0.018	0.025	0.013	0	0.017	0.021	0.021	0.023	0.008	0.011	-0.012	0.013
Aurariya	Z	-0.142	0.132	0.194	0.119	-0.043	0.042	0.082	**0.293**	0.189	0.139	0.225	0.030	0.169
	Q	-0.021	0.019	0.034	0.021	-0.008	0.008	0.012	0.024	0.017	0.015	0.024	0.003	0.01
Bahraich	Z	-0.225	0.098	0.160	0.142	0.007	0.005	0.036	0.207	0.235	0.179	0.207	-0.081	0.126
	Q	-0.034	0.013	0.028	0.022	0.000	0.000	0.005	0.011	0.017	0.015	0.02	-0.01	0.008
Balampur	Z	-0.233	0.114	0.184	0.150	0.071	0.002	0.161	**0.330**	0.270	0.158	0.205	-0.070	0.189
	Q	-0.033	0.016	0.031	0.021	0.012	0.000	0.015	0.013	0.021	0.015	0.018	-0.009	0.01
Banda	Z	-0.132	0.132	0.230	0.093	0.030	0.073	0.077	**0.330**	0.263	0.172	**0.281**	0.106	0.225
	Q	-0.02	0.017	0.036	0.018	0.006	0.013	0.01	0.024	0.024	0.018	0.031	0.013	0.015
Bareily	Z	**-0.239**	0.114	0.235	0.152	-0.014	-0.031	0.154	0.165	0.107	0.199	0.196	-0.068	0.153
	Q	-0.036	0.013	0.037	0.029	-0.002	-0.005	0.014	0.011	0.007	0.017	0.015	-0.005	0.009
Bijnor	Z	-0.180	0.128	**0.300**	0.201	0.059	-0.020	**0.242**	0.268	0.124	**0.242**	0.248	-0.053	**0.317**
	Q	-0.024	0.024	0.063	0.039	0.013	-0.003	0.03	0.017	0.01	0.022	0.025	-0.005	0.019
Etah	Z	**-0.257**	0.122	0.227	0.113	0.012	-0.080	0.142	0.207	0.125	0.170	0.230	-0.012	0.184
	Q	-0.033	0.02	0.042	0.022	0.002	-0.012	0.018	0.017	0.01	0.012	0.02	-0.002	0.008
Farukhabad	Z	-0.223	0.111	0.223	0.135	-0.032	-0.027	0.098	**0.249**	0.143	0.159	0.192	-0.053	0.176
	Q	-0.032	0.017	0.036	0.025	-0.006	-0.008	0.013	0.015	0.012	0.016	0.018	-0.004	0.011
Gautambudh Nagar	Z	**-0.270**	0.086	**0.253**	0.144	0.024	-0.046	**0.245**	0.131	0.019	0.178	0.203	-0.068	0.133
	Q	-0.035	0.012	0.038	0.03	0.006	-0.01	0.029	0.015	0.000	0.019	0.013	-0.005	0.007
Ghazipur	Z	-0.125	0.216	0.222	0.214	0.142	0.088	0.212	**0.367**	0.305	0.168	0.193	-0.042	**0.331**
	Q	-0.014	0.025	0.032	0.03	0.019	0.018	0.025	0.02	0.02	0.014	0.019	-0.003	0.018
Gorakhpur	Z	-0.149	0.210	0.204	0.210	0.083	0.035	0.180	**0.318**	0.299	0.159	0.171	-0.063	**0.260**
	Q	-0.027	0.025	0.029	0.028	0.012	0.008	0.019	0.019	0.022	0.015	0.018	-0.007	0.014
Jaunpur	Z	-0.149	0.158	0.182	0.168	0.082	0.057	0.132	**0.298**	0.282	0.182	0.195	-0.009	0.194
	Q	-0.026	0.02	0.031	0.019	0.006	0.014	0.016	0.015	0.022	0.014	0.022	0.000	0.012
Jhansi	Z	-0.154	0.120	0.225	0.153	0.091	-0.054	0.005	0.231	0.123	0.134	**0.311**	0.171	**0.256**
	Q	-0.019	0.02	0.038	0.029	0.013	-0.014	0.000	0.02	0.017	0.014	0.038	0.017	0.014
Kaushambi	Z	-0.180	0.102	0.180	0.098	0.034	0.066	0.103	**0.307**	0.284	0.181	**0.247**	-0.010	0.189
	Q	-0.031	0.011	0.03	0.013	0.006	0.021	0.014	0.017	0.024	0.017	0.025	0.000	0.01
Kheri	Z	**-0.253**	0.105	0.221	0.159	-0.014	-0.025	0.119	0.146	0.124	0.171	0.144	-0.088	0.164
	Q	-0.034	0.014	0.036	0.029	-0.003	-0.006	0.011	0.007	0.008	0.015	0.013	-0.01	0.009
Lalitpur	Z	-0.163	0.162	0.208	0.119	0.088	-0.022	-0.008	0.211	0.139	0.098	0.291	**0.239**	**0.271**
	Q	-0.02	0.027	0.033	0.019	0.017	-0.004	0.000	0.025	0.02	0.017	0.038	0.025	0.017
Maharajganj	Z	-0.190	0.192	0.201	0.201	0.079	0.008	0.189	**0.313**	0.297	0.124	0.134	-0.075	0.209
	Q	-0.029	0.028	0.028	0.032	0.014	0.005	0.021	0.015	0.023	0.012	0.014	-0.007	0.012
Mahoba	Z	-0.161	0.095	0.196	0.088	0.037	0.007	0	0.232	0.166	0.137	**0.270**	0.105	0.174
	Q	-0.025	0.015	0.034	0.017	0.006	0.000	0	0.021	0.015	0.014	0.031	0.011	0.011
Mathura	Z	**-0.266**	0.118	**0.257**	0.170	0.037	-0.056	0.176	0.167	0.041	0.163	0.218	0.034	0.202

	Q	-0.026	0.019	0.044	0.03	0.009	-0.008	0.026	0.014	0.003	0.015	0.023	0.005	0.012
Moradabad	Z	**-0.257**	0.126	**0.250**	0.147	0.019	-0.044	0.198	0.179	0.060	0.190	0.190	-0.070	0.207
	Q	-0.026	0.022	0.045	0.027	0.004	-0.008	0.025	0.012	0.004	0.018	0.014	-0.006	0.011
Sitapur	Z	-0.222	0.128	0.196	0.144	-0.039	0.022	0.107	**0.267**	0.206	0.157	0.157	-0.090	0.148
	Q	-0.033	0.019	0.032	0.025	-0.008	0.007	0.013	0.017	0.016	0.016	0.016	-0.011	0.009
Sultanpur	Z	-0.216	0.097	0.174	0.117	-0.002	0.007	0.101	0.228	**0.272**	0.156	0.217	-0.058	0.165
	Q	-0.035	0.014	0.031	0.018	0.000	0.002	0.013	0.013	0.021	0.013	0.021	-0.007	0.01
Unnao	Z	-0.168	0.148	0.199	0.150	-0.002	0.041	0.080	**0.289**	0.253	0.186	0.212	-0.009	0.197
	Q	-0.027	0.019	0.032	0.026	0.000	0.01	0.012	0.016	0.021	0.019	0.023	0.000	0.012

Where, bold are for 0.05 level of significance, (-) decreasing trend (+) increasing trend

Table 2: Trend analysis of monthly & annual rainfall data 1980-2014 for UP region using Mann-Kendall test (Z) and Sen's Slope Estimator(Q).

Stations		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Ambedkar Nagar	Z	-0.212	-0.005	-0.008	-0.245	-0.072	-0.126	-0.18	-0.203	-0.19	-0.072	-0.235	**-0.318**	0.030
	Q	-0.255	0	-0.004	-0.179	-0.174	-1.533	-3.3	-2.647	-2.571	-0.187	-0.044	-0.111	0.537
Aurariya	Z	-0.199	0.034	-0.008	-0.21	-0.04	-0.119	-0.176	-0.176	-0.106	-0.111	-0.164	**-0.275**	0.303
	Q	-0.306	0.037	0	-0.083	-0.043	-0.918	-2.75	-2.215	-1.39	-0.225	-0.035	-0.071	18.8
Bahraich	Z	-0.19	0.039	-0.066	-0.094	-0.221	-0.099	-0.17	**-0.301**	-0.244	0.01	-0.201	**-0.248**	0.030
	Q	-0.3	0.064	-0.1	-0.17	-0.982	-1.683	-3.32	**-4.567**	-3.767	0.012	-0.082	-0.196	1.647
Balampur	Z	-0.164	0.013	-0.05	-0.143	-0.173	-0.109	-0.17	**-0.321**	-0.229	-0.052	-0.214	**-0.276**	0.091
	Q	-0.194	0.015	-0.048	-0.196	-0.528	-1.826	-2.711	-3.508	-3.379	-0.163	-0.067	-0.19	1.712
Banda	Z	-0.203	0.014	-0.02	0.061	-0.012	-0.059	-0.049	**-0.277**	-0.057	-0.123	-0.082	**-0.293**	0.030
	Q	-0.378	0	-0.004	0.014	0	-0.83	-0.927	-3.6	-0.672	-0.185	0	-0.214	0.074
Bareily	Z	-0.178	0.148	-0.177	-0.086	-0.153	-0.126	-0.173	**-0.257**	-0.005	0.059	-0.04	-0.193	0.061
	Q	-0.287	0.467	-0.28	-0.082	-0.4	-0.932	-3.08	-3.456	-0.047	0.083	0	-0.14	1.64
Bijnor	Z	-0.124	0.173	-0.161	-0.079	-0.113	-0.034	-0.193	-0.133	0.103	0.059	-0.036	-0.159	0
	Q	-0.296	0.65	-0.3	-0.125	-0.275	-0.317	-2.721	-1.872	1.176	0.081	-0.007	-0.186	-0.014
Etah	Z	-0.118	0.173	-0.17	-0.003	-0.108	0.008	-0.103	-0.16	0.116	0.044	0.003	-0.165	0.030
	Q	-0.146	0.45	-0.15	0	-0.125	0.067	-1.2	-1.932	0.959	0.053	0	-0.105	0.938
Farukhabad	Z	-0.17	0.108	-0.142	-0.039	-0.17	-0.055	-0.116	**-0.277**	-0.035	0.005	-0.067	**-0.244**	0.061
	Q	-0.233	0.2	-0.162	-0.047	-0.255	-0.538	-1.375	-3.008	-0.312	0.016	-0.007	-0.19	1.578
Gautambudh Nagar	Z	-0.072	0.175	-0.164	-0.062	-0.044	-0.022	-0.13	-0.059	0.202	0.035	-0.028	-0.123	0.030
	Q	-0.105	0.504	-0.159	-0.056	-0.083	-0.18	-1.471	-0.667	2.274	0.029	0	-0.069	-0.197
Ghazipur	Z	-0.152	0.037	0.054	**-0.256**	-0.066	-0.089	**-0.247**	-0.126	-0.035	-0.073	-0.166	**-0.271**	0.030
	Q	-0.108	0.026	0.026	-0.113	-0.194	-0.806	-3.525	-1.229	-0.78	-0.3	-0.027	-0.037	-0.153
Gorakhpur	Z	-0.13	0.039	0.003	**-0.249**	-0.059	-0.076	-0.129	-0.151	-0.173	-0.061	-0.204	**-0.322**	0.061
	Q	-0.159	0.057	0.004	-0.357	-0.208	-1.245	-2.246	-1.455	-2.829	-0.23	-0.014	-0.129	1.574
Jaunpur	Z	-0.217	0.007	-0.012	**-0.245**	-0.062	-0.136	-0.203	-0.18	-0.17	-0.108	-0.175	**-0.307**	0
	Q	-0.278	0.011	0	-0.128	-0.111	-1.412	-2.875	-2.429	-2.256	-0.28	-0.033	-0.06	0.017
Jhansi	Z	-0.175	0.042	-0.063	0.166	0.02	0.024	0.034	-0.135	0.069	-0.093	0.082	-0.18	0.121
	Q	-0.2	0.009	-0.019	0.082	0.027	0.144	0.414	-1.532	0.885	-0.1	0	-0.103	0.44

Kaushambi	**Z**	-0.203	0.017	-0.053	-0.046	0.008	-0.057	-0.103	**-0.25**	-0.072	-0.13	-0.134	**-0.308**	0
	Q	-0.39	0	-0.013	-0.016	0.005	-0.807	-1.806	-3.844	-0.813	-0.192	0	-0.143	-0.051
Kheri	**Z**	-0.15	0.106	-0.142	-0.071	**-0.256**	-0.109	-0.21	**-0.277**	-0.187	0.054	-0.124	-0.173	0.030
	Q	-0.382	0.457	-0.2	-0.052	-1.211	-1.692	-4.257	-5.583	-2.6	0.165	-0.018	-0.15	2.451
Lalitpur	**Z**	-0.175	0.019	-0.027	0.186	0.071	0.062	0.092	-0.049	0.113	-0.104	0.034	-0.172	0.152
	Q	-0.227	0.004	-0.01	0.07	0.059	0.405	1.483	-1	1.145	-0.124	0	-0.091	0.486
Maharajganj	**Z**	-0.104	0.059	-0.012	-0.2	0.012	-0.045	0.008	-0.015	-0.089	-0.071	-0.177	**-0.25**	0.182
	Q	-0.164	0.14	-0.015	-0.563	0.037	-0.65	0.2	-0.363	-1.832	-0.3	-0.011	-0.09	2.757
Mahoba	**Z**	-0.179	0.037	-0.042	0.138	-0.003	-0.008	-0.005	**-0.237**	-0.022	-0.12	0.013	-0.235	0.121
	Q	-0.37	0.02	-0.014	0.035	-0.007	-0.208	-0.1	-3.421	-0.184	-0.154	0	-0.2	0.303
Mathura	**Z**	-0.088	0.206	-0.15	0.084	-0.007	0.066	-0.035	-0.067	0.2	0.025	0.081	-0.084	0.091
	Q	-0.08	0.374	-0.113	0.059	-0.004	0.3	-0.283	-0.731	1.91	0.013	0	-0.035	0.619
Moradabad	**Z**	-0.128	0.17	-0.178	-0.096	-0.138	-0.109	-0.193	-0.183	0.022	0.049	-0.023	-0.158	0.030
	Q	-0.294	0.611	-0.275	-0.12	-0.313	-1.074	-2.969	-2.725	0.418	0.071	0	-0.146	0.527
Sitapur	**Z**	-0.185	0.092	-0.145	-0.079	-0.225	-0.082	-0.166	**-0.277**	-0.193	0.04	-0.139	-0.169	0.030
	Q	-0.295	0.236	-0.17	-0.108	-0.758	-1.3	-2.932	-4.689	-2.938	0.144	-0.02	-0.114	3.416
Sultanpur	**Z**	-0.202	-0.017	-0.052	-0.139	-0.059	-0.103	-0.156	**-0.261**	-0.183	-0.054	-0.218	**-0.292**	0.030
	Q	-0.248	-0.008	-0.025	-0.065	-0.121	-1.244	-3.011	-3.667	-2.538	-0.136	-0.054	-0.159	0.854
Unnao	**Z**	-0.172	0.062	-0.125	-0.019	-0.13	-0.092	-0.099	-0.297	-0.066	-0.022	-0.133	-0.272	0.242
	Q	-0.242	0.089	-0.088	-0.009	-0.2	-0.622	-1.579	-3.558	-1.114	-0.032	-0.018	-0.278	123.4

CONCLUSION

Trend analysis was done for temperature, January & December months had a decreasing trend, while increasing trend were observed from February to November. Anuualy there was a significant increase in trend. There is an increasing trend was found most of districts under study except Bijnor, Gautambudh nagar, Ghazipur, Kausambi while no significant trend was found by Mann-Kendall test in both monthly & annual. The trend analysis will help scientists to find some serious implications of climate change. Similarly, Sen‘s Slope has also estimated increasing magnitude of slope for temperature data. This study has also revealed that the temperature (annual) time series found to be increasing (positive) with level of non-significance trend mostly.

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SENSOR BASED NITROGEN MANAGEMENT FOR HIGHER PRODUCTIVITY AND RESOURCE EFFICIENCY IN MAIZE-WHEAT SYSTEM

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ABSTRACT

Field experiments were conducted from 2017 to 2019 to investigate the effect of sensor-based nitrogen (N) management (using Green Seeker) to enhance productivity and resource use efficiency in a maize-wheat cropping system. The study evaluated various nutrient management practices, including soil test crop response (STCR), Nutrient Expert, and Green Seeker (GS), alongside the recommended dose of fertilizers (RDF). The research was focused on yield attributes, overall yield, system productivity, and nutrient efficiency. Results indicated that GS-based N management at later growth stages (tasseling in maize and maximum tillering in wheat) outperformed early-stage applications (knee-high in maize and crown root initiation in wheat). On average, the highest grain yields for both maize and wheat, as well as overall system productivity, were achieved with N-rich strips, followed by STCR and RDF treatments. Among the GS-based N management strategies, applying 35% N basal + 35% at 25 days after sowing (DAS) + GS based N at the tasseling stage produced highest grain yield for both maize and wheat. This treatment was comparable to the RDF treatment. System productivity increased by 7.18-9.30% under GS-based N management at the tasseling and maximum tillering stages compared to early-stage applications. Additionally, GS-based N management saved approximately 21.3% N in maize and 15.3% in wheat compared to RDF. This method also led to higher partial factor productivity (PFP) at 48.3 kg of grain per kg of N applied and improved agronomic efficiency, with an increase of 27.5 kg of grain per kg of nitrogen applied. The study concludes that Green Seeker-based N management effectively optimizes nitrogen use in maize and wheat, resulting in better nutricent utilization and higher productivity.

Key words: Agronomic efficiency; Green seeker; Nutrient Expert; Partial Factor productivity; STCR

Cereal grains are vital staple foods, providing substantial energy, protein, and essential micronutrients to most of the world's population. Major cereals, including wheat, maize, rice, barley, sorghum, millet, oats, and rye, collectively occupy nearly 60% of the world's cultivated land. Corn, in particular, supports heart health through its fiber content and significant amounts of folate. Corn also contains cryptoxanthin, a natural carotenoid pigment that may reduce lung cancer risk. The phenolic compounds in maize enhance its free radical scavenging activity (CIMMYT, 2000). In India, maize accounts for nearly 9% of the national food basket. It serves as a staple food for humans, a quality feed for animals, and a key raw material in numerous industrial products, including starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceuticals, cosmetics, films, textiles, gum, packaging, and paper. In the poultry feed industry, maize constitutes about 60% of the feed, making it a critical raw material. Over the past five years, maize exports have doubled, and by 2025, it is expected to become the largest crop in the developing world, with demand projected to double by 2050. Due to its wide range of applications, maize is often referred to as the 'Queen of Cereals'. Its adaptability across diverse agro-climatic zones further underscores its versatility. In India, maize ranks as the third most important food crop after rice and wheat (Murdia *et al.,* 2016). India's maize cultivation spans approximately 9.86 million hectares, with a production of around 28.5 million tons and a productivity rate of 2.89 tons per hectare (FAOSTAT, 2020). The major maize-producing states in India include Karnataka, Andhra Pradesh, Maharashtra, Uttar Pradesh, and Bihar (Kumar *et al.,* 2022).

Nitrogen is essential for regulating various physiological and biological processes in plants. Under natural conditions, nitrogen fertilizer application is subject to numerous losses, including denitrification, volatilization, leaching, and fixation with clay colloids. Cereals require large amounts of nitrogen, but the demand for fertilizer varies. Nitrogen is one of the most important nutrients required in crop production. It is subject to losses in different forms, such as ammonia, nitrate, and nitrous oxide, through processes like denitrification, volatilization, and leaching, which cause environmental pollution, including eutrophication of water bodies and increased nitrate content in groundwater. Insufficient nitrogen availability results in low yields and significantly reduced profits compared to properly fertilized crops. Efficient nutrient management programs supply plant nutrients in adequate quantities to sustain maximum crop productivity and profitability while minimizing the environmental impacts of nutrient use (Jat *et al.,* 2013). A mismatch between nitrogen supply and demand can hinder crop growth and negatively impact the environment, leading to poor nitrogen use efficiency and economic losses. To optimize crop growth, economic returns, and environmental sustainability, a balanced approach to nitrogen management is necessary. This approach involves applying inputs based on the specific needs of the farm. Field spatial variability often results in uniform fertilizer application, as farmers treat fields as homogeneous units. Need-based strategies involve supplying nitrogen fertilizers according to crop demand, thereby reducing nitrogen losses. Precision agriculture can address the varied spatial nitrogen requirements across a field using variable rate application guided by crop canopy reflectance sensors. Sensors like the SPAD chlorophyll meter, GreenSeeker, and rapidSCAN are used to determine the nitrogen needs of field crops (Rayapati *et al.,* 2022). Globally researchers are working on standardizing these sensors for different crop growth stages. Currently, precision input management in cereals is lacking in most growing areas. While substantial information on crop nutrition exists, data on need-based nitrogen management using sensors like GreenSeeker is limited. To address this, an experiment was conducted to validate sensor-based nitrogen management using GreenSeeker for higher productivity and profitability in the maize-wheat cropping system in the Western Plain Zone of Uttar Pradesh.

MATERIAL AND METHODS

Experimental location

The experiment was executed during 2017-2019 at the research farm of ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut, India situated at 29°04’38.8"N (latitude) and 77°42’09.9"E (longitude), 237 m (altitude) above mean sea level (Arabian sea). Experimental site falls under semi-arid and sub-tropical zone with hot summers and cold winters. The experimental site representing the part of the Upper Gangetic Plain region is alkaline in reaction with sandy loam texture soil (50.5% sand, 31.9% clay, and 17.6% silt) of Gangetic alluvial origin, very deep (> 20 m), well-drained, and with flat (1% slope) topography. The soil of the experimental site was medium in soil organic carbon, low in available nitrogen (199 kg/ha), medium in available P (22.4 kg/ha) and K (179 kg/ha).

Layout and treatment details

The experiment was laid out in randomized complete block design with three replications. Twelve nutrient management practices were used for experimentation. Details of treatments are presented in Table 1. Nutrients were applied through Urea, DAP and MOP as per the treatment. A full dose of phosphorus and potassium was applied as basal in maize and wheat, while nitrogen was applied according to the treatment. The nitrogen dose in the STCR treatment was calculated using the equation developed by ICAR-IISS, Bhopal, for the NAC region. GreenSeeker was used to calculate in-season nitrogen requirements at the knee-high and tasseling stages in maize and the CRI and maximum tillering stages in wheat. The N-rich strip is a high nitrogen rate strip applied in the field prior to or soon after planting to ensure nitrogen is not limiting in the strip. Recommended practices for plant protection, irrigation, and weed management were uniformly followed across treatments for both crops.

The experiment involved twelve distinct treatments to evaluate the effects of different nutrient application on crop growth and yield. The first treatment was a control with no nutrient application. The second treatment followed the Recommended Dose of Fertilizers (RDF), where nitrogen (N) was split into three equal parts and applied at the basal, knee-high/ CRI (Critical Root Initiation), and tasseling/ maximum tillering stages. The third treatment applied the Soil Test Crop Response (STCR) approach, also using a three-way N split at similar growth stages. The fourth treatment used the Nutrient Expert system, which again split N application into three parts across the basal, knee-high/ CRI, and tasseling/ maximum tillering stages. The fifth treatment applied 33% basal N with additional N application based on GS technology at the knee-high/CRI and tasseling/maximum tillering stages. The sixth and seventh treatments increased the basal N application to 60% and 70%, respectively, with the remaining N applied based on GS readings at the knee-high/ CRI stage. The eighth and ninth treatments followed a similar approach but applied the additional N at the tasseling/maximum tillering stage instead.

The tenth treatment involved a split of 30% basal N and 30% at 25 DAS (Days After Sowing), with the remainder applied based on GS readings at the tasseling/ maximum tillering stage. The eleventh treatment altered this slightly to a 35% basal N and 35% at 25 DAS, followed by GS-based N application at tasseling/ maximum tillering. Finally, the twelfth treatment featured an N-rich strip with a split application of N at 300:60:40 proportions, divided similarly across the basal, knee-high/CRI, and tasseling/ maximum tillering stages.

Growth, yield attributes and yield

Growth parameters (plant height and number of tillers) and SPAD values of ten randomly selected maize and wheat plants in each treatment were recorded at periodic intervals. Yield attributes such as the number of rows per cob, cob length, and number of grains per cob in maize and spike length, spike weight, number of grains per spike, and 1,000-grain weight in wheat were recorded from a sample of ten spikes/cobs collected randomly from each plot. The grain yield of maize and wheat was estimated at 14% moisture content and expressed in kg/ha. Partial factor productivity was calculated by dividing yield of particular treatment with quantity of N applied. Similarly, agronomic efficiency was measured by dividing the difference of yield in treated to control by dose of N applied.

Statistical analysis

The experimental data on different parameters recorded during the study period were statistically analyzed using the F-test as per the procedure given by Gomez and Gomez (1984). Significant differences between treatment means were compared with the least significance at the 5% level of probability.

Table 1: Yield parameters and yield of Maize as affected by different treatments (Mean of 2 years)

Treatment	No. of rows/ cob	Cob length (cm)	No. of grains/cob	1000 grains weight (g)	Maize yield (kg /ha)		
					2017	2018	Mean
Control	13.3	8.9	283	300	3156	1336	2246
RDF	14.1	14.4	425	341	5378	3911	4645
STCR	13.8	12.0	408	337	5402	4042	4722
Nutrient expert	14.2	14.2	390	348	5274	3271	4272
33% Basal + GS at knee high & tasseling	13.6	13.3	418	328	5800	2618	4209
60% basal + GS at knee high	13.7	13.1	410	338	5367	3043	4205
70% basal + GS at knee high	13.7	13.7	397	339	5319	2826	4073
60% basal + GS at tasseling	13.9	13.1	383	336	4948	3473	4211
70% basal + GS at tasseling	14.0	14.1	403	323	5194	3543	4368
30% basal + 30% @ 25 DAS + GS at tasseling	13.4	13.7	416	331	5502	3610	4556
35% basal + 35% @ 25 DAS + GS at tasseling	13.9	13.2	403	339	5449	3696	4573
N rich strip	14.2	16.3	443	329	5625	4470	5048
SEm±	0.27	1.09	9.49	6.62	185.1	209.1	197.1
CD(P=0.05)	0.78	3.19	27.84	19.41	542.9	613.3	578.1

RESULT AND DISCUSSION

Performance of maize

Yield attributing parameters and yield of maize was affected significantly by different nutrient management. Yield attributes such as no. of row/cob, cob length and grains/cob were found highest under N rich strip followed by STCR based N management and recommended dose of fertilizer (RDF) treatment (Table 2). Under nutrient expert based treatment yield of maize was reduced by 8% as compared to RDF. Among the different green seeker based treatments, N management using green seeker at tasseling stage was found better as compared to knee high stage. So it is indicating that green seeker can be used for N management in maize at tasseling stage. On an average basis, highest grain yield of maize was recorded under N rich strip followed by RDF. Among different sensor based N management treatments, application of 35% N as basal + 35 at 25 DAS + green seeker based N management at tasseling stage recorded highest yield and on par with 30% basal + 30% at 25 DAS and Green seeker based at tasseling stage as well as RDF treatment. Green seeker based N management in maize also saved about 21.3% N (22 kg/ha) as compared to RDF. This indicates that green seeker can be used for better resources utilization and conservation without compromising the productivity of maize. The increase in the yield in these treatments was mainly due to application of precise quantity of N fertilizer as per the crop demand. These results are in accordance with those obtained by Sujatha et al. (2021), Shyam et al. (2021) and Kadam et al. (2022). The need-based variable-rate fertilizer-nutrient application approach has a great potential in increasing crop growth, yield attributes and ultimately higher seed yield and also revamped fertilizer/nutrient use efficiency by overcoming the problem of over- and under fertilization (Schirrmann and Domsch, 2011).

Table 2: Growth, yield parameters and productivity of wheat affected by different managements (Mean of 2 years).

Treatment	Plant height (cm)	No. of tillers /m.r.l.	Spike length (cm)	No. of grains/ spike	1000-grain weight (g)	Wheat yield (kg /ha)		
						2017-18	2018-19	Mean
Control	71.4	64	6.1	28.1	39.7	2628	1546	2087
RDF	98.4	103	9.1	54.0	44.9	6333	6328	6331
STCR	99.4	98	8.7	47.3	43.1	6384	6468	6426
Nutrient expert	99.4	102	8.6	48.8	44.1	6025	6132	6079
33% Basal + GS at CRI & Max. tillering	99.6	99	8.3	44.9	44.2	6033	5977	6005
60% basal + GS at CRI	97.2	92	8.3	46.1	43.7	4838	5389	5114
70% basal + GS at CRI	97.6	96	8.7	52.2	45.9	4647	5898	5273
60% basal + GS at Max. tillering	98.9	99	9.0	53.4	43.9	5894	5614	5754
70% basal + GS at Max. tillering	99.3	101	9.0	52.9	43.2	6063	5617	5840
30% basal + 30% @ 25 DAS + GS at Max. tillering	98.8	102	9.1	53.8	44.6	5816	5610	5713
35% basal + 35% @ 25 DAS + GS at Max. tillering	99.5	102	9.2	54.1	44.7	5998	6078	6038
N rich strip	105.1	112	9.8	59.4	45.1	6733	6825	6779
SEm±	1.02	2.73	0.33	2.39	1.40	249.5	230.5	240.0
CD (P=0.05)	3.00	8.02	0.96	7.00	4.11	731.9	675.9	703.9

*m.r.l: meter row legth

Performance of wheat

Growth and yield parameters of wheat were significantly affected by different management. Plant height and number of tillers were recorded highest under N rich strip followed by STCR and recommended dose of fertilizer (150 kg N/ha) (Table 3). Among the different green seeker based N management, application of N at maximum tillering stage using green seeker reading was found superior with respect to growth, yield parameters and yield as compared N application at CRI stage. Application of 35% N as Basal + 35% at CRI + Green seeker based N application at maximum tillering stage was found superior as compared to other green seeker based N management treatments.

Poor response of GS based N management at CRI stage of wheat might be due to poor ground cover by the crop at early stages. N management using green seeker at maximum tillering stage also saved 15.3% N as compared recommended dose of fertilizer without significant reduction in wheat yield. The blanket recommendations based on the fixed-time application of fertilizer N doses at specified growth stages do not consider the dynamic soil nutrient supply and crop nutrient requirements and lead to the untimely and inefficient application of fertilizer nutrients (Biradar *et al.,* 2012). Therefore, need-based fertilizer management in crop can help in improving productivity, recovery efficiency and reducing losses of nutrients (Manjunath *et al.,* 2021). Improvement in crop productivity with nutrient expert and Greed seeker based N management in spring wheat was also reported by Hasanain et al. (2021).

Table 3: System productivity, partial factor productivity and agronomic efficiency of maize-wheat system influenced by different treatments.

Treatment	System MEY (t/ha)	Total N applied (kg/ha)	Partial factor productivity (kg grain/kg N)	Agronomic efficiency (kg grain increased/kg N applied)
Control	4.50	0	-	-
RDF	11.50	300	38.3	23.3
STCR	11.68	332	35.2	21.6
Nutrient expert	10.85	243	44.7	26.1
33% Basal + GS at CRI & Max. tillering	10.71	274	39.1	22.6
60% basal + GS at CRI	9.74	227	42.9	23.1
70% basal + GS at CRI	9.78	226	43.3	23.3
60% basal + GS at Max. tillering	10.44	216	48.3	27.5
70% basal + GS at Max. tillering	10.69	251	42.6	24.6
30% basal + 30% @ 25 DAS + GS at Max. tillering	10.74	234	45.9	26.6
35% basal + 35% @ 25 DAS + GS at Max. tillering	11.11	260	42.7	25.4
N rich strip	12.39	600	20.6	13.1
SEm±	0.20		0.81	1.35
CD (P=0.05)	0.59		2.40	3.97

*MEY: Maize Equivalent Yield

System productivity and nutrient use efficiency

System productivity in terms of maize equivalent yield (MEY) was significantly affected by different N management treatments (Table 4). Highest MEY was recorded under N rich strip followed by STCR and RDF treatments. Significant yield reduction (5.7%) was recorded under nutrient expert based N management as compared to RDF. Among different GS based N management, system productivity was reduced by 4.4-15.3%. Among GS based treatment, highest system productivity was recorded under 35% basal + 35% @ 25 DAS + GS at tasselling/maximum tillering treatment followed by 30% basal + 30% @ 25 DAS + GS at tasselling/maximum tillering with saving of 13.3% N fertilizer. Green seeker based N management at later stages (tasselling in maize and maximum tillering stage in wheat) performed better as compared to application at early stages (knee high and CRI stage). System productivity was 7.18-9.30% higher under GS based N management at tasselling and maximum tillering stage as compared to knee high and CRI stage. It indicates that GS based N management at later stages is an effective approach for higher productivity and resource saving. Partial factor productivity (PFP) (48.3 kg grain/kg N applied) and agronomic efficiency (27.5 kg grain increased/kg N applied) of the system was registered higher under GS based N management treatment and recorded highest in 60% basal + GS at tasseling/maximum tillering stage followed by 30% basal + 30% @ 25 DAS + GS at tasseling/maximum tillering stage treatment. Application of GS based N management in maize at later stages was also reported by Shyam et al. (2021) and Kadam et al. (2022).

CONCLUSION

The study concludes that Green Seeker-based nitrogen management can effectively optimize nitrogen use in maize and wheat, leading to better resource utilization and higher productivity. Application of Green Seeker based nitrogen management at tasseling stage in maize and at maximum tillering stage in wheat is recommended for achieving the optimal productivity and resource use efficiency in this cropping system. This approach not only enhances crop growth and yield but also ensures environmental benefits by reducing unnecessary nitrogen application. Future research should focus on refining these techniques across different agro-climatic conditions to further validate and optimize precision nitrogen management strategies.

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RESPONSE OF RICE-BASED CROPPING SYSTEMS UNDER DIFFERENT NUTRIENT MANAGEMENT PRACTICES

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ABSTRACT

This experiment was conducted from 2013-14 to 2020-21 at Jabalpur which is situated at the centre of India and comes under Kymore Plateau and Satpura hills zone of Madhya Pradesh. It lies at about 23° 90' N latitude and 79° 90' E longitude with an altitude of 411.78 m above the mean sea level to study the "response of rice-based cropping systems under different nutrient management practices" with the following nutrient management practices: (6) 100% and 75% organic (1/3 N through each of FYM, Vermicompost and Neem cake), 100% inorganic and farmer packages (100% NPK through fertilizers) and integrated management 50-50 (50% NPK through fertilizers + 50% N through organic sources) and 75-25 Integrated management (75% NPK through organic + 25% N through fertilizers sources) and cropping systems (4) Basmati rice (Pusa Basmati)-Durum wheat (HD-4672)-green manuring, Basmati rice – chickpea-maize (fodder), Basmati rice – berseem (fodder and seed) and Basmati rice – vegetable pea – sorghum (fodder). As regards the total productivity as rice equivalent yield, the highest REYs (10173 kg/ha/year) was recorded where 100% organic (100% NPK through organic sources) was applied followed by 100% inorganic management (100% NPK through fertilizers) 9577 kg/ha/year. Under the different rice-based cropping systems Basmati rice (Pusa Basmati-1)- berseem (fodder and seed) gave the highest REY (10037 kg/ha/year) followed by rice-veg pea- sorghum (fodder) (9500 kg/ha/year). As regards interaction effect of different nutrient management practices and cropping systems, Basmati rice – vegetable pea – sorghum (fodder) under 100% organic (100% NPK through organic sources) fetched highest REY (11745 kg/ha/year). However, lowest REY (6540 kg/ha/year recorded from Basmati rice (Pusa Basmati)-Durum wheat (HD-4672)-green manuring under 75-25 Integrated management (75% NPK through organic + 25% N through fertilizers sources).

Key words: Rice-based cropping systems, farmer packages, FYM, vermicompost and neem cake.

Rice is a pre-dominant crop, about 20% of global total human food calories are supplied by rice. More than 150 million ha were sown with 90% of that in Asia. Demand for rice in Asia is projected to increase by 70% over the next 30 years. At ~45 million ha, India has the largest national area of rice cropping. Much of this rice area is multi-cropped and cropping patterns. rice-based cropping system can be described as mix of farming practices that comprises of rice as the major crop followed by subsequent cultivation of other crops which include the rotation of crops involving cereals, pulses, oilseeds, green manures, vegetable etc. To fulfill a negative balance of fertilizers, there is an urgent need to identify suitable integrated plant nutrient systems for different crops and cropping systems. Rice–wheat cropping system is an important cropping system of Madhya Pradesh. In rice–wheat cropping systems, green manuring has proved a feasible and reliable practice to improve the productivity and soil fertility as well. In simple terms, Integrated Nutrient Management system refers to a balanced use of chemical fertilizers in combination with organic manures, crop residues, bio-fertilizers and other biological sources. Hence, for restoration of productivity, there is an urgent need to look forward to an alternate of chemical fertilizers. On the other hand, organic farming is a good option for maintaining soil health (Ramesh et al. 2009). Organic sources such as FYM, Vermicompost, Neem oil cake conjunction with green manure crops were found to substitute of nitrogen requirement in rice wheat cropping system. Ganajaxi and Math (2008). The cropping systems with the inclusion of legume fodder may result in high crop productivity and returns per unit area. The present experiment was therefore conducted with the object to study the effect of organic nutrient management practices on the productivity and economics of rice-based cropping systems in Kymore Plateau and Satpura hill zone of Madhya Pradesh. To fulfill the gap of above fact entitled study "response of rice-based cropping systems under different nutrient management practices" with objective to evaluate the balanced nutrient management practices and rice-based cropping systems productivity was conducted.

MATERIAL AND METHODS

Jabalpur is situated in the central part of the Madhya Pradesh and country as well. It lies between 22°49' N to 24°08' N latitude and 78° 21' E to 80° 58' E longitude at an altitude of 411.78 m above the mean sea level. It comprise of subtropical and semi-arid climate. Jabalpur region is characterized by three cropping seasons as K*harif* (semi-humid rainy) season from mid-June to October; *Rabi* (dry cool winter) season from November to February and *Zaid (* dry hot summer) season from March to mid-June. Agro-climatically the district is grouped under Kymore Plateau and Satpura hills zone of Central region.

The soils of Jabalpur region are broadly classified as 'Vertisols' which pose serious problems of poor workability under both wet and dry conditions. The water holding capacity of these soils is quite high and drainage is poor. In general, soils are neutral in reaction with low organic matter content and analyzing low in available N, low to medium available P and medium to high in available K contents. The deficiency of S and Zn is also observed in the pockets under intensive cropping system.

The fertilizer consumption is about 68 kg/ha in the district, which is mostly applied in irrigated production systems. Cultivation of vegetable pea and okra as vegetable crops, sugarcane and potato as commercial crops and berseem and sorghum as forage crops are also popular under irrigated condition. Use of agro-chemicals such as insecticides, fungicides and herbicides are not much common. Though insecticides are used in soybean, chickpea and rice crops to some extent, other agro-chemicals viz. herbicides and fungicides etc. are rarely used. Thus, organic farming may be an alternate option for sustainable cropping in the region

A strip plot design experiment was conducted to study the effect of management practices and cropping systems. Gross size of plot was 9.0 m x 7.2 m and net plot size was 8.0 m x 6.0 m. Six management practices were evaluated:- MP_1- 100% organic (100% organic and 75% organic), MP_2- 100% inorganic (100% inorganic and farmer package), MP_3- Integrated nutrient management (50% organic + 50% inorganic) & (75% organic + 25% inorganic) with four cropping systems:- CS_1- Green manure-basmati rice-durum wheat, CS_2- Basmati rice-chickpea-maize (fodder), CS_3- Basmati rice-berseem (fodder & seed) and CS_4- Basmati rice- vegetable pea-sorghum (fodder). The recommended fertilizer doses for rice (Pusa Basmati) and wheat (JW-1215) were 120 kg of Nitrogen (N), 60 kg of Phosphorus (P_2O_5), and 40 kg of Potassium (K_2O) per hectare. For chickpea (JG-14), berseem (JB-1), and vegetable pea (Arkel), the recommended doses were 20 kg of Nitrogen, 60 kg of Phosphorus, and 20 kg of Potassium per hectare. Maize (African Tall) and sorghum (MP Chari) were applied @ 100 kg of Nitrogen, 50 kg of phosphorus, and 30 kg of potassium per hectare. The seed rate varies for different crops in the state. For rice, wheat, chickpea, berseem, vegetable pea, maize and sorghum, the recommended seed rate were 20 kg, 100 kg, 80 kg and 25 kg, 50kg and 30 kg per hectare respectively.

Rice equivalent yield (REY) was calculated to compare system performance by converting the yield of non-rice crops into equivalent rice yield on a price basis, using the formula:

REY = Yx (Px/Pr),

Where, Yx is the yield of non-rice crops (kg ha^{-1}), Px is the price of non-rice crops and Pr is the price of rice crop.

RESULTS AND DISCUSSION

The economic yield (grain/ vegetable/ fodder) of kharif rice as well as different Rabi/ Summer crops were found to be considerably lower under organic nutrient management when compared to that under inorganic and INM. The reduction in productivity was well compensated with 25% higher price of organic produce. Accordingly, the mean rice equivalent yield with organic nutrient management (10173 kg/ha) was higher than inorganic nutrient management (9577 kg/ha) as well as integrated nutrient management (8498 kg/ha)

Table 1: Rice equivalent yield (kg/ha) of different cropping systems under nutrient managements practices during 2013-14 to 2020-21.

S. No.	Cropping System's	Nutrient management						
		Organic		Inorganic		INM		Mean
		100 %	75 %	100 %	F P	50 + 50	75 + 25	
1.	Green manure-Basmati rice – durum wheat	8841	8267	8447	4780	7349	6540	7371
2.	Basmati rice – chickpea-maize (fodder)	9158	8190	8864	5873	8034	7627	7958
3.	Basmati rice – berseem (fodder and seed)	10946	10735	11034	7994	9666	9846	10037
4.	Basmati rice – vegetable pea – sorghum (fodder)	11745	10718	9962	6958	8942	8675	9500
	Mean		10173	9478	9577	6401	8498	8172

Where - CS_1 : Basmati rice – durum wheat-green manure, CS_2 : Basmati rice – chickpea-Maize (fodder), CS_3 : Basmati rice – berseem (fodder and seed), and CS_4 : Basmati rice – vegetable pea – sorghum (fodder)

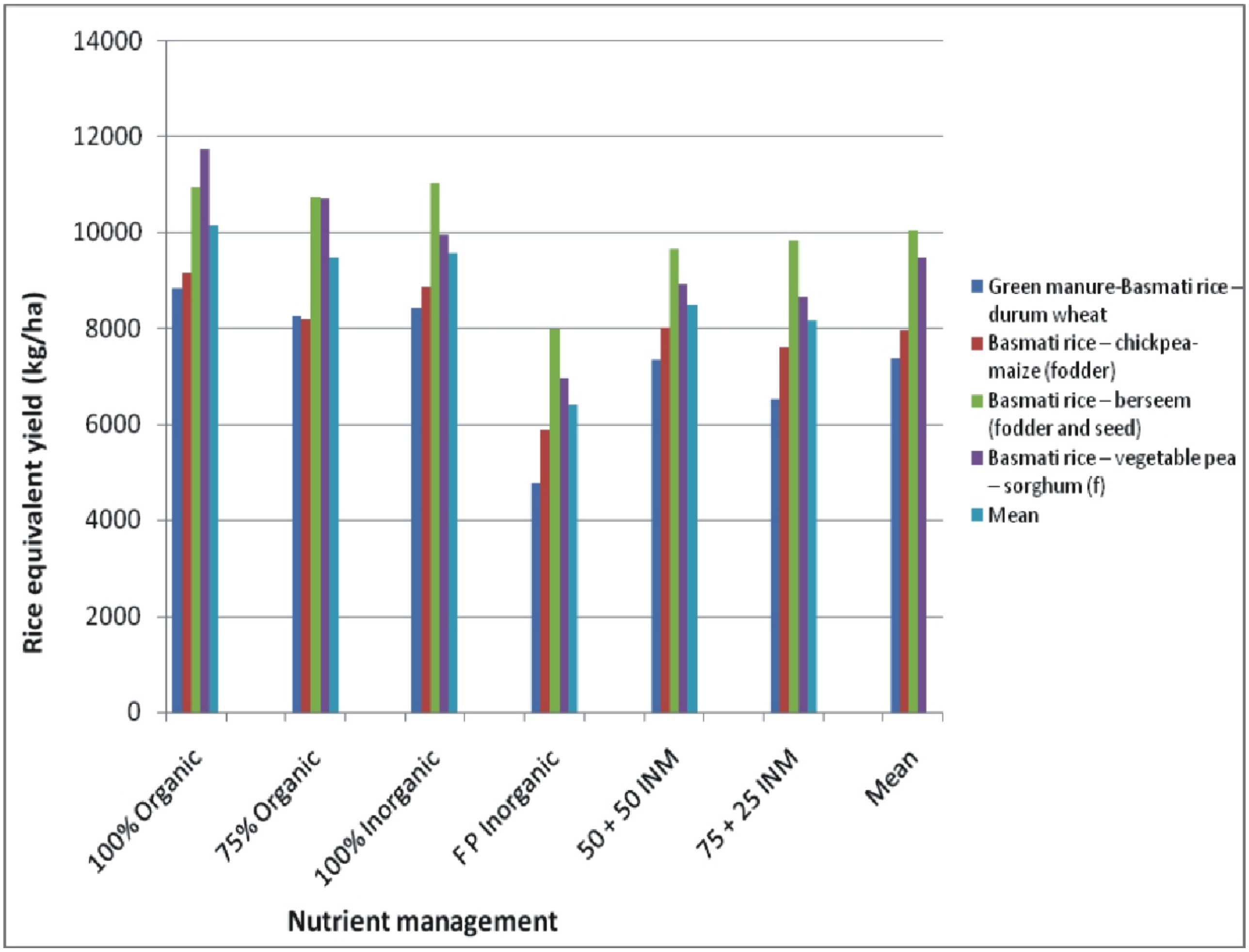

Fig: 1 Rice equivalent yield (kg/ha) of rice-based cropping systems under nutrient managements

Nutrient management practices (6) 100 % and 75% organic (1/3 N through each of FYM, Vermicompost and Neem cake), 100% inorganic and farmer packages (100% NPK through fertilizers) and Integrated management 50-50 (50% NPK through fertilizers + 50% N through organic sources) and 75-25 Integrated management (75% NPK through organic + 25% N through fertilizers sources). The higher yields of rice under organic nutrient management reflected due to organic sources provide nutrient in regular and static manner to crop which promote the growth and establishment of rice seedlings and have positive correlation with the plant growth and biomass production (Shekaran *et al.* 2010 Pardhan and Moharana 2017)

CONCLUSION

The total productivity evaluated as rice equivalent yield, the highest REYs (kg/ha/year) was recorded where under 100% organic (100% NPK through organic sources) nutrient was applied followed by 100% inorganic management (100% NPK through fertilizers). Under the different rice-based cropping systems. Basmati rice (Pusa Basmati -1)- berseem (fodder and seed) gave the highest REY followed by rice-veg pea-sorghum (fodder). The interaction effect of different nutrient management practices and cropping systems, Basmati rice – vegetable pea – sorghum (fodder) under100% organic (100% NPK through organic sources) fetched highest REY.

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EXECUTION OF GUAVA BASED VALUE ADDITION MODULE THROUGH SHG FORMULATION: A DIVERSE INCOME GENERATION AVENUE FOR RURAL WOMEN

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ABSTRACT

In India, the declining trend in size of landholding possesses a serious challenge to the profitability and sustainability of farming. Lack of land for farming is perhaps the severest constraint faced by the rural poor, and one that affects more women than men. Social and economic empowerment through entrepreneurial skill of women will not only generate income for them but also improve the decision-making capabilities that led to overall empowerment. Therefore, the present study aimed to explore the value addition as a diverse income generation avenue through self-help group (SHG) formulation. Assistance to rural women by organising women training programmes to secure income through their own efforts can be categorized as `income-generating activities' and cover initiatives as diverse as small business promotion through processing and value addition by SHG formulation. Women Self Help group (*Devanjali Mahila Samuh*) has been formulated in *Sathedi* village of Western plain Zone of Uttar Pradesh for the skill enhancement in secondary agriculture activities as a diversified income generating avenue. Different trainings on value addition and processing of various products have been delivered to the women's group. The group has gained expertise in the development of different products through blended squash (guava+orange) and (guava + pineapple + pomegranate) mixed jam (guava + apple + gooseberry + orange + persimon) and (guava + pinapple + pomegranate + apple) etc. The mixed jam were packed into glass bottles and blended squash were packed into PET bottles. All the products were then labeled with the combined tag of ICAR-IIFSR and *Devanjali Mahila Samuh.* Alongwith the skill enhancement the group has also gained experience on labeling, branding, marketing and maintaining of sale records by selling the developed products through exhibitions and door to door marketing techniques. Group has recorded ~123,400 Rs additional net returns per annum with value addition module in comparison to the earlier income.

Key words: Value addition, SHG, rural women, diversified income

Agriculture and allied activities support livelihoods of nearly 70 per cent of India's rural population (Hiremath 2007). Small-holders are under continuous pressure to increase production from their limited land resource. Thus, the sub-marginal- and marginal-size farms cannot remain "subsistence-oriented". As a result, rural households are forced to look at alternative means for supplementing their livelihoods. In this context, value addition and processing through micro-enterprises have emerged as alternative livelihood opportunities in rural areas. Varying socio-economic and environmental trends including declining crop prices, swelling labour forces, migration and urbanization increased the demand for alternative employment and off-farm livelihood opportunities. Policies and strategies - existing and new, must help diversify on-farm and *off-farm activities* and thereby enhance sustainability and productivity. The income from off-farm employment assists the small-farm households to become or remain hunger-free. Through effectively-managed "monetization", small-farm households could benefit from globalization and avoid poverty. Sen (1999) demonstrated that during years when non-agricultural rural employment increases, rural poverty declines, and that the converse also holds. Thus, on-farm, off-farm, and on-off-farm rural employment is essential to combat rural poverty and to secure adequate livelihood within the households of small-holders and landless agricultural labourers. Such employment would lessen the urban migration of the rural poor, and thereby help prevent the urbanization of poverty. The rural off-farm economy through value addition and processing plays a significant role in providing employment and income for the poor in rural areas. As population pressure grows in the land-scarce developing countries like India, the growth in agricultural production cannot absorb the increasing rural labour force in agricultural employment.

Guava (*Psidium guajava L.*) is an important subtropical fruit grown widely in tropical and subtropical regions of India. In the year 2017-18, the area under guava cultivation was in 261 thousand Ha of area, 3916 thousand MT production with productivity of 13.9 MT/Ha. (Horticultural Statistics at a Glance 2017, Ministry of Agriculture and Farmers Welfare). In India, Uttar Pradesh had stood 1st in regard to the area under guava production amongst guava producing states (Indian Horticulture Database 2014). In Meerut, guava ranks second in cultivation after mango and occupies an area of 1423 ha with a production of 4205 MT (Pal *et al* 2016) Guava is popular among the people of all social strata due to it's less price, nutrient value and good flavour. Guava is a highly palatable fruit valued as a potential source of pectin, ascorbic acid (vitamin C), sugars and minerals (Hassimotto *et al*. 2005). It is with a rich source of vitamin C containing (299 mg/100 g) (Pal *et al*., 2004).

Guava fruit has a characteristic flavour, to which its acidity (pH 4.0 to 5.2) contributes (Jagtiani *et al*. 1988). Guava is popular to consumers because of its aroma. More than 500 volatile compounds have already been found in the guava. Volatile compounds change in guava fruits at different stages of maturity during ripening.

Most of the guava produced around the world is consumed fresh. The level of total sugar and its major components, glucose and sucrose, increase during growth and development of intact guava fruits. However, harvested guava has short shelf life of one week because of high moisture content (Bal *et al* 2014) that leads to perishable during storage periods. It is a climacteric fruit exhibiting respiratory and ethylene peaks during ripening (Akamine and Goo, 1979; Brown and Wills, 1983), It exhibits a high respiration rate and fast ripening with intense metabolic activity after harvest. Amongst all the fruits growing in India guava possess highest rank in harvest and post-harvest loss (15-18 per cent), Nanda *et al* (2012), Jha *et al* (2015). Therefore, it is urgent to find a feasible solution to reduce decay incidence and improve fruit quality of guava after harvest. Also, to have the combination of several fruits while preparing finished products, since it will comprise maximum possible essences with a rich and natural colour which otherwise may fall deficient because of the use of single fruit products. Tripathi *et al.* (1992) reported that two or more fruit juices or pulps may be blended in various proportions for the preparation of more palatable and nutritious nectar beverages, etc. Therefore, the present study aimed to explore the locally available guava based value addition module as a diverse income generation avenue through self-help group (SHG) formulation.

MATERIALS AND METHODS

Guava based blended products were developed in the participatory manner with the women's group. Rural women were assisted by organising women training programmes to secure income through their own efforts can be categorized as `income-generating activities' and cover initiatives as diverse as small business promotion through processing and value addition of locally available produce by SHG formulation.

Women Self Help group (*Devanjali Mahila Samuh*) has been formulated in Sathedi village under Farmer FIRST programme by the institute for the skill enhancement in secondary agriculture activities as a diversified income generating avenue. Different trainings on value addition and processing of various products have been delivered to the women's group. The group has gained expertise in the development different products *viz.* blended squash (guava+orange) and (guava + pineapple + pomegranate) mixed jam (guava+apple+ aonla+orange+persimmon) and (guava+ pineapple+pomegranate+apple). Blended squash are rich in vitamins and antioxidants alongwith the natural colour, essence hence, very important from several views.

Product: Blended squash (guava+orange)

For preparation of blended squash fully matured guavas were taken, and washed with clean water. The fruits were sliced and dipped for 4-5 hours into drinking water in 1:1 ratio. Afterwards sliced guavas along with water was heated and removed the pan before reaching the boiling point so that the pectin content of the guavas could be extracted in water. Afterwards the sliced guavas were crushed into mixer grinder, strained and then juice extracted from oranges were blended together. (The water containing pectin content was kept aside for further use for the preparation of jam). The sugar syrup has been prepared (60%) and mixed with 40 % of blended mixture (guava + orange extract) Citric acid was mixed into the squash (0.4 per cent). Potassium metabisulphite was added as per (FPO, 1954). Blended squash was then packed into PET bottles. The flowchart of blended squash is given below

Fully matured guavas

Slicing and dipping for 4-5 hours into drinking water in 1:1 ratio

Heating before boiling

Crushing and straining to get uniform pulp

Extract the orange juice and blend together (40%)

Addition of Sugar syrup (60 %)

Add citric acid (0.4 %)

Add KMS (FPO, 1954)

Pack into PET bottles

Product: Mixed jam (guava+apple+ gooseberry+orange+persimmon)

For the preparation of mixed jam apple, persimmon, gooseberry was washed, peeled, sliced and made into pulp by using mixer grinder. Oranges were peeled and extracted into juice. All the material was then mixed into the water exhibiting guava pectin. Sugar was taken equal to the weight of the pulp. Around 2/3rd sugar was mixed into the pulp initially while the pulp was kept for heating. Rest of the sugar was mixed after the start of boiling. Before reaching the end point Carboxymethyl Cellulose (0.4 percent along with 1.2 per cent sugar was powdered into fine particles and sprinkled into mixture). Citric acid was mixed into the mixture (0.4 per cent). The end point of the jam was checked using sheet test. The prepared jam was then removed from the flame. Potassium metabisulphite was added as per (FPO, 1954). The mixed jam was then filled into glass bottles. The flowchart of mixed jam is given below:

Wash, peel and slice apple, gooseberry, and persimmon

Peel the oranges, extract into juice

All the material is mixed into water consists of guava pectin

Around 2/3rd of sugar mixed into pulp initially while kept for heating, rest after the start of boiling

Sprinkle CMC (0.4 %) + 1.2 %sugar (powdered) before reaching the end point

Add citric acid (0.4 %)

Check the end point and remove from flame

Add KMS (FPO, 1954)

Fill into glass bottles after cooling

Product: Blended squash (guava + pineapple + pomegranate)

For preparation of blended squash fully matured guavas were taken, and washed with clean water. The fruits were sliced and dipped for 4-5 hours into drinking water in 1:1 ratio. Afterwards sliced guavas along with water was heated and removed the pan before reaching the boiling point so that the pectin content of the guavas could be extracted in water. Then the sliced guavas were crushed into mixer grinder, strained and then mixed into crushed and strained pomegranate and pineapple juice. (The water containing pectin content was kept aside for further use for the preparation of jam). The sugar syrup has been prepared (60%) and mixed with 40 % of blended mixture (guava + pomegranate + pineapple extract) Citric acid was mixed into the squash (0.4 per cent). Potassium metabisulphite was added as per (FPO, 1954). Blended squash was then packed into PET bottles. The flowchart of blended squash is given below:

Fully matured guavas

Slicing and dipping for 4-5 hours into drinking water in 1:1 ratio

Heating before boiling

Crushing and straining to get uniform pulp

Extract the pineapple and pomegranate juice and blend together (40%)

Addition of Sugar syrup (60 %)

Add citric acid (0.4 %)

Add KMS (FPO, 1954)

Pack into PET bottles

Product: Mixed jam (guava + pineapple+pomegranate+apple)

For the preparation of mixed jam apple,and pineapple were washed, peeled, sliced and made into pulp by using mixer grinder. Pomegranates was peeled and the fruit was crushed, strained and extracted into juice. All the material were then mixed into the water consists of guava pectin. Sugar was taken equal to the weight of the pulp. Around 2/3rd sugar was mixed into the pulp initially while the pulp was kept for heating. Rest of the sugar was mixed after the start of boiling.

Before reaching the end point Carboxymethyl Cellulose (0.1 percent alongwith 1.2 per cent sugar was powdered into fine particles and sprinkled into mixture). Citric acid was mixed into the mixture (0.4 per cent). The end point of the jam was checked using sheet test. The prepared jam was then removed from the flame. Potassium metabisulphite was added as per (FPO, 1954). The mixed jam was filled into glass bottles. The flowchart of blended squash is given below:

Wash, peel and slice apple and pineapple

Peel the pomegranates, crushed and strained into juice

All the material is mixed into water consists of guava pectin

Around 2/3rd of sugar mixed into pulp initially while kept for heating, rest after the start of boiling

Sprinkle CMC (0.4%) + 1.2% sugar (powdered) before reaching the end point

Add citric acid (0.4%)

Check the end point and remove from flame

Add KMS (FPO, 1954)

Fill into glass bottles after cooling

RESULTS AND DISCUSSION

Nutritional properties of the developed products

Blended squash (guava+orange)

TSS of blended squash was 48^{o}brix. Guava + orange blended squash is very good source of ascorbic acid, B carotenes and B vitamins *viz.* thiamine, riboflavin and niacin. The blended squash is rich in minerals *viz.* iron, potassium and magnesium and phosphorus. Guava possesses primary antioxidant potential. Therefore, the blended squash may act as protective or preventive roles against the diseases arising from oxidative stress. It can be kept for 30 days in refirigerated condition. Therefore, the blended squash may act as protective or preventive roles against the diseases arising from oxidative stress.

Mixed jam (guava+apple+ gooseberry +orange+persimmon)

TSS of guava+apple+ gooseberry+orange+ persimmon mixed jam was 65^{o}brix. Mixed jam is very good source of ascorbic acid, B carotenes and B vitamins *viz.* thiamine, riboflavin and niacin and choline. Also, the squash is rich in minerals *viz.* iron, calcium, potassium and magnesium and phosphorus. Mixed jam has rich phytochemical properties along with excellent antioxidant potential. The functional ingredients like proanthocyanidin in persimmon may helps against hyperlipidemia and hyperglycemia (Butt *et al* 2015). Therefore, the blended squash may act as protective or preventive roles against the diseases arising from oxidative stress. Mixed can be kept for 180 days refirigerated conditions.

Blended squash (guava + pineapple + pomegranate)

TSS of blended squash was 42^{o}brix. Guava + pineapple + pomegranate blended squash is a rich source of minerals (calcium, sodium, potassium, magnesium and iron), vitamins (B carotene and ascorbic acid) including high phenolic and flavonoid content with extremely high antioxidant potential. It can be kept for 30 days in refirigerated conditions.

Table 1: Economics of guava based blended products

Particulars	Amount (Rs)
Blended squash (guava+orange)	
Variable cost (raw material+ packaging material+ fuel+ labour)	19200
Fixed Cost (Depreciation of equipments)	860
Total cost of production (320 liter/annum)	20060
Gross Income	44880
Net Income	24740
Benefit: Cost ratio	2.33
Mixed jam (guava+apple+ gooseberry+orange+persimmon)	
Variable cost (raw material+ packaging material+ fuel+ labour)	54,000
Fixed Cost (Depreciation of equipment's)	1250
Total cost of production (360 kg/annum)	55250
Gross Income	93600
Net Income	38350
Benefit: Cost ratio	1.73
Blended squash (guava + pineapple + pomegranate)	
Variable cost (raw material+ packaging material+ fuel+ labour)	24000
Fixed Cost (Depreciation of equipment's)	950
Total cost of production (300 liter/annum)	24950
Gross Income	48000
Net Income	23050
Benefit: Cost ratio	2.0
Mixed jam (guava+pineapple+ pomegranate+apple)	
Variable cost (raw material+packaging material+ fuel+ labour)	56000
Fixed Cost (Depreciation of equipments)	1250
Total cost of production (350 liter/annum)	57250
Gross Income	94500
Net Income	37250
Benefit: Cost ratio	1.68

Mixed jam (guava + pineapple + pomegranate + apple)

TSS of mixed jam was 67° brix. Guava + pineapple + pomegranate + apple blended squash is a rich source of minerals (calcium, sodium, potassium, magnesium, iron and phosphorus), vitamins (B carotene and ascorbic acid and choline) including high polyphenols and flavonoid content with extremely high antioxidant potential kept for 180 days in refirigerated conditions.

The SHG women's were trained in processing packaging and labeling of guava based blended products. Necessary technical support and market linking was provided by the team. The mixed jam was packed into glass bottles and blended squash were packed into PET bottles. All the products were then labeled with the combined tag of ICAR-IIFSR and *Devanjali Mahilaa Samuh*. The group has also gained experience on marketing and maintaining of sale records by selling the developed products amongst the staff of ICAR-IIFSR through stall organized by ICAR-IIFSR. The profit margin on the sold products was shared amongst the women group. Blended squash is being marketed at Rs. 60-80 per litre, whereas blended jam is being marketed at Rs. 260-280 Rg/kg. At this price, on an average, the net income generated by the SHG is substantial as shown in Table 1. The calculation of cost of production and income was made on actual production of blended products per annum. This model was found scalable provided market demand for nutraceuticle products is expanded with consistency in quality, timely delivery and suitable market promotion.

CONCLUSION

The study emphasizes on the role played by SHGs in promoting socio-economic empowerment of women in India through a more effective use of local biodiversity and its products. Such types of interventions can play in rural and peri-urban situations where women are too often marginalized in income generation activities and decision making processes. Processing and nutritional value additions through SHG's under brand name will be directly helpful in enhancing food security, nutrition and income of women farmers and indirectly improving nutritional intake of consumers. Apart from that, this model helps in reduction of post-harvest losses of perishable fruits like guava. As a result of capacity building interventions to enhance local skills in value addition, women's group were able to generate substantial income and use this towards their quality life.

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ENHANCING FODDER PRODUCTIVITY AND PROFITABILITY OF SORGHUM AND COWPEA THROUGH INTERCROPPING

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ABSTRACT

A field experiment was conducted at agriculture farm, ICAR-Central Institute for Research on Goats, Makhdoom, Mathura, Uttar Pradesh during *kharif* season of 2020. The treatments consist of sole sorghum, sole cowpea; and intercropping of sorghum + cowpea in 1:1, 2:1, 1:2, 2:2, 3:1, 1:3 and 3:3 row ratios. The experiment was laid out in randomize block design with three replications. The results revealed that maximum total green (44.4 t ha^{-1}) and dry (7.5 t ha^{-1}) fodder yield, net returns (Rs. 29812 ha^{-1}) and Benefit: Cost ratio (1.98) was recorded with 2:1 row ratio of sorghum + cowpea intercropping combination followed by 3:1 row ratio. It was found that two rows sorghum + one row of cowpea (2:1) intercropping combination perform best in terms of yield and profitability of fodder sorghum and cowpea.

Keywords: B:C ratio, Cowpea, Fodder Productivity, Net returns, Sorghum

Green fodder plays a crucial role in the optimal growth and development of animals. However, India currently faces a net deficit of 35.6% in green fodder (IGFRI Vision 2050). To bridge this gap and enhance animal productivity, it is essential to either increase the area under forage production or boost fodder productivity per unit area per unit time. The competition with other agricultural crops and the prioritization of food crops, expanding the area for forage production is not possible. Therefore, the focus must be on increasing fodder yield per unit area per unit time. An intercropping system, which intensifies cropping in both time and space, can be a valuable tool for producing adequate green fodder (Reddy 2012). Cereal-legume intercropping is a promising approach to enhancing forage yield, reducing production risk, and providing greater financial stability (Tamta *et al.* 2019). The combination of cereals and legumes is considered ideal because cereals benefit from the symbiotic nitrogen fixation facilitated by the associated legumes, resulting in a balanced diet for livestock. The intercropping practices of cereals and legumes, particularly sorghum and cowpea, have not been extensively evaluated in the Yamuna ravines region of Uttar Pradesh. Identifying suitable intercropping combinations for this region can help farmers improve farm profitability and livestock productivity. Therefore, the present study aims to evaluate the appropriate intercropping combinations of sorghum and cowpea to enhance forage yield, land use efficiency, and net profitability in the Yamuna ravines region of Uttar Pradesh.

MATERIALS AND METHODS

The experiment was conducted at agriculture farm, ICAR-Central Institute for Research on Goats (CIRG), Makhdoom, Mathura, Uttar Pradesh, India during *kharif*, 2020 to study the effect of intercropping row ratios on yield, intercropping indices and economics of fodder sorghum + cowpea intercropping system. The soil of the experimental field was nearly neutral in reaction (pH 7.3) with EC of 0.27 dS/m. The soil was low in organic carbon (0.22 %) and available nitrogen (241 kg ha^{-1}); and medium in available phosphorus (44 kg ha^{-1}) and potassium (168 kg ha^{-1}). The treatments consist of sole sorghum, sole cowpea, sorghum + cowpea intercropping in 1:1, 2:1, 1:2, 2:2, 3:1, 1:3 and 3:3 row ratios. The experiment was laid out in randomize block design with three replications. The field was allocated into 27 plots and each plot was 3.6 m x 6 m in size. All treatments were allocated in these small plots without any biasness. Sorghum variety MP chari and cowpea variety Russian giant were sown as per the treatment on 20th July, 2020, by using the seed rate of 25 kg ha^{-1} in sole sorghum and sole cowpea treatment. Further, the crops were sown with row to row spacing of 30 cm in both sole as well as in intercropping combinations. All other agronomic practices were carried out as per standard recommendations. Harvesting for green fodder was taken from net plot then weighed and converted into t ha^{-1} to obtain green fodder yield.

To find out the most profitable treatments, economics of different treatments was worked out as follow in terms of net return (Rs. ha^{-1}) and B: C ratio. Net return = Gross return (Rs. ha^{-1}) – Cost of cultivation (Rs. ha^{-1}) and B: C ratio = Gross return (Rs. ha^{-1}) /Cost of cultivation (Rs. ha^{-1}). All the data were subjected to statistical analysis by adopting appropriate method of analysis of variance as described by Gomez and Gomez (1984). The results are presented at 5% level of significance.

RESULTS AND DISCUSSION

Intercropping combinations had significant effect on green and dry fodder yield of sorghum and cowpea (Table 1). The maximum value of total green fodder yield (Sorghum + Cowpea) was recorded with 2:1 row ratios of Sorghum + Cowpea intercropping (44.4 t ha^{-1}) followed by 3:1 row ratios of Sorghum + Cowpea intercropping (43.3 t ha^{-1}). The increase in total green fodder yield in 2:1 row ratio was 17.5 and 68.8 % over sole sorghum and sole cowpea, respectively. The increase in green fodder yield in the intercropping systems might be owing to better utilization of space and light interception coupled with nutrient contribution of leguminous fodder to cereal. Tamta *et al.* (2019) and Ramanakumar and Bhanumurthy (2001) also obtained highest green fodder yield of maize + cowpea intercropping in 2:1 row ratio. These results are also in agreement with the statement that inclusion of legume component in the cereal-legume association increased the green forage yield up to 35 to 45 per cent over monocrops due to reduced intercrop competition and better use of resources (Tripathi *et al.* 1997, Obuo *et al.* 1998, Pandita *et al.* 1998).

Table 1: Effects of different intercropping combinations on green and dry fodder yield of fodder sorghum and cowpea

Treatments	Green Fodder Yield (t ha^{-1})				Dry Fodder Yield (t ha^{-1})			
	Sorghum		Cowpea	Total	Sorghum		Cowpea	Total
	I Cut	II Cut			I Cut	II Cut		
Sole Sorghum	26.2	11.6		37.8	4.6	2.1	4.3	6.72
Sole Cowpea	-	-	26.3	26.3	-	-	1.7	4.35
Sorghum + Cowpea (1:1)	17.5	7.6	11.0	36.1	3.0	1.4	1.4	6.07
Sorghum + Cowpea (2:1)	25.0	10.9	8.5	44.4	4.2	1.9	2.7	7.50
Sorghum + Cowpea (1:2)	11.6	5.0	16.4	33.0	1.9	0.9	1.8	5.44
Sorghum + Cowpea (2:2)	16.6	7.4	11.3	35.3	2.8	1.3	1.0	5.78
Sorghum + Cowpea (3:1)	25.9	11.2	6.3	43.3	4.4	2.0	3.1	7.35
Sorghum + Cowpea (1:3)	9.3	4.1	19.0	32.4	1.5	0.7	1.7	5.29
Sorghum + Cowpea (3:3)	16.1	7.2	10.8	34.1	2.8	1.3	0.1	5.74
SEm	0.7	0.5	0.6	0.7	0.2	0.1	0.3	0.18
CD at 5%	2.1	1.5	1.8	2.2	0.5	0.3	8.6	0.53

The highest gross return (Rs. 60303 ha^{-1}), net return (Rs. 29812 ha^{-1}) and benefit: cost ratio (1.98) was obtained with 2:1 row ratio of sorghum + cowpea intercropping combination followed by 3:1 row ratio (Table 2). The 2:1 row ratio of sorghum + cowpea intercropping combination recorded 76.41 and 101.2 % higher net return over sole sorghum and sole cowpea, respectively. It is obvious because of higher total green fodder yield of sorghum + cowpea intercropping system with 2:1 row ratio as compared to other intercropping combinations which consequently resulted in higher net return and benefit: cost ratio. Tamta *et al.* (2019) also reported that 2:1 row ratio of maize + cowpea intercropping recorded highest net return and benefit cost ratio.

Table 2: Effects of different intercropping combinations on economics of sorghum + cowpea intercropping system

Treatments	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
Sole Sorghum	49183	16899	1.52
Sole Cowpea	42080	14817	1.54
Sorghum + Cowpea (1:1)	50283	20510	1.69
Sorghum + Cowpea (2:1)	60303	29812	1.98
Sorghum + Cowpea (1:2)	47830	18778	1.65
Sorghum + Cowpea (2:2)	49227	19454	1.65
Sorghum + Cowpea (3:1)	58213	27010	1.87
Sorghum + Cowpea (1:3)	47810	19117	1.67
Sorghum + Cowpea (3:3)	47517	17744	1.60
SEm	950	950	0.03
CD at 5%	2849	2849	0.09

CONCLUSION

Results of this study stated that intercropping of sorghum and cowpea significantly influenced by different row ratios. Maximum value of green and dry fodder yield, net returns and B: C ratio was obtained with intercropping of two rows sorghum + one row cowpea (2:1). Hence, this investigation recommended two row sorghum + one row cowpea (2:1) intercropping combination for obtaining maximum value of green and dry fodder yield and profitability of fodder sorghum and cowpea.

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CHEMICAL INDUCERS TRIGGERED BIOCHEMICAL CHANGES AND REDUCED SEVERITY OF BROWN SPOT DISEASE OF RICE CAUSED BY DRECHSLERA ORYZAE

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ABSTRACT

In the present investigation, an effort was made to induce resistance in paddy against the brown spot disease through pre-treatment with abiotic inducers viz. hydrogen peroxide, calcium chloride ($CaCl_2$), dipotassium hydrogen phosphate (K_2HPO_4) and salicylic acid. The results showed pre-treatment with hydrogen peroxide, calcium chloride, K_2HPO_4 etc reduced mean number of lesions per leaf as well as the percent disease index. In untreated (Check-II) plants, the mean number lesions were 14.5; however calcium chloride, K_2HPO_4, hydrogen peroxide reduced the number of lesions substantially to 3.02, 3.15 and 4.36 per leaf respectively. The percent disease index (PDI) in control plants (Check-II) was as high as 60.12% which declined remarkably by the inducing agents. The reduction of disease severity was highest by calcium chloride (67.15%) followed by K_2HPO_4 (64.47%). In order to investigate the biochemical changes associated with induction of resistance against rice brown spot, the influence of the chemical inducers on the soluble protein content, phenol content, sugar content, ascorbic acid content and mineral elements contents of the rice leaves were studied. The chemical inducers increased soluble protein, phenol, ascorbic acid and non-reducing sugar content of paddy leaves, however the reducing sugar contents were found to decline. The inducer treatments were found to influence the mineral contents viz. nitrogen (N), potassium (K), iron (Fe), manganese (Mn) and particularly K/N and Fe/Mn ratio of the paddy leaves. However, phosphorus (P), copper (Cu) and sulphur (S) contents didn't show any reasonable trend.

Keywords: *Drechslera oryzae*, brown spot disease, induced resistance, chemical elicitors

Brown spot caused by *Drechslera oryzae* is an important disease of rice. The disease has a world-wide distribution and it has been reported in all rice-growing countries in Asia, America and Africa. The disease is of great importance in several countries including USA, Japan, Italy, Philippines, India, Sri Lanka and Turkey (Rangaswami and Mahadevan 1999). In India, the disease is widely distributed throughout the country especially in West Bengal, Orissa, Andhra Pradesh, Assam, Uttar Pradesh, Punjab, Bihar, Tamil Nadu, Karnataka and Haryana (Gogoi 2002). The pathogen *Drechslera oryzae* can infect paddy in all stages of crop growth viz, seedling, tillering, panicle initiation and grain filling. However, the occurrence of the disease is more when the crop approaches maturity. There are three phases of damage caused by this disease: poor germination of infected seeds, leaf infection resulting in reduction of effective leaf surface and shriveling and poor setting of the seed. Normally the damage caused by the pathogen is not much serious, but under certain conditions enormous losses are caused when it can assume epiphytotic proportions.

Induced resistance refers to heightened resistance in a plant towards pathogens as a result of a previous treatment with a pathogen, an attenuated pathogen or a chemical that is not itself a pesticide. There is enhancement in resistance in response to an extrinsic stimulus without a known alteration of the genome. The protection is based on the stimulation of defense mechanisms by metabolic changes that enable the plants to defend themselves more efficiently (Hammerschmidt and Kuc 1995). Of late, induced resistance is increasingly gaining attention of researchers as an ecofriendly means of disease management. Kuc reported effectiveness of induced resistance in different plants against a broad spectrum of pathogens including fungi, bacteria and viruses (Kuc 1982). Ciba-Geigy AG of 2, 6-dichloraisonicotinic acid (CGA-41396) was reported to induce local and systemic resistance in cucumber against *Colletotrichum lagenarium* and some other pathogens (Metraux *et al.* 1990) and in tobacco against broad range of pathogens including a virus, few bacteria and fungi (Ahl Goy *et al.* 1990). Treatment with chitosans (0.1% solution) protected pea plants from infection by *Fusarium solani* f. sp. *pisi* (Kendra *et al.* 1989). Injection of salicylic acid into cucumber leaves or petioles was found to induce chitinase gene expression (Metraux *et al.* 1989). Reduction in anthracnose lesion size, total necrotic lesion area and penetration of *C. lagenarium* into salicylic acid treated cucumber cotyledons was also reported (Rasmussen *et al.* 1991). Ren *et al.* (2022) reported that â-aminobutyric acid (BABA)-induced resistance to tobacco black shank in tobacco (*Nicotiana tabacum* L.). In rice, induced resistance has been reported against blast, brown spot, sheath blight and bacterial blight. The inducing agents could be either biotic or abiotic. Resistance has been reported to be induced through preinoculations with non-pathogens, less virulent or avirulent races, biocontrol agents and pre-treatments of the plants with naturally occurring metabolites or chemically defined substances. Kouzai *et al.* (2018) recently demonstrated that Salicylic acid, but not BTH, confers resistance against *Rhizoctonia solani*, the causal agent of sheath blight disease, in *Brachypodium distachyon*. In the present investigation an effort was made to induce resistance in paddy against the brown spot disease through pretreatment with abiotic inducers viz. hydrogen peroxide, calcium chloride ($CaCl_2$), dipotassium hydrogen phosphate (K_2HPO_4) and salicylic acid.

MATERIALS AND METHODS

The present investigation based on laboratory and glasshouse experiments, was undertaken at the Department of Plant Pathology, C. S. Azad University of Agriculture and Technology, Kanpur, India.

Isolation of the Pathogen

Paddy leaves showing distinct young lesions were selected for isolation of *Drechslera oryzae,* the pathogen of brown spot disease of rice. The leaf samples were surface sterilized by 0.1% sodium hypochlorite. The pathogen was cultured in 2% PDA medium and maintained at 25°±1°C.

Rice Genotype

The variety Pant-12 is a popular variety of rice in eastern Uttar Pradesh. The farmers in the vicinity of Kanpur also grow this cultivar. The genotype has been proved susceptible to brown spot disease of paddy. Hence, the varietyPant-12 was selected and the seeds were obtained from "AICRP on Cropping Systems" centre located at C.S. Azad Univ. of Agric. & Tech., Kanpur, for conducting the experiment.

Selection of Chemical inducers

In order to induce resistance in paddy against brown spot disease, some abiotic agents were tried as inducers. The abiotic agents selected were Salicylic acid ($C_7H_6O_3$), Hydrogen peroxide (30% w/v H_2O_2), Calcium chloride ($CaCl_2$) and Dipotassium hydrogen phosphate (K_2HPO_4).

Pot experimentation

Seedlings of Pant-12 variety were raised in the glass house in earthen pot of 30 cm diameter. Each pot was filled with a mixture of garden soil and farm yard manure in the ratio of 4:1. In each pot, 10 seeds were sown with proper spacing and the pots were watered regularly. Paddy seedlings were inoculated with *Drechslera oryzae* at two-leaf stage. For inoculation, homogenous suspension of inoculum was prepared from seven days old culture in sterilized water. The suspension containing conidia and mycelial bits was churned in a warring blender and strained with cheese cloth. The culture inoculum of the isolate containing 10^5/ml conidia was sprayed on paddy leaves with the help of automizer. The inoculated pots were kept in humid chamber for 48 hours, after that they were taken out and kept on the glass house benches. Paddy seedlings sprayed with only water were also kept under identical conditions as check. Pots were regularly inspected for appearance of disease symptoms on paddy leaves. The abiotic agents viz. 1 mM Salicylic acid, 1% hydrogen peroxide, 15 ppm calcium chloride and 25 mM dipotassium hydrogen phosphate were applied as soil drenches. For soil drenches, pots with one week old seedlings were drenched with 250 ml solution per pot of the chemicals at the above-said concentrations. The control pots of Check-I (Healthy) and Check-II (Inoculated) were drenched with same quantity of distilled water. All the inducer treated and control plants of Check-II were challenge inoculated with *D. oryzae* when they were two weeks old. The plants were sprayed with the conidial suspension of *D. oryzae* (10^4 conidia/ml) until run-off using a plastic hand sprayer. The inoculated plants were kept at 100% humidity covering by plastic bag for 48 hrs. The plants were then exposed to open air in the glass house and grown until assessment of disease.The pots were arranged in randomized complete block design with three replications.

Measurement of disease severity

Disease observations were recorded one week after challenge inoculation with *D. oryzae* on formation of brown leaf spot lesions. Five plants from each pot were randomly selected and number of lesions per leaf for each treatment was counted.

Disease severity was recorded using a score chart consisting of five (0, I, II, III, IV) different grades of infection prepared on the basis of the per cent diseased area of the total leaf area (Nayak and Padmanabhan, 1970). The leaves with no disease spots received a score of zero while those with highest infection i.e. 76 per cent or more diseased area received a score of IV. Similarly leaves with 1-25, 26-50 and 51-75 per cent spotted area received a score of I, II and III respectively. The mean P.D.I. of selected five plants represented the disease severity of the concerned treatment replication.

Biochemical Analysis

Soluble protein contents of fresh leaf samples of paddy under different treatments were determined by the method developed by Lowry *et al.* (1951). Whereas the total phenol content in fresh paddy leaves was estimated by following the procedures developed by Bray and Thorpe (1954). The total reducing sugar was estimated following Nelson's modification of Somogyi's method (Nelson 1994). The non-reducing sugar was calculated by subtracting the reducing sugar from the total sugar content.

The ascorbic acid contents in dried leaf samples were determined colorimetrically as described by the Thimmaiah (1999).

N, P, K and S

Nitrogen content in dried leaf samples was estimated by Kjeldahl's method as described by Jackson (1967). Similarly, P, K and S contents were determined by the methods developed by Chapman and Pratt (1961) and Chesnin and Yien (1950) respectively. Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu) contents in dried leaf samples were determined with the help of Atomic Absorption Spectrophotometer (AAS) (Tandon 1993).

RESULTS AND DISCUSSION

Effect of chemical inducers on disease severity

Pre-treatment with abiotic inducers reduced mean number of lesions per leaf as well as the percent disease index (PDI). Among the selected abiotic inducers, the mean number of lesions were lowest (3.02) in calcium chloride, treatment. The average number of lesions/leaf were 3.15, 4.36 and 10.50, in case of K_2HPO_4, Hydrogen peroxide and salicylic acid respectively whereas it was as high as 14.5 in control plants (Table - 1).

Biochemical changes induced by the botanicals

Soluble protein content

The soluble protein contents of rice leaves after 10, 15 and 20 days of inducer application have been presented in Table-2. The results revealed that soil drenching with abiotic inducers in general increased the soluble protein content. However, it was maximum at 15 days of inducer application. The soluble protein contents after 20 days of inducer

Table 1: Effect of abiotic inducers on severity of brown spot disease in paddy

Treatment	Shoot length (cm) at 30 days	Disease severity		
		Mean no. of lesions per leaf	Percent Disease Index (PDI)	Percent reduction compared to control (Check-II)
Hydrogen peroxide	19.14	4.36 (2.19)	27.93 (5.33)	53.54
Calcium chloride	23.15	3.02 (1.88)	19.75 (4.5)	67.15
$K_2 2HPO_4$	22.06	3.15 (1.91)	21.36 (4.67)	64.47
Salicylic acid	15.73	10.50 (3.31)	55.34 (7.47)	7.95
Check-I(Healthy)	15.60	0 (0.71)	0 (0.71)	
Check-II D. oryzae)	14.55	14.50 (3.86)	60.12 (7.78)	
S.E. (Diff.)	0.48	0.18	0.22	
C.D. (P = 0.05)	1.05	0.39	0.48	

Values in the parenthesis are transformed (vx + 0.5) treatment recorded more or less same or even lower than that at 10 days of application.

The soluble protein contents of rice leaves pre-treated with hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid were 22.11, 26.19, 25.39 and 20.25 mg/g respectively, at 15 days. Whereas at the same time, it was as low as 16.53 and 16.28 mg/g in case of Check-I (Healthy) and Check-II (Diseased) respectively. Calcium chloride registered the highest soluble protein content among the abiotic inducers with 58.44 and 60.87% increase over Check-I and Check-II respectively. The increases in soluble protein content by K_2HPO_4 and hydrogen peroxide were 53.59 and 33.76% over Check-I and 55.96 and 35.81% over Check-II. But salicylic acid recorded only 22.50 and 24.38% increase in soluble protein content over Check-I and Check-II respectively.

Total Phenol content

Soil drenching with hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid increased the total phenol content of rice leaves. The total phenol contents recorded at 10, 15 and 20 days after inducer treatments have been presented in Table – 3. The results revealed that the total phenol content at 15 days of treatment application increased from what recorded at 10 days. However, it was noted to decline at 20 days of treatment. After 10 days of inducer treatments the total phenol contents of rice leaves in hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid treatment were 1.68, 1.73, 1.99 and 1.59 mg/g respectively, whereas it was only 1.34 and 1.40 mg/g in Check-I (Healthy) and Check-II (Diseased) respectively. The highest phenol content was recorded at 15 days of treatment with K_2HPO_4 (2.11 mg/g) followed by calcium chloride (1.87 mg/g), hydrogen peroxide (1.74 mg/g) and salicylic acid (1.67 mg/g). There was 6.47% increase in total phenol content in diseased plants (Check-II) as compared to healthy ones (Check-I). The abiotic inducers viz. hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid increased the total phenol contents by 25.18, 34.53, 51.79 and 20.14 per cent over Check-I and by 17.57, 26.35, 42.57 and 12.84 per cent over Check-II respectively. (Table 3).

Reducing and non-reducing sugar

The reducing sugar, non-reducing sugar and total sugar contents of paddy leaves after 15 days of treatment with abiotic inducers have been presented in Table-4. The highest reducing sugar of 196 mg/100g was recorded in diseased plants (Check-II). In healthy plants (Check-I) to the reducing sugar content was high (190 mg/100g). But in case of the selected abiotic inducers treatment, the reducing sugar contents were lower. Hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid treated plants recorded reducing sugar to the tune of 172, 154, 158 and 177 mg/100g respectively. The reduction in reducing sugar contents in hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid treated plants were 9.47, 18.95, 16.84 and 6.84 per cent over Check-I, and 12.24, 21.43, 19.39 and 9.69 per cent over Check-II respectively.

The non-reducing sugar contents in control plants were low with 148 mg/100g in Check-II and 150 mg/100g in Check-I. However, the inducer treated plants showed increase in non-reducing sugar content. Hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid recorded as high as 196, 220, 208 and 172 mg/100g respectively. There were 30.67, 46.67, 38.67 and 14.67 per cent increase over Check-I, and 32.43, 48.64, 40.54 and 16.22 per cent increase over Check-II by the respective inducer.

Ascorbic acid content

Soil drenching with hydrogen peroxide, calcium chloride and dipotassium hydrogen phosphate (K_2HPO_4) caused considerable increase in ascorbic acid content of rice leaves. However, salicylic acid treatment caused only minor increase. The results have been presented in Table-5. The ascorbic acid content of rice leaves in case of hydrogen peroxide, calcium chloride, dipotassium hydrogen phosphate and salicylic acid were 17.58, 20.65, 19.35 and 16.67 mg/100g at 10 days of treatment, and were 19.65, 22.36, 21.32 and 17.33 mg/100g at 15 days of treatment respectively. Hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid treatment recorded 19.09, 35.51, 29.21 and 5.03 per cent increase over Check-I (Healthy) and 25.39, 42.69, 36.05 and 10.59 per cent increase over Check-II (Diseased) respectively.

Table 2: Effect of abiotic inducers on total soluble protein content of paddy leaves (fresh) after 10, 15, and 20 days of application

Treatment	Total soluble protein content (mg/g of fresh leaves)			Percent increase in protein contents	
	10 days	15 days	20 days	Over healthy Plants (Check-I)	Over diseased Plants (Check-II)
Hydrogen peroxide	22.00	22.11	21.57	33.76	35.81
Calcium chloride	25.64	26.19	24.94	58.44	60.87
K_2HPO_4	24.77	25.39	24.12	53.59	55.96
Salicylic acid	19.11	20.25	19.00	22.50	24.38
Check-I (Healthy)	16.33	16.53	17.01		1.53
Check-II (D. oryzae)	16.05	16.28	16.50		
S.E. (Diff.)	0.32	0.29	0.41		
C.D. (P = 0.05)	0.69	0.62	0.90		

Table 3: Effect of abiotic inducers on total phenol content of paddy leaves (fresh) after 10, 15, and 20 days of application

Treatment	Total phenol content (mg/g of fresh leaves)			Percent increase in protein contents	
	10 days	15 days	20 days	Over healthy Plants (check-I)	Over diseased Plants (check-II)
Hydrogen peroxide	1.68	1.74	1.54	25.18	17.57
Calcium chloride	1.73	1.87	1.69	34.53	26.35
K_2HPO_4	1.99	2.11	1.85	51.79	42.57
Salicylic acid	1.59	1.67	1.53	20.14	12.84
Check-I (Healthy)	1.34	1.39	1.50		
Check-II (Diseased)	1.40	1.48	1.61	6.47	
S.E. (Diff.)	0.053	0.059	0.039		
C.D. (P = 0.05)	0.115	0.129	0.084		

Table 4: Effect of abiotic inducers on sugar content of paddy leaves (fresh) after 15 days of application

Treatment	Non reducing sugar (mg/100 g of dry leaves)	Per cent increase over		Reducing sugar (mg/100 g of dry leaves)	Percent increase over		Total sugar (mg/100 g of dry leaves)
		Check-I	Check-II		Check-I	Check-II	
Hydrogen peroxide	196	30.67	32.43	172	-9.47	-12.24	368
Calcium chloride	220	46.67	48.64	154	-18.95	-21.43	374
K_2HPO_4	208	38.67	40.54	158	-16.84	-19.39	366
Salicylic acid	172	14.67	16.22	177	-6.84	-9.69	349
Check-I (Healthy)	150	-	1.35	190	-	-3.06	340
Check-II (Diseased)	148	-	-	196	-		344
S.E. (Diff.)	4.88			2.47			5.70
C.D. (P = 0.05)	10.62			5.39			12.43

Table 5: Effect of abiotic inducers on ascorbic acid content of paddy leaves (dry) after 10 and 15 days of application

Treatment	Ascorbic acid (mg/100g of dry leaves) at 10 days	Per cent increase over		Ascorbic acid (mg/100g of dry leaves) at 15 days	Per cent increase over	
		Check-I	Check-II		Check-I	Check-II
Hydrogen peroxide	17.58	7.52	14.45	19.65	19.09	25.39
Calcium chloride	20.65	26.29	34.44	22.36	35.51	42.69
K_2HPO_4	19.35	18.35	25.98	21.32	29.21	36.05
Salicylic acid	16.67	1.96	8.53	17.33	5.03	10.59
Check-I (Healthy)	16.35		6.44	16.50		5.29
Check-II (Diseased)	15.36			15.67		
S.E. (Diff.)	0.38			0.36		
C.D. (P = 0.05)	0.83			0.79		

Mineral elements

The nitrogen content was highest in diseased plants (Check-II) with 0.498% and was lowest (0.387%) in calcium chloride treated plants. Hydrogen peroxide and K_2HPO_4 recorded more or less same (0.412%) nitrogen content. Whereas salicylic acid treated plants showed nitrogen content close to healthy check. The highest phosphorus content (0.147%) was recorded in K_2HPO_4 treated plants and lowest (0.112%) in the hydrogen peroxide treated plants. The potassium content was highest in plants treated with calcium chloride (1.74%) followed by K_2HPO_4 (1.72%), hydrogen peroxide (1.56%) and salicylic acid (0.134%) treated plants. The sulphur content (%), Manganese (ppm), Iron (ppm), Copper (ppm), and Zinc (ppm) contents under various treatments have been presented in Table-6. The highest K/N ratio of 4.49 was recorded in calcium chloride treatment. It was followed by K_2HPO_4 (4.17), hydrogen peroxide (3.79) and salicylic acid (3.19). The K/N ratio of Check-I (Healthy) and Check-II (Diseased) was 2.73 and 2.63 respectively. The Fe/Mn ratios of rice leaves pretreated with hydrogen peroxide, calcium chloride, K_2HPO_4 and salicylic acid were 0.64, 0.55, 0.59 and 0.71 respectively. Whereas the Fe/Mn ratio of Check-I and Check-II were respectively 0.77 and 0.79 (Table-6).

Table 6: Effect of abiotic inducers on mineral elements contents of paddy leaves (dry) after 15 days of application

Treatment	N (%)	P (%)	K (%)	S (%)	Mn (ppm)	Fe (ppm)	Cu (ppm)	Zn (ppm)	K/N ratio	Fe/Mn ratio
Hydrogen peroxide	0.412	0.112	1.56	0.187	95.89	61.25	35.45	25.36	3.79	0.64
Calcium chloride	0.387	0.128	1.74	0.187	108.26	59.87	37.12	23.36	4.49	0.55
K_2HPO_4	0.412	0.147	1.72	0.245	99.35	58.96	40.12	28.96	4.17	0.59
Salicylic acid	0.419	0.124	1.34	0.195	87.36	62.35	38.56	27.56	3.19	0.71
Check-I (Healthy)	0.418	0.121	1.14	0.202	96.35	74.32	37.89	29.97	2.73	0.77
Check-II (Diseased)	0.498	0.118	1.31	0.222	87.26	69.69	37.12	31.25	2.63	0.79
S.E. (Diff.)	0.008	0.006	0.044	0.006	1.86	2.11	0.22	0.21	0.13	0.032
C.D. (P = 0.05)	0.017	0.013	0.097	0.013	4.06	4.59	0.48	0.45	0.29	0.069

The inducer treatments increased the soluble protein contents of rice leaves. Fifteen days after treatment the soluble protein content was maximum in case of calcium chloride (26.19 mg/g) followed by K_2HPO_4 (25.39 mg/g), and hydrogen peroxide (22.11 mg/g). The increase in protein content due to salicylic acid was negligible. The higher soluble protein contents were associated with low disease severity. The percent disease index showed negative correlation (r = -0.470) with soluble protein content indicating a role of the protein in induced resistance. Antoniew *et al.* (1980) considered that pathogenesis related proteins (PR) are involved in plant defence responses to pathogens.

Phenols are also involved in the expression of disease resistance in many ways viz., hypersensitive cell death, lignification of cell walls. In the present investigation, the total phenol content of paddy leaves had negative correlation (r = -0.500) with the severity of brown spot disease. The application of inducers increased the phenol contents. At fifteen days of treatment the highest total phenol content (2.11 mg/g) was recorded in case of K_2HPO_4 followed by calcium chloride (1.87 mg/g), hydrogen peroxide (1.74 mg/g) and salicylic acid (1.67 mg/g) (Chowdhury (1995) reported that seed treatment with cycloheximide, cupric chloride, DL-phenylalanine and indole-3-acetic acid induced resistance to groundnut rust and increased the total phenol content by 11-55%.

Hait and Sinha (1987) reported that treatment of rice seeds of susceptible variety 'Dharial' in solutions of sodium selenite and cysteine conferred resistance against brown spot disease and increased phenol and protein levels. The induced resistance in cucumber against *C. lagenarium* by Ciba-Geigy compound (CGA-41396) was attributed to accumulation of proteins including chitinases (Metraux *et al.* 1990). Rice plants sprayed with *Methylobacterium* sp. showed increased presence of PR proteins and phenolics contents (Madhaiyan *et al.* 2004). Babu *et al.* (2003) reported increased phenolic content and accumulation of PR proteins in rice plants treated with Acibenzolar-S-methyl which induced resistance to bacterial blight. Application of salicylic acid in rice plants was also reported to enhance PR proteins and phenol content (XinZhong and Zhong 1997). In the present study K_2HPO_4, calcium chloride and hydrogen peroxide caused substantial increase in soluble protein and total phenol contents of paddy leaves.

Brown spot of rice is a high sugar disease. The rice cultivars resistant to this disease were reported to have lower sugar content as compared to susceptible cultivars (Mishra and Prasad 1964). Gangopadhyay and Chattopadhyay (1976) reported that reducing sugars were positively whereas non-reducing sugars were negatively correlated with the development of brown spot disease in rice. The present investigation also revealed a positive correlation of brown spot severity with reducing sugar (r = 0.431) and a negative correlation with non-reducing sugar (r = -0.493) content of paddy leaves. The inducer treatments were noticed to increase the non-reducing sugar contents and to reduce the reducing sugar contents of the treated plants while inducing resistance to the disease. Engstrom and Stromberg (1996) also reported changes in sugar content during induction of systemic acquired resistance to late blight in potato. In the present study, the maximum non-reducing sugar to the tune of 208 mg/100 g was recorded in treatment with K_2HPO_4 followed by hydrogen peroxide (196 mg/100 g) and salicylic acid. The non-reducing sugar content in leaves of untreated healthy (Check-I) plants was as low as 150 mg/100 g, but the reducing sugar content was to the tune of 190 mg/100g. The reducing sugar contents were found to decline due to inducer treatments. The reducing sugar contents in case of calcium chloride, K_2HPO_4, and hydrogen peroxide inducers were respectively 154, 158 and 172 mg/100 g of dry leaves.

Although external application of ascorbic acid was reported to enhance the brown spot disease in paddy (Mathur 1989) the cultivars resistant to it contained higher amount of ascorbic acid as compared to susceptible varieties (Mishra and Prasad 1964). In the present investigation the disease severity showed negative correlation (r = -0.514) with ascorbic acid content of rice leaves. Application of inducers increased the ascorbic acid content in treated plants indicating a role of ascorbic acid in plant defence or induced resistance. At 15 days after inducers application, the maximum ascorbic acid content of 22.36 mg/100 g was recorded in treatment with calcium chloride followed by K_2HPO_4 (21.32 mg/100 g), and hydrogen peroxide (19.65 mg/100 g). At the same time, the ascorbic acid contents in healthy (Check-I) and diseased check (Check-II) were respectively 16.50 and 15.67 mg/100 g of dry leaves.

As the nutritional factors have important role in brown spot disease of rice, the mineral status of the host plant must have some influence on the disease severity. In the present investigation the inducer treatments were noticed to influence the mineral contents viz. nitrogen (N), potassium (K), iron (Fe), manganese (Mn) and zinc (Zn) contents of the paddy leaves. However, phosphorus (P), copper (Cu) and sulphur (S) contents didn't show any reasonable pattern.

The N content of the paddy leaves was found to decline under different inducer treatments. The lowest N content of 0.336% was recorded in leaves treated with calcium chloride (0.387%). The N contents in healthy and diseased check were as high as 0.418% and 0.498% respectively. Unlike N content, the K content in paddy leaves was noticed to be increased by the inducer treatments. The maximum K content (1.74%) was noted in case of calcium chloride followed by K_2HPO_4 (1.72%) and hydrogen peroxide (1.56%). However, K content in diseased check was as low as 1.14%. Kaur *et al.* (1984) demonstrated a non-significant positive correlation between N status and brown spot disease expression. But, the disease had significant negative relationship with K, K/N ratio (Kaur *et al.* 1986). These reports support the findings of the present investigation wherein the brown spot disease severity showed negative correlation (r = -0.505) with K/N ratio. The inducer treatments caused an increase in K/N ratio. The highest K/N ratio of 4.49 was recorded in calcium chloride followed by K_2HPO_4 (4.17) and hydrogen peroxide (3.79).

All the inducers caused reduction in Fe contents of paddy leaves. The lowest Fe content of 59.87 ppm was noted in case of calcium chloride followed by K_2HPO_4, hydrogen peroxide and salicylic acid with 58.96, 61.25 and 62.35 ppm respectively. Whereas the Fe content in diseased check and healthy check were respectively 69.69 and 74.32 ppm. The Mn content was found to increase under all the treatments. The maximum Mn content of 131.29 ppm was recorded in case of calcium chloride (108.26 ppm) and K_2HPO_4 (99.35). The Mn content in diseased check was as low as 87.26 ppm. The inducer treatments caused a decrease in Fe/Mn ratio. The lowest Fe/Mn ratio (0.41) was noted in case of calcium chloride (0.55) followed by K_2HPO_4 (0.59) and hydrogen peroxide (0.64). The brown spot disease severity showed positive correlation (r = 0.498) with Fe/Mn ratio of paddy leaves. These results are in conformity with what reported by Kaur *et al.* (1986) who demonstrated a positive relationship of the disease with Fe and Fe/Mn ratio. In the present study, the Zn content of paddy leaves was noticed to decline slightly under all the treatments. The lowest Zn content of 23.36 ppm was recorded in case of calcium chloride treatment. It was followed by hydrogen peroxide (25.36 ppm), salicylic acid (27.56 ppm) treatments. Whereas, the Zn content in diseased check was as high as 31.25 ppm. The biochemical variables were noticed to influence the disease severity.

The use of induced resistance in a crop like rice has certain advantages, i.e. seeds or seedlings of paddy can be treated in several ways before transplanting to the field (Manandhar *et al.* 1998). Chemical agents may be more applicable as inducers than biotic agents, provided that they are inexpensive and not hazardous. Wu et al. (2021) reported probenazole induced resistance against rice blast through changes in metabolic pathways. In the present investigation too, the inducer treatments triggered many biochemical changes in the paddy leaves among which the most prominent ones were increases in soluble protein, total phenol, ascorbic acid, non-reducing sugar and K/N ratio; and decreases in reducing sugar and Fe/Mn ratio which could be attributed to the induction of resistance.

CONCLUSION

The present study demonstrated that the chemicals viz. calcium chloride, dipotassium hydrogen phosphate (K_2HPO_4) and hydrogen peroxide were able to substantially suppress the brown spot disease in paddy through induced resistance. However, much research is still needed before any commercialization of the inducers may take place and several issues need to be addressed. For the chemical inducers, it is important to thoroughly study their toxic effects if any, on the environment. The costs of using the inducers should also be considered. Experiments are required to further determine the optimal crop growth stages for application of the inducers in order to reduce consumption of the active ingredients.

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DYNAMICS OF GROWTH IN PRODUCTION AND PRODUCTIVITY OF MAJOR CROPS OF UTTAR PRADESH

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ABSTRACT

Agriculture is a major contributor to Uttar Pradesh's economy with large area under cultivation of wheat, sugarcane potato and rice crops. The state falls under nine agro-climatic zones and the zone wise crop sector growth in terms of production and productivity is discussed in the current study. Uttar Pradesh (UP) is the largest producer of sugarcane and potato with a share of 43.9 and 26.7 % in Indian production respectively. UP also contributes around 32.4 % of the national wheat production and 12.4 % of rice production. The compound annual growth rate of decadal change of major crops production and yield was evaluated for the 2007-08 to 2017-18 period. The decadal growth of rice has shown a positive trend over the period for both production and yield. Wheat production had decreased in the western and central plains. Bundelkhand region has reported a reduction in the growth of maize production and yield in the same period. Pearl millet has tremendously reduced production in the whole UP, similarly for black gram production, in the last decade. Potato production reduced in babar & tarai and the mid-western plains area. The study finds that the region of Bundelkhand has severely affected the growth of maize, pearl millet and black gram and it needs policy measures to improve agriculture development.

Keywords: CAGR, Trend analysis, Millets, Potato, Bundelkhand

Agriculture reigns supreme in Uttar Pradesh's economy, engaging 46.9% of its workforce (GOI, 2016). As of 2011, a staggering 77.7% of the state's population resided in rural areas, surpassing the national average of 68.8%. With a significant impact on the nation's agricultural performance, UP contributed 12% (GDP) to the country's Gross Domestic Product from agriculture and allied activities in 2017-18 (Gulati *et al*, 2021). Covering 15.8% of the nation's food grain cultivated area, UP boasted a 16.9% share in total food grain production in 2016-17. The state held sway as the top producer of wheat, sugarcane, mangoes, watermelon, gooseberry, potatoes, peas, milk, and meat. Its diverse topography, terrain, and climate classify the state into nine distinct agro-climatic zones, ranging from the Terai Region to the Vindhyan Region. The northern expanse features the expansive Indo-Gangetic plains, while the southern landscape is marked by the Vindhya Range and Plateau areas. Annual rainfall spans from 600-1000 mm in the west to 1000-1200 mm in the east (Verma *et al*, 2017). The western and central regions enjoy superior irrigation facilities compared to other zones, while the eastern region grapples with floods, high population density, and limited land per capita.

In Uttar Pradesh, cereal production, being fundamental dietary staples, provide significant quantities of carbohydrates, dietary fiber, and protein. Furthermore, they serve as abundant sources of essential nutrients such as vitamin B, other vitamins, and vital minerals including iron, zinc, magnesium, and phosphorus (Shahidi and Chandrasekara, 2015). Beyond mere sustenance, cereals also meet the requirements for fodder and fuel among farming communities in the area. Over the years, the cropping system in the region has undergone notable transformations, resulting in fluctuations in the area, production, and productivity of major cereal crops. This paper aims to analyze the temporal dynamics of these factors in the in the last decades.

MATERIALS AND METHODS

Positioned in Northern India, the state shares borders with Uttarakhand to the north, Haryana and Delhi to the northwest, Rajasthan to the west, Bihar and Jharkhand to the east, and Chhattisgarh and Madhya Pradesh to the south. Ranking as the fourth largest state in India, it spans an area of 240,928 square kilometres, constituting 7.33 percent of the nation's total land area.

In this study, we scrutinize the regional performance of major agricultural crops in Uttar Pradesh from 2007-08 to 2017-18. Utilizing the compound annual growth rate, we assess the growth of identified crops across the regions. Specifically, crops with significant cultivation areas such as sugarcane, potato, wheat, rice, maize, pearl millet, black gram, and maize were chosen for analysis. District-level data pertaining to these crops was gathered and analyzed. Area, production, and productivity data for these crops during the specified period were compiled from secondary sources, specifically from the Ministry of Agriculture and Farmers' Welfare and the Directorate of Agricultural Statistics, Government of India. Growth rates were calculated using the formula provided below:

$$r = \{\text{Antilog}(B) - 1\} * 100$$

$$\ln Y_t = \ln A + t \ln B$$

Where,

Y_t = Area/yield of major crops in 't' period

A = Constant: $B = (1 + r)$

r = Compound growth rate: t = Time variable (1, 2, 3...n)

RESULTS AND DISCUSSION

Table 1 illustrates the share of crop production area and output of major identified crops in Uttar Pradesh (UP) compared to the national figures for India. In UP, the proportion of sugarcane cultivation area stands notably higher at 44% compared to the country's average. The state alone contributed 44% to the total sugarcane production of 370 million tonnes in India in 2022. However, UP's sugarcane yield per hectare was lower than the national average, registering at 81 tons per hectare.

Wheat cultivation covers a substantial area of 31 million hectares in India, with UP accounting for 31% of this total. In 2022, the national wheat production reached 109 million tonnes, with UP contributing 32% to this output, indicating the state's significant role in the agricultural landscape. UP's wheat productivity slightly exceeded the national average, largely due to the adequate availability of irrigation facilities. Potato emerged as another major crop in UP, with 27.8% of the national potato cultivation area attributed to the state. UP's potato production contributed 11.8% to India's total potato output.

Table 1. Current agricultural status in UP with reference to India (2020-21)

Major crops	India area (000 ha)	UP % share in area	India Production (000 tons)	UP % share in production	India productivity (kg/ha)	UP productivity (kg/ha)
Rice	45768.69	12.40	124368.32	12.47	2717	2733
Wheat	31125.16	31.65	109586.49	32.40	3521	3604
Sugarcane	4851.23	44.93	370500.30	43.99	83566	81807
Maize	9891.96	7.81	31646.91	5.74	3199	2352
Pearl millet	7652.10	11.85	10863.2	18.54	1374	2115
Potato	2248.0	27.79	54230.20	26.77	23688	22807
Black gram	4142.50	13.4	2229.58	11.8	538	573

Source: Authors calculation based on Agricultural Statistics at a Glance-2022, MoA&FW. GoI

The decadal growth of major crops production and productivity is presented in Tables 2a and 2b. Table 2a shows that rice has higher production growth in the Bundelkhand region and the highest productivity growth in the Vindhya region. Wheat production growth was reduced in the western plains and central plains and reduced productivity growth in the Bundelkhand region, rest of the regions are positive growth in production and yield of wheat. Sugarcane found a significant increase in production growth in the Bundelkhand region and a decrease in growth in a south-western semi-arid region. Overall, the sugarcane productivity has shown positive growth in all the regions of UP. Maize significantly recorded decrease in production and productivity growth at Bundelkhand,

Table 2a: Decadal Growth in production and productivity of major crops in UP (2007-08 to 2017-18)

Major crops	Rice		Wheat		Sugarcane		Maize	
	Production growth	Productivity growth	Production growth	Productivity growth	Production growth	Productivity growth	Production growth	Productivity growth
Babar & tarai	1.02***	1.02***	1.00	1.00**	1.04	1.03**	1.01***	1.03
Western plains	1.00	1.01**	0.97**	1.00***	1.00	1.03	0.99**	1.00**
Mid- western plain	1.00	1.01**	0.98	1.00	1.04	1.03	0.91	1.03
South western semi-arid	1.02**	1.00	1.00	1.00**	0.94**	1.02	1.02	1.03
Central plains	1.02	1.01	0.99***	1.00	1.06	1.03**	1.03	1.02**
Bundelkhand	1.08***	1.03	1.01**	0.99***	1.09**	1.00***	0.86**	0.99***
North Eastern plains	1.00	1.00	1.01	1.01	1.04	1.03	1.03***	1.04
Eastern plain	1.01	1.01	1.01	1.01**	1.04***	1.04	1.04	1.02**
Vindhya	1.02	1.03**	1.02**	1.02	1.05	1.03	1.04	1.04
Uttar Pradesh	1.01**	1.01	1.00	1.00***	1.03***	1.03	1.01***	1.02

Source: Authors calculation based on various issues of Agricultural Statistics at a Glance, MoA&Fw. GoI

Table 2b: Decadal Growth in production and productivity of major crops in UP (2008-09 to 2017-18)

Major crops	Pearl millet		Potato		Black gram	
	Production growth	Productivity growth	Production growth	Productivity growth	Production growth	Productivity growth
Babar & tarai	0.91**	0.99	0.98**	1.01	0.96	0.99
Western plains	1.07	0.99	0.99	1.01	0.95	1.01
Mid-western plain	0.91***	1.01**	0.93***	1.12***	0.98	1.06
South western semi-arid	1.04	1.03	1.01***	1.00	0.95**	0.97**
Central plains	0.98	0.99***	1.01	1.00**	1.03	0.99
Bundelkhand	1.04***	1.03	0.97	0.99	0.95***	0.97
North Eastern plains	0.96***	1.00	1.00	1.01	0.97**	0.99
Eastern plain	0.99	0.99	1.02	1.01	0.99	0.99
Vindhya	0.96	0.99***	1.04***	1.03**	1.08	1.13
Uttar Pradesh	0.98**	1.00***	1.01	1.04	1.00***	1.04

Note: ***, ** indicates significance at 1% and 5% level

whereas, the increase in production growth was higher at Babar and tarai and the northeastern plains. The western and mid-western plain also recorded lower growth in the production of maize in the last decade.

The decadal growth of production and yield of pearl millet, potato, and black gram is presented in Table 2b. The results show that the pearl millet has an increase in production growth in Bundelkhand and reduced growth in babar and tarai, mid-western plains and northeastern plains with stagnant productivity growth in the state. Potato had higher growth in Vindhya for production and productivity, mid-western plain had significantly higher productivity growth. Black gram has decreased in production growth in the southwestern semi-arid, Bundelkhand, and northeastern plains. The Bundelkhand region despite being the traditional pulses-growing region, accounts for about 6.4 per cent of total area and total production of cereals in the state (Sah *et al*, 2022).

CONCLUSION

The overall scenario of growth in the production and productivity of the major crops of Uttar Pradesh was discussed in the present paper. The babar and tarai region has a good growth of cereals and sugarcane, and reduced growth of pearl millet, potato and black gram. In the Bundelkhand region, rice production has the highest growth and lowest growth recorded in maize cultivation in the last decade. The overall growth in Uttar Pradesh shows that crops such as rice, wheat, sugarcane, maize, potato, and black gram have shown improvement with a positive growth rate from 2007 to 2017. The pearl millet has shown a decrease in growth of production leading to lower millet production in India. More importance has to be given by the state government to promote the millets in consumption patterns of the households for augmenting growth in millets.

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MULCHING PRACTICES AND AWARENESS OF FARMERS FOR TEXTILE MULCHES: A CASE STUDY FROM PUNJAB REGION

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ABSTRACT

The present investigation was undertaken to study mulching practices and awareness of farmers for textile mulches from Punjab region in 2021-22.The two highly vegetable cultivated districts were selected from Sub-mountain Undulating Zone. Farmers were drawn randomly from selected agro-climatic zone of Punjab and an interview schedule was prepared for collecting data. The results indicated that majority farmers in Gurdaspur and Hoshiarpur districts were in the age group between 35-45 and 45-55 years and their education was till intermediate and graduate level. Gurdaspur farmers grew more seasonal vegetables using paddy straw mulches as compared to Hoshiarpur farmers, who were mostly using plastic mulches. Gurdaspur farmers always used mulch in contrast to Hoshiarpur, where 86% farmers used mulch for vegetable cultivation, but farmers at Hoshiarpur were more aware of coloured mulches. Maximum farmers at Hoshiarpur and Gurdaspur opined that mulch usage resulted in an increase of crop yield by 10-20%. Very few farmers (<35%) were aware of biodegradable textile mulches but most of them were willing to buy and use such mulches if made available to them. Hence, there is a need to popularize such mulches, as there is a great scope for manufacturing them on a commercial level. Like other industries, the agro-textile industry can also take initiatives to make its processes green and provide a situation in which industrial growth and prosperity can be maximized without a negative impact on the environment.

Keywords: Agrotextile, Cultivation, Farmers, Sustainability, Textiles, Mulches

The agriculture sector is the backbone of the economy with more than 70% of the population living in rural areas depending on agriculture for their livelihood. Currently, this sector contributes to about 18% of GDP and 30% of the employment. Mulch is a protective covering mat spread on the ground and is used to reduce evaporation, maintain soil temperature, enhancing the yield growth, inhibiting the weed growth and also preventing soil erosion (Iqbal *et al.*, 2020; Li *et al.*, 2018; Chen *et al.*, 2021). This also overcomes the need of herbicides required to control the weeds (Bhardwaj, 2013). Besides this, mulching helps in increasing downward movement of water (Bodner *et al.*, 2015).The effectiveness of mulches in conserving moisture has generally been found to be higher under more frequency of rainfall, drought conditions and also during early period of plant growth when canopy cover is scanty (Gan *et al.*, 2013).By using mulching technology, the yields of grain and cash crops can increase by 20-35% and 20-60%, respectively (Li *et al.*, 2020). The soil temperatures were warmest with clear plastic mulch followed in order of decreasing temperatures by black-on-white, black and white on-black plastic mulch stated by Huang *et al.*, (2020) Himelrick *et al.*, (1992). Changes in root zone temperature effect the uptake and translocation of essential nutrients, therefore influencing root and shoot growth (Tindall *et al.*, 1990). Plastic mulch most commonly used for intensive cultivation of fruits and vegetables (Lamont and William, 2017) and are inexpensive option for growers (Cirujeda *et al.*, 2012; Akhir and Mustapha, 2022). Polythene films do not contribute any organic matter to the soil. Organic mulches are a better option to polythene mulches since they improve the soil's physical, chemical, and biological qualities while also adding nutrients (Ajmeri and Ajmeri, 2016). With growing frequency of human diseases due to various chemicals and plastic mulch used in growing vegetables, outstanding emphasis is laid on organic product (Serrano *et al.*, 2021). Organic coverage is an attractive option because it provides opportunities for farmers to recycle on-farm agricultural by-products or urban waste products at little or no cost (Wortman *et al.*, 2015) Such a production can be best achieved by the use of agro textiles. Agro textiles products help to keep sufficient soil humidity and protect the fruits against the damage caused by the hail/rain (Debnath, 2014).These agro textiles helps in increasing the crop yield and quality, enhance freshness in fruits and vegetables (Yousuf *et al.*, 2018; Subramaniam *et al.*, 2009). They provide high standard products to farmers and consumers which result in satisfaction as well as value for their money (Padam *et al.*, 2014). Woven and non-woven mulch mats are preferable, because they provide better durability, breathability, strength, elongation, stiffness, resistance to sunlight, and also biodegradable in soil. Spun bonding and needle punch techniques are mainly used for the production of mulch. Biodegradable mulch mats based on jute, coir, sisal, etc. are a sustainable option to be used in agriculture reported by Basu (2011). Paper-based mulches are a commercially available alternative to plastic mulches and are popular due to their low cost (Olsen and Gounder, 2001). There is also some evidence that vegetable crop yields in paper and nonwoven mulch systems can be competitive with those in plastic mulch (Jenni *et al.*, 2002; Liu *et al.*, 2021). Therefore, developing environmentally friendly and biodegradable alternatives to current plastics represents an emerging need for a sustainable future.

MATERIALS AND METHODS

The present investigation was undertaken to study the awareness of farmers for textile mulches used in vegetable crop. Keeping in mind the objectives of investigation, a suitable methodology to conduct the research in a scientific manner was adopted. The present study was exploratory research design to explain the mulching practices used by farmers in Punjab. Data was collected from agro-climatic zone (Hoshiarpur and Gurdaspur) of Punjab regarding mulching practices. The sample consisted of thirty farmers which were drawn randomly from Sub-mountain Undulating Zone in 2021-22 year. Fifteen farmers from each selected district were considered randomly for collecting the data. A complete list of farmers was procured from horticulture department and KVK in each district. Fig. 1 represents the diagrammatic procedure of the sample selection for the current study.

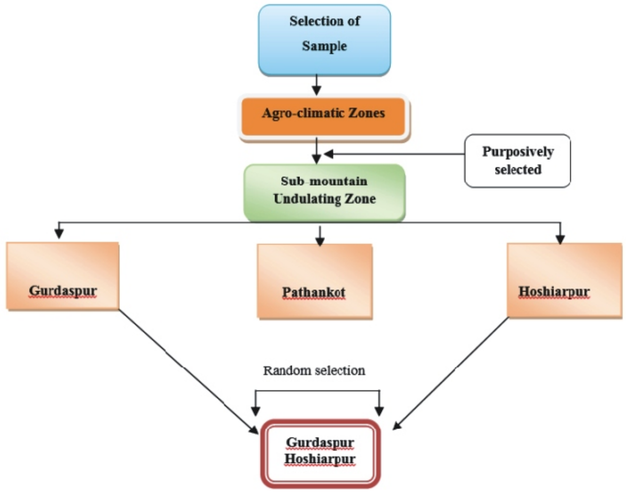

Fig. 1. Procedure for selecting the sample for study

RESULTS AND DISCUSSIONS

Socio- personal background of the farmers

The results indicated that 40% of farmers in Hoshiarpur were in the age group of 35-45 years and in Gurdaspur, majority (53.3%) of farmers were found in the age group of 45-55 years. In Hoshiarpur majority farmers were intermediate while majority of farmers were graduate in Gurdaspur. No respondents were found to be post-graduate in both Hoshiarpur and Gurdaspur districts. Maximum % of the farmers belonged to nuclear families at both places. As far as six-monthly income of the respondents was concerned, in Hoshiarpur and Gurdaspur largest % of farmers (66.6%) had family income between ₹1,00,000-₹2,00,000.

Table 1: Socio-personal traits of farmers

Socio-personal traits	Hoshiarpur (n=15) Frequency (%)	Gurdaspur (n=15) Frequency (%)	Total (n=30) Frequency (%)
Age (in years)			
25?35	4 (26.67)	1 (6.67)	5 (16.67)
35?45	6 (40)	5 (33.33)	11 (36.67)
45?55	5 (33.33)	8 (53.33)	13 (43.33)
55?60	0	1 (6.67)	1 (3.33)
Educational qualification			
Matriculate	2 (13.33)	3 (20)	5 (16.67)
Higher Secondary (+2)	8 (53.33)	4 (26.67)	12 (40)
Graduate	5 (33.33)	8 (53.33)	13 (43.33)
Family type			
Nuclear	11 (73.33)	9 (60)	20 (66.67)
Joint	4 (26.67)	6 (40)	10 (33.33)
Six monthly income in (₹)			
Below 1,00,000	5 (33.33)	3 (20)	8 (26.67)
1,00,000?2,00,000	10 (66.66)	7 (46.67)	17 (56.67)
2,00,000?3,00,000	0	4 (33.33)	4 (13.33)
Above 3,00,000	0	1 (6.67)	1 (3.33)

Note: Figures in parentheses indicate percentage

Land on lease and operational holder status

In Hoshiarpur and Gurdaspur, 60 and 53.3% of the farmers were cultivating on their own land respectively in sub mountain undulating zone. Hoshiarpur district had greater % of large farmers with land area >25 a whereas at Gurdaspur, only 33.3% farmers were in the category of large farmers. In total, under sub-mountain undulating zone, 43.3% farmers were grouped as large farmers based on their operational lands.

Table 2: Land on lease and operational holder status of the farmers

Land on lease	Hoshiarpur (n=15) f (%)	Gurdaspur (n=15) f (%)	Total (n=30) f (%)
Yes	6 (40)	7 (46.67)	13 (43.33)
No	9 (60)	8 (53.33)	17 (56.67)
Operational holder status			
Marginal Farmer (below 2.5 acer)	0	2 (13.33)	2 (6.67)
Small Farmer (2.5-5 acer)	2 (13.33)	1 (6.67)	3 (10)
Semi- Medium Farmer (5-10 acer)	0	3 (20)	3 (10)
Medium Farmer (10-25 acer)	5 (33.33)	4 (26.67)	9 (30)
Large Farmer (above 25 acer)	8 (53.33)	5 (33.33)	13 (43.33)

Note: Figures in parentheses indicate %

Crops cultivated by the farmers

The dynamics of different crops cultivated by the farmers revealed that there was a similarity in cultivation trend of farmers at both places. At Hoshiarpur, maximum vegetable cultivation (60%) was undertaken in area of <5 acer. Grain crops were widely cultivated with 33.3% respondents following cultivation on land areas >25 acer. Apart from these groups, flower (<5 acer) and fodder (5-10 acer) crops were also grown in this district by the farmers. At Gurdaspur, highest% of farmers (53.3%) grew vegetable crops on less than 5 acer land area. Grain crops were given high importance and were widely grown with 40% farmers using <5 of their land. Apart from these, flower crops were also grown by the farmers on less than 5 acer of their land areas (Table 3).

Vegetables cultivated by farmers

Farmers at sub-mountain undulating zone were highly flexible with the kind of vegetables. Maximum% of farmers grew all different vegetables in their field both in Hoshiarpur and Gurdaspur district.

Table 3: Crops cultivated by the farmers

	n=30							
	Hoshiarpur n=15				Gurdaspur n=15			
	Different crops							
Land area (acres)	Veg	Fruits	Grains	Others	Veg	Fruits	Grains	Others
0	0	13 (86.67)	1 (6.67)	14.5 (96.67)	0	8 (53.33)	2 (13.33)	2 (13.33)
Less than 5	9 (60)	2 (13.33)	3 (20)	-	8 (53.33)	7 (46.67)	6 (40)	-
5-10	2 (13.33)	0	0	-	2 (13.33)	0	4 (26.67)	-
10-15	2 (13.33)	0	2 (13.33)	-	2 (13.33)	0	2 (13.33)	-
15-20	2 (13.33)	0	4 (26.67)	-	0	0	0	-
20-25	0	0	0	-	1 (6.67)	0	0	-
Above 25	0	0	5 (33.33)	-	2 (13.33)	0	1 (6.67)	-

Note: Figures in parentheses indicate percentage

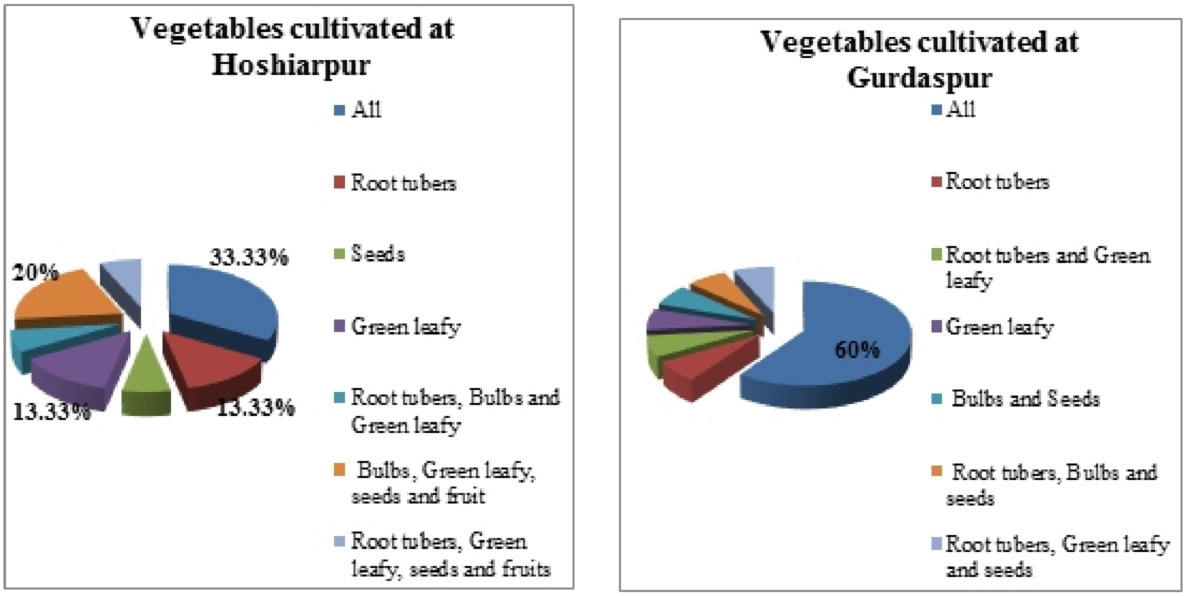

Fig. 2. Different vegetables cultivated by farmers at Hoshiarpur and Gurdaspur (n=15)

Awareness for biodegradable textile mulches

Data on the awareness of the farmers under study (Table 4) show that they had knowledge about mulch and all had used mulch during their course of cultivation. About different biodegradable textile mulches, it was found that very few farmers, only 26.6% in Hoshiarpur and 33.3% in Gurdaspur were aware thus, there is a strong need to popularize such mulches for discouraging the use of plastic ones.

Table 4: Awareness and willingness of farmers to buy biodegradable textile mulches

Sub-mountain undulating zone	Awareness about biodegradable textile mulches		Buy biodegradable textile mulches	
	Yes	No	Yes	No
Hoshiarpur	27%	73%	87%	13%
Gurdaspur	33%	67%	80%	20%
n=15				

Further, an attempt was made to find out that if given an opportunity, whether the farmers were willing to buy such biodegradable textile mulches or not. Table 4 indicate that 86.6% of farmers at Hoshiarpur and 80% at Gurdaspur were conscious about environment and hence were willing to buy and use the biodegradable mulches made out of textile waste.

Vegetables grown by farmers using mulches

At Hoshiarpur, 40% farmers grew cucumber while cabbage, brinjal and *haldi* were least preferred. At Gurdaspur, garlic was highly preferred whereas, onion, tomato and capsicum were least preferred by using mulch method(Fig. 3).

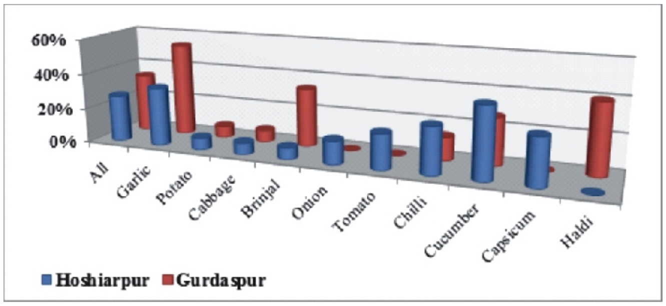

Fig. 3. Vegetables grown by mulching method in Hoshiarpur and Gurdaspur (n=30)

Motivation for mulch usage

In Hoshiarpur, majority of the farmers (60%) started using mulches after motivation from their friends (Fig. 4). At Gurdaspur, 46% farmers used mulch after knowing about it from their colleagues or fellow farmers. Slightly less% of farmers in this district also came to know about mulches from their family members who were also practicing agriculture.

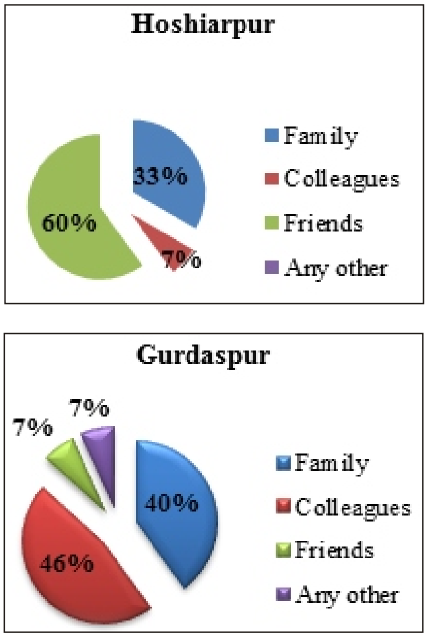

Fig. 4. Sources for motivation of mulch usage to farmers at Hoshiarpur and Gurdaspur(n=15)

Subsidy available to farmers for mulch

None of the farmers at Hoshiarpur and Gurdaspur received subsidy for using mulch for their crops. This is a serious concern and should be taken care if mulch application has to be increased in the agriculture fields in the coming times (Table 5).

Table 5: Time frame and frequency of mulch usage amongst farmers at Hoshiarpur and Gurdaspur

Sub-mountain undulating zone	Time frame for the usage of mulch			Frequency of mulch usage	
	0-5 years	5-10 years	Above 10 years	Always	Sometimes
Hoshiarpur	60%	40%	-	86.67%	13.33%
Gurdaspur	33.33%	53.33%	13.33%	100%	-
n=15					

Time frame and frequency of usage of mulch by farmers during cultivation

Majority of farmers (60%) at Hoshiarpur started using mulches less than 5 years ago. While at Gurdaspur, majority of farmers (53.3%) started using mulch from last 5-10 years ago. Thus, it can be inferred that common use of mulches is only a decade old in the region of Punjab. As shown in Table 5, 100% farmers at Gurdaspur claimed that they always used mulch for their cultivation as they were convinced of the advantages of using mulch in fields for better production while at Hoshiarpur, 86.67% farmers used the mulching method regularly. So, more motivation is required at Hoshiarpur.

Mulch types and mode of purchase used by farmers

Farmers at Hoshiarpur majorly used plastic mulch (67%) in their fields and most of them bought it from retailers, while at Gurdaspur, paddy straw mulch was preferred by majority farmers (46.6%) in their fields and 40% of farmers bought from retailers. Only 13.3% farmers used a combination of both plastic and paddy straw mulches (Fig. 5&6).

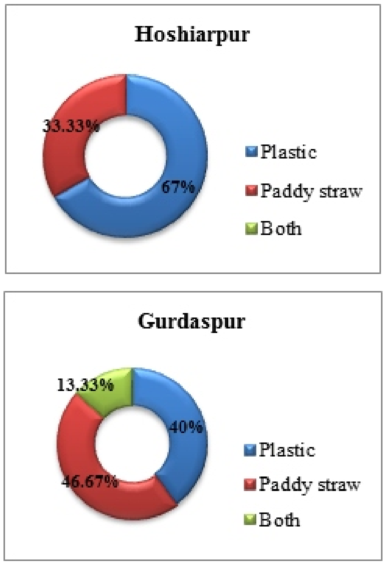

Fig. 5. Different types of mulches used by farmers at Hoshiarpur and Gurdaspur (n=15)

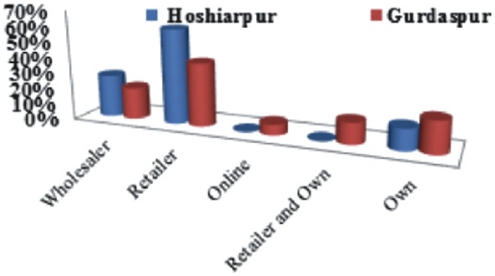

Fig. 6. Mode of purchase of mulch by the farmers at Hoshiarpur and Gurdaspur (n=30)

Knowledge about coloured mulches and effect of mulch usage on various crops

Majority of farmers at Hoshiarpur (73%) and Gurdaspur (67%) were familiar with coloured mulches (Fig. 7). Silver black (SB) mulch followed by black mulch (B) was most preferred at both Hoshiarpur and Gurdaspur. Maximum farmers at Hoshiarpur and Gurdaspur opined that mulch usage resulted increase in crop yield by 10 to 20% where as more farmers at Gurdaspur than in Hoshiarpur were of the belief that due to mulch placed with the crops, the crop yield increased between 20-30%.

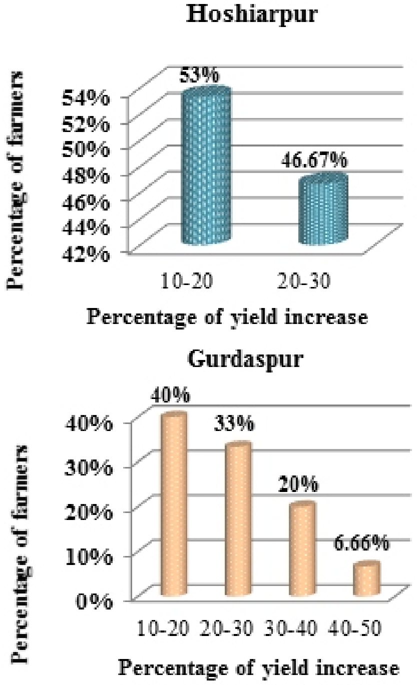

Fig. 7. Percentage increase in crop yield through mulching at Hoshiarpur and Gurdaspur (n=15)

Labour hired while placement and problems faced by farmers in mulch usage

All the farmers at Hoshiarpur hired labour for using the mulch during cultivation in contrast to 58.3% observed at Gurdaspur. Approximately 47% of the farmers at Gurdaspur placed and removed mulch themselves in their field. At Gurdaspur, majority of farmers faced problems associated with placing and removing of mulch. At Hoshiarpur, 60% farmers did not report any problem while using mulch in cultivation. Some of the issues they listed were the high cost of labour for placing and removing mulch from the field was a major concern for them (Table 6).

Table 6: Farmers facing problems in mulch usage at Hoshiarpur and Gurdaspur

Sub-mountain undulating zone	Hiring of labour for mulch placement		Facing problems in mulch usage	
	Yes	No	Yes	No
Hoshiarpur	100%	-	40%	60%
Gurdaspur (n=15)	53.33%	46.67%	53.33%	46.67%

Comparison of mulching practices amongst farmers in Hoshiarpur and Gurdaspur

Few similarities and some dissimilarities were observed as far as the mulching practices of farmers in Hoshiarpur and Gurdaspur are concerned. At Hoshiarpur, more% of farmers was cultivating on their own land and belonged to category of large farmers as compared to Gurdaspur. Hoshiarpur and Gurdaspur both places, majorly grains and vegetables were cultivated. The reason behind this similarity might be similar soil and climate type as both districts belong to same zone of Punjab. Similar type of seasonal vegetables, roots tubers, bulbs and green leafy respectively were grown at both places by the farmers but in Gurdaspur, more percentage of farmers were growing seasonal vegetables. This could be attributed to more demand of seasonal vegetables in Gurdaspur area. The farmers had less knowledge about biodegradable textile mulches. If, however comparison was made, then, in Gurdaspur, more percentage of farmers was aware. This could be attributed to more education level of farmers in Gurdaspur as compared to Hoshiarpur. But, Hoshiarpur farmers were more willing to buy and use the biodegradable textile mulches. At Hoshiarpur, majority farmers grew cucumber and also capsicum, chilli, garlic, tomato and onion in good amounts using mulch method but in Gurdaspur, farmers grew garlic,*haldi*, *brinjal* and cucumber in good amounts using mulch methods. At Hoshiarpur, farmers were motivated for usage of mulch in cultivation by their friends. Whereas, at Gurdaspur, farmers gave credit to both colleagues and their family members.

At Hoshiarpur, majority of the farmers used plastic mulch whereas at Gurdaspur, farmers mostly used paddy straw mulch indicating their stronger concern of using biodegradable mulches for protection of environment. More farmers in Hoshiarpur were aware of the coloured mulches as compared to Gurdaspur. This might be because more plastic mulches were being used in Hoshiarpur so the farmers were more aware about the new colors available in this category. Similarity was observed in data concerning increase in crop yield using mulch as majority farmers at both places were of the view that crop yield increased between 10 to 20% if mulches were placed in fields. As higher amount of plastic mulch was being used in Hoshiarpur so that the farmers hired more labour. At Gurdaspur, farmers faced more problems in mulch usage, where less% of farmers complained about such issues. The reason behind this could be different type of mulch being used at both places.

Majority of the farmers at Hoshiarpur started using mulch after motivation from their friends whereas at Gurdaspur, majority farmers used mulch after knowing about it from their colleagues. Majority of farmers (60%) at Hoshiarpur started using mulches less than 5 years ago. While at Gurdaspur, majority of farmers were using mulch from last 5-10 years. None of the farmers at Hoshiarpur and Gurdaspur received subsidy for their crops. All the farmers at Gurdaspur claimed that they always used mulch for their cultivation while at Hoshiarpur, 86.67 percent farmers practiced mulching regularly. Farmers at Hoshiarpur majorly used plastic mulch at their fields. While at Gurdaspur, paddy straw mulch was preferred by farmers. Most of the farmers at Hoshiarpur and Gurdaspur bought mulch from retailers Majority of farmers at Hoshiarpur (73%) and Gurdaspur (67%) were familiar with coloured mulches.

CONCLUSION

The study concludes that at Hoshiarpur, more than 40% of farmers was cultivating on their own land and belonged to category of large farmers as compared to Gurdaspur. Hoshiarpur and Gurdaspur both places, majorly grains and vegetables were cultivated. The farmers had less knowledge about biodegradable textile mulches. If, however comparison was made, then, in Gurdaspur, more 46.67% of farmers were aware. This could be attributed to more education level of farmers in Gurdaspur as compared to Hoshiarpur. More farmers in Hoshiarpur were aware of the coloured mulches as compared to Gurdaspur. This might be because more plastic mulches were being used in Hoshiarpur so the farmers were more aware about the new colors available in this category. The study concluded that majority of the farmers at both places were not aware about biodegradable textile mulches hence, there is a need to popularize such mulches. This will not only provide sustainable and biodegradable mulches but will also contribute in using textiles for this purpose paving a way for developing the new dimension of agro-textiles. Government should also take necessary steps for providing subsidy for biodegradable mulches so that farmers are motivated to use them more in their field to benefit both themselves and the environment.

ACKNOWLEDGEMENTS

AK initiated the study and designed the experiment. AK and SM KS co-designed the experiment on Mulching Practices and Awareness of Farmers for Biodegradable Textile Mulches. AKdrafted the manuscript. AK and SM KS provided key comments for manuscript writing. All authors read and approved the final manuscript.

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SYSTEMATIC SURVEYS, HOST STUDIES AND INFLUENCE OF SOIL PH AND SOIL ORGANIC CARBON ON INCIDENCE OF RICE ROOT-KNOT NEMATODE *(MELOIDOGYNE GRAMINICOLA)*

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ABSTRACT

Systematic surveys were conducted in Southern transition zone districts *viz.,* Shivamogga, Chikmagaluru, Davanagere and parts of Mandya districts of Karnataka to the study incidence and distribution with respect to soil types, cultivar, geographical location, soil pH, soil organic carbon and host range. The survey indicated that, there is incidence of rice root-knot nematode in all the surveyed locations. But their level of incidence varies with respect to soil type, soil pH, soil organic carbon, cultivar, and geographical location. Chi-kadadkatte of Davanagere district, V.C Farm of Mandya district, Tuduru, Beguvalli, Hasudi of Shivamogga, Karagunda and Lakkavalli of Chickmagaluru district recorded highest nematodes population ranging between 586.33 to 841.00 J_2 / 100 cc of soil with root knot indices varying from 3 to 4. The lowest incidence (210.56 and 240.66 J_2 100 cc of soil) was observed in Kumsi of Shivamogga and Vadeyarhatturru of Davanagere district. Interestingly it was observed that where the places recorded highest nematode population having sandy loam soil, soil pH level ranged between 4.41 to 5.80, soil organic carbon level varied from 0.90% to 1.44%. However, several weed hosts such as *Echinochloa crusgalli, Cyperus eragrostis, Paspalum distichum*, *Axonopus compressus*, *Cyperus rotundus* and *Cynodon dactylon* serves as alternate host for *M. graminicola* and Jyothi was predominant cultivated variety in most of the locations it is highly susceptible to rice root-knot nematode. Whereas, the least nematode population observed in Kumsi of Shivamogga and Vadeyarhotturru of Davanagere district having clay loamy soil showed pH level between 6.13 to 6.43 and soil organic carbon of 1.50% to 1.59%. Analysis of correlation coefficient showed that population of *M. graminicola* had significantly negative correlation with soil pH and soil organic carbon when soil pH and soil organic carbon increases the nematode population decreases.

Keywords: *M. graminicola*, Rice root-knot nematode, Rice, Survey, pH and Organic carbon

Rice is one of the most important staple foods for more than half of the world's population (IRRI 2006) and influences the livelihoods and economies of several billion people especially concentrated in Asia, Latin America, the Middle East, and the West Indies. Of late, among the several biotic stresses, plant parasitic nematodes are gaining much importance. So far, 300 plant parasitic nematode species belonging to 35 genera have been reported infesting rice. Among them, *Meloidogyne graminicola* has become major production constraint both in nurseries and main fields. The yield loss due to this nematode varies from 17% to 80%. However, unfortunately, farmers and extension workers are unaware of the symptoms, damage and yield losses due to rice root-knot nematode as symptoms produced are non-specific and misdiagnosed. (Ravindra *et al.,* 2016). *M. graminicola* has emerged as a pest of international importance. De Waele and Elsen 2007. In India, which was earlier found in West Bengal, Odisha, Assam, Kerala only, has also spread to newer areas of Uttar Pradesh, Delhi, Haryana, Punjab, Himachal Pradesh, Jammu-Kashmir, Tamil Nadu, Karnataka, and recently to Gujarat as per the reports from various co-operating centres of All India Coordinated Research Project (Nematodes) (Jain *et al.* 2012). It is a serious problem in the nurseries and upland rice but has been found to be widespread in the deepwater and irrigated rice also in many states of India (Prasad *et al.* 1985; Bridge *et al.* 1990; Jairajpuri and Baqri 1991). *M. graminicola* appeared in devastating form in parts of major rice growing areas of Shivamogga during 2001, which was a first report from Karnataka and subsequently, reported from Mandya district of the state (Krishnappa *et al.,* 2001). Outbreak of root-knot nematode is also observed in Shivamogga, Karnataka (Sehgal *et al.,* 2012). Initially it was noticed only in aerobic condition. Since 2011, it has been observed in anaerobic condition also and appearing in all types of rice cultivating situations. In order to know the incidence surveys were conducted in Shivamogga, Davanagere, Chikmagaluru and Mandya districts of Karnataka with respect to soil type, soil pH, soil organic carbon, type of cultivar and geographical location and host studies.

MATERIALS AND METHODS

Survey

Random Surveys were conducted in southern transition districts of Karnataka, *viz.,* Shivamogga, Davanagere, Chikamagaluru and parts of Mandya district to know the incidence of rice root-knot nematode. While collecting samples the following observations were recorded viz., soil type, type of cultivar, (GIS/GPS) Geographical information soil pH, soil organic carbon and weed hosts.

Collection of sample

Estimation of nematode population and Root Knot Index

During the survey, rice plants in both nursery and main field showing uneven patches with yellowing, stunted growth, reduced tillering with galls on roots were observed. The plants in infested patches were dried up early. Such plants were selected for sampling and minimum of five villages are visited and root and soil samples were collected and analyzed in the lab to know the population of rice root-knot nematodes and root knot index. Root knot index was recorded based on 0 to 5 scale given by Taylor and Sesser, (1978)

Analyses of soil pH

From the collected sample part of samples were used for analyses of soil pH, by using Blackman's glass electrode pH meter (soil: water: 1:2)

Analyses of soil organic carbon

Soil organic carbon (%) estimated by using Walkley and Black's (1934) rapid titration method as described by Jackson (1967)

RESULTS & DISCUSSION

The survey revealed that, there is incidence of rice root-knot nematode in all the surveyed villages. But their level of incidence varies with respect to soil type, geographical location, type of cultivar, soil pH and soil organic carbon and weed hosts. Maximum nematode population was found in Chi-kadadkatte of Davanagere district, while, Tuduru, Beguvalli, Hasudi of Shivamogga, Karagunda and Lakkavalli of Chickmagaluru district recorded highest nematodes population ranging between 586.33 to 841.00 J_2 / 100 cc of soil with root knot indices varying from 3 to 4. (Plate.1). The least incidence (210.56 and 240.66 J_2 /100 cc of soil) was observed in Kumsi of Shivamogga and Vadeyarhatturru of Davanagere district with root knot index of 1 and nematodes population ranging between 210.56 J_2 to 240.66 J_2/ 100 cc of soil (Table.1 and figure.1). Interestingly it was observed that where the places recorded highest nematode population having sandy loamy type of soil and pH level ranged between 4.41 to 5.80, soil organic carbon level varied from 0.90% to 1.44% and Jyothi was predominant cultivated variety. Whereas, the least nematode population observed in Kumsi of Shivamogga and Vadeyarhotturru of Davanagere district having clay loamy soil, pH ranges between 6.16 to 6.43 and soil organic carbon of 1.50% to 1.59%. However, the places showing highest nematode population recorded different types of weeds which showing severe incidence of root-knot nematode which also serves as alternate hosts for this nematode (Table.2 and Plate. 2). Analysis of correlation coefficient showed that population of *Meloidogyne graminicola* had significantly negative correlation with soil pH and soil organic carbon (Table3. Figure. 2). when soil pH and soil organic carbon increases the nematode population decreases. The present investigations are in conformity with the findings of Ravindra *et al.* (2014) found the incidence of root-knot nematode from all major rice growing districts of Karnataka but level of incidence differed from region to region. Soriano *et al.* (2000) found greater damage to rice varieties in sandy soils than in clay soil. Larger nematode population densities observed in the fields with light soil as compared to heavy soil (Israel and Rao, 1972; Port *et al.,* 1995). Further, Similar findings were also observed by Nagaraju *et al.* (2002) Dangal *et al.* (2009); Rehman *et al.* (2015).

Plate.1. Rice root-knot nematode infested fields A) Chi-Kadadkatte (Honnali Tq); B) V.C. Farm Mandya; C) Karagunda (N.R.Pura, Chikmagaluru)

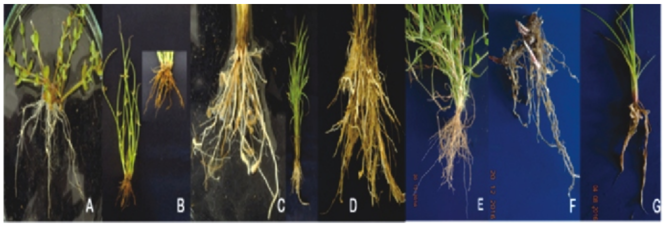

Plate. 2. *M. graminicola* infected weed hosts A) Unknown B) *Cyperus eragrostis* C) *Echinochloa crusgalli* D) *Paspalum distichum* E) *Axonopus compressus* F) *Cyperu rotundus* G) *Cynodon dactylon*

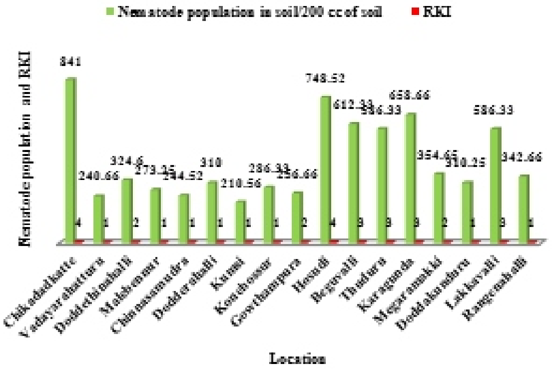

Fig 1. Incidence of rice root-knot nematode

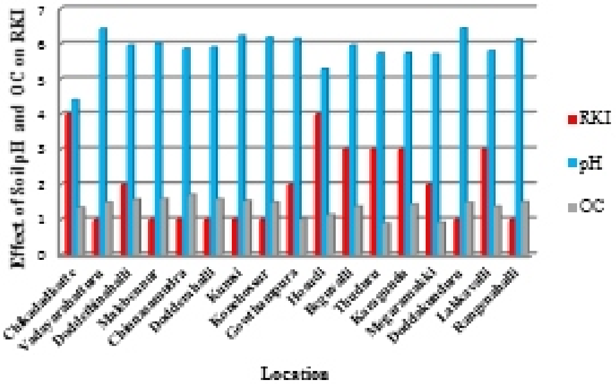

Fig.2. of soil pH and soil organic carbon on incidence of rice root-knot nematode Effect

Table 2: Reaction of weed hosts on rice root-knot nematode

S. No	Scientific name	Local name	family	RKI
A	*Unknown*	-	-	1
B	*Cyperus eragrostis* Lam.	Nutgrass	Cyperaceae	3
C	*Echinochloa crusgalli*	Wild rice	Poaceae	3
D	*Paspalum distichum L.*	Knot grass	Poaceae	4
E	*Axonopus compressus*	Carpet-grass	Poaceae	2
F	*Cyperus rotundus*	purple nut sedge	Cyperaceae	4
G	*Cynodon dactylon*	Bermuda grass	Poaceae	3

Table 3: Correlation matrix of relationship between soil pH, soil organic carbon and nematode population

Variables	X_1	X_2	X_3
Soil pH (X_1)	1	0.313	-0.516
Soil organic carbon(X_2)		1	-0.18
Nematode population (X_3)			1

N=20; *Values are significant at 0.05% significant levels. X_1: Relation of nematode population with with soil pH, X_2: Relation of nematode population with with soil organic carbon

Table 1: Incidence of rice root-knot nematode in Southern transition district of Karnataka

District name	Taluk	Village name	Variety	Latitude/ Longitude	Soil type	RKI	Nematode population in soil (J_2/100cc of soil)	Soil pH	Soil organic carbon
Davanagere	Hannali	Chikadadkatte	Jyothi	14°12’ 06.6"N 75°67’ 29.3"E	Sandy loam	4	841.00	4.41	1.35
		Vadayarahatturu	Jyothi	14°12’ 48.1"N 75°63’ 02.6"E	Sandy loam	1	240.66	6.43	1.50
		Doddethinahalli	Sanna Akki	14°13’ 82.8"N 75°59’ 53.4"E	Sandy loam	2	324.60	5.96	1.58
	Davanagere	Malebennur	Jyothi	14°34’ 98.8“N 75°74’ 02.6“E	Sandy loam	1	273.25	6.01	1.60

		Chinnasamudra	Ankur sona	14°35’ 89.4"N 76°07’ 90.7"E	Sandy loam	1	244.52	5.86	1.72
		Dodderahalli	MTU 1001	14°23 ‘94.2“N 75°60’ 36.1“E	Sandy loam	1	310.00	5.90	1.59
Shivamogga	Shivamogga	Kumsi	JJL	14°05’ 92.6"N 75°39’ 10.3"E	Clay loam	1	210.56	6.23	1.54
		Konehossur	Bhagyajyothi	14°10’ 07.0"N 75°28’ 75.4"E	Clay loam	1	286.33	6.18	1.50
		Gowthampura	JGL	14°15’ 35.5"N 75°21’ 72.5"E	Sandy loam	2	256.66	6.14	1.02
		Hosudi	Jyothi	13°92 ‘19.8"N 75°64’ 50.3"E	Sandy loam	4	748.52	5.29	1.14
	Theerthahalli	Beguvalli	MTU 1001	13°70’ 46.2"N 75°40’ 24.2"E	Sandy loam	3	612.33	5.96	1.38
		Thuduru	Jyothi Jyothi	13°71’ 54.9"N 75°37’ 49.2"E	Sandy loam	3	586.33	5.73	0.90
Chikmagaluru	N.R. Pura	Karagunda	Jyothi	13°24’ 85.2"N 76°20’ 44.5"E	Sandy loam	3	658.66	5.74	1.44
		Megaramakki	BPT Sona IET	13°41’ 49.0"N 75°46’ 06.9"E	Clay loam	2	354.65	5.71	0.93
	Tarikere	Doddakunduru	Jyothi	13°66 ‘90.0"N 75°67’26.2"E	Sandy loam	1	310.25	6.45	1.49
		Lakkavalli	Jyothi	13°69’ 86.9"N 75°54 ‘43.0"E	Sandy loam	3	586.33	5.80	1.38
		Rangenahalli	Jyothi	13°70’59.5"N 75°69’86.2"E	Sandy loam	1	342.66	6.13	1.51
Mandya	Mandya	V.C. Farm, ZARS	IR-64	12°31’ 12.4"N 76°53 ‘58.5"E	Red Sandy	4	806.33	6.25	1.70
		Chottanahalli	Thanu	12°66‘ 28.4“N 76°96 ‘14.2“N	Sandy loam	3	486.23	6.02	1.65
	K.R. Pet	Akkihebbal	IR-64	12°62‘ 26.9“N 76°38‘ 97.7“N	Sandy loam	4	654.68	6.54	1.42

CONCLUSION

The survey revealed that the incidence of *M. graminicola* varied from location to location, soil type and type of cultivar, soil pH, soil organic carbon and wed hosts. *M. graminicola* is soil borne in nature it is adapted to congenial condition favored in these districts and continuous growing of susceptible cultivar Jyothi, soil pH and soil organic carbon and weed hosts prevailing in paddy fields results in spreading throughout all rice growing areas of the Shivamogga, Davanagere, Chickmagaluru and Mandya districts.

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IMPACT OF GERMINATION ON NUTRITIONAL AND ANTI-NUTRITIONAL FACTOR IN CHICKPEA (CICER ARIETINUM) AND GREEN GRAM *(VIGNA RADIATA)*

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ABSTRACT

Commonly consumed pulses type viz., chickpea and green gram were tested under processing method of germination at 30°C for 48hr after soaking. The present study was conducted to evaluate the effect of germination on nutritional, anti-nutritional, total phenolic content and antioxidant activity (DPPH) in pulses flour. The nutritional composition of pulses flours was analyzed using AOAC methods. Anti-nutritional and antioxidant properties were measured in terms of oxalates, tannins, total phenolic contents. The results showed that the sprouting process showed a maximum influence on the nutritional, antioxidant and anti-nutritive factors. Total ash content for RCF (Raw Chickpea Flour), GCF (Germinated chickpea Flour), RGGF (Raw Green Gram Flour) and GGGF (Germinated Green Gram flour) were 3.8±0.16, 3.7±0.11, 3.88±0.09 (g/100g) and 3.91±0.04 (g/100g). Chickpea and green gram are good source of protein and in the same line protein content was 6.9±0.18 in RGGF, 9.8±0.30 in GGGF, 7.2±0.4 g/100g in RCF and 9.5±0.4 g/100g in GCF. Mineral analysis of processed forms of green gram revealed that calcium and iron content increased significantly during germination as followed by chickpea. Tannin content decreases with an increase in germination. The reduction in tannin was about 50% in green gram (0.374 mg/g) and the highest was recorded in chickpea (2.85 mg/g). The highest amount of saponin content was found in green gram (37.53 mg/g) followed by chickpea (33.16 mg/g) after germination. Phytic acid content for RGGF was 854.4±1.5 mg/100g, in germination it was 281.5±1.2 mg/100g (GGGF) and in RCF it was 741.1±1.09 mg/100g (RCF) while in GCF was 375±1.5 mg/100g. It also increased DPPH radical scavenging activity of pulses flours. As germinated pulses flours are rich source of antioxidant properties with good radical scavenging activity could be recommended to develop functional foods for the treatment of various degenerative diseases. Household food processing strategies like germination can be used for improving the nutritional quality to promote green gram and chickpea utilization.

Key Words: Chickpea, Green gram, Germination, Anti-nutritional, Antioxidants

Globally, legumes play a significant role in diets; on the Indian subcontinent, chickpea (Cicer arietinum) is the second and green gram (Vigna radiata L.) is third most important pulse crop. It is recommended for feeding infants and the elderly since it is an excellent source of high-quality protein and amino acids and is almost free of substances that cause flatulence (Dattatray *et.al*, 2020). Due to a lack of sulfur-containing amino acids and the presence of anti-nutritional elements as phytates, polyphenols, protease inhibitors, etc., raw green grams and chickpea are only of secondary nutritional value. This may be avoided by improving the nutritional quality through the use of three strategies: fortification, processing, and biotechnology (Uppal & Bains, 2012).

Chickpea is a vital legume grown in India, with a production of 2.926% and a yield of 651 kg/ha. Chickpea is a rich source of carbohydrates, protein, essential amino acids, polyphenols, and dietary fiber, making it a valuable consumer product in the Indian subcontinent (Kumar *et. al*, 2020). Its snacks are widely available, sweet, and cost-effective. However, other legumes are underutilized due to undesirable flavors and antinutritional compounds like trypsin inhibitors. Germination and roasting are commonly used methods for preparing snacks and ready-to-eat foods, which reduce these compounds and improve their nutritional value (Walker *et.al*, 2007). These processes simplify complex compounds, enhancing their nutritional value and reducing undesirable flavors. Overall, Chickpea offers a viable alternative to other legumes in the Indian subcontinent.

Green gram is a rich source of dietary proteins and fiber, aiding digestion and absorption of food. It plays a crucial role in cholesterol metabolism, controlling blood cholesterol levels (Badau *et. al*, 2005). Green gram is recommended for consumption in various forms, such as cooking with vegetables or meats, desserts, or as a starch or flour in food products. However, anti-nutritional factors limit its food applications. Germination, or sprouting, is a traditional process to overcome these issues. Green gram sprouts can be eaten fresh or cooked as a vegetable accompaniment to meals. Although literature suggests nutrient improvement in green gram sprouts through germination, there is limited information on the nutrient alteration when seeds sprout until true leaves appear, known as high chlorophyll green gram sprouts (Vayupharp *et. al*, 2013).

Germination is a slow, natural process that occurs at low temperatures, altering the metabolic activities and digestibility of carbohydrates. It enhances protein content, antioxidants, and nutrient bioavailability. Roasting, a high-temperature controlled process, improves digestibility, shelf life, and antioxidant properties (Singh *et.al*, 2017). Exposure to high temperatures leads to the development of characteristic flavors, tastes, and crisp texture in grains. These processes also enhance the functional properties of grains and legumes, affecting their processing applications, quality, acceptance, and formulation of ready-to-eat snack foods (Jogihalli, *et.al*, 2017). Germination and roasting also affect the pasting properties, determining the textural characteristics of cooked legumes, and aiding in designing process parameters.

The current study evaluated the impact of the germination process on the phenolic content and antioxidant capacity of green gram and chickpea seeds in order to produce an extract or flour that is suitable for use as an ingredient in supplements or medications due to its high nutritional value and antioxidant activity.

MATERIALS AND METHODS

The seeds of green Gram and chickpeas were purchased from a nearby market in Meerut, Uttar Pradesh, India. After manually cleaning the seeds to get rid of any foreign objects, they were processed in a home flour mill to a 60-mesh flour.

Sample preparation The cleaned grains that were collected were subjected to a 24-hour oven drying process at 40°C, followed by a draining and washing process (Model No. DHG-9101 ISA). To create raw green gram flour (RGGF) and raw chickpea flour (RCF), which were used as controls the dried green gram.

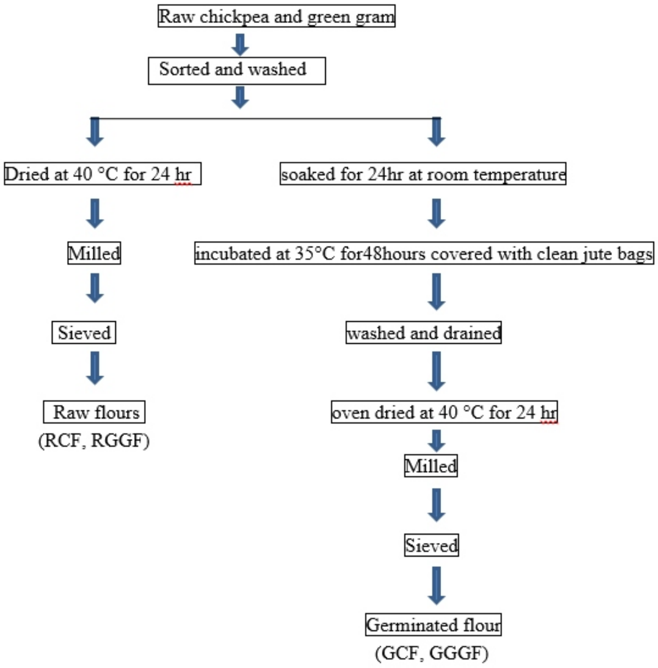

Fig. 1. Preparation of germinated and raw fours (chickpea and green gram)

Chickpea grains were ground and sieved (with a 100 ìm screen diameter). The cleaned grains were immersed in water for 24 hours at room temperature in order to initiate the germination process. Grain was soaked, and water was then drained. Chickpea and green gram seeds were placed one on top of the other on clean jute bags, covered with a moist cotton cloth, and allowed to germinate for 48 hours at 35°C. To accelerate the germination process, water was sprayed on the seeds during the 4-hour interval. The ideal temperature for green gram and chickpea grains to germinate is between 28 and 35°C. Once this temperature is reached, the rate of germination typically rises until it hits 42 to 72 hours. Upon germination, the germinated grains underwent a distilled water wash, draining, and a 24-hour oven drying process at 40°C. Dried germinated grains were milled and sieved (100 ìm mesh sieve) to obtain germinated green gram flour (GGGF) and germinated chickpea flour (GCF). Airtight plastic containers contained such flours. In preparation for additional examination, the packaged germinated flour was kept at room temperature (Fig.1).

Proximate Analysis

The approximate values were obtained using the techniques outlined by AOAC (1990): crude protein through the Kjeldahl method using a Kjeltec (Tecator TM, 91716369) (method 978.04), crude fat through soxhlet extraction (method 930.09), crude fiber through defatting, extraction, and ashing (method 930.10), ash incinerating in a muffle furnace (Gallenkamp, SG93/11/888) (method 930.05), moisture by drying at 105°C in an oven (Genlab DC 500, 12B154) (method 930.04)]. The carbohydrate content was calculated by subtracting the total of the values of crude protein, crude fat, crude fiber, ash, and moisture from 100 (Bakare *et al.*, 2020).

Minerals content

Following the wet-ashing process, the minerals were measured using concentrated nitric acid and perchloric acid (1:1, v/v). An atomic absorption spectrophotometer (Perkin–Elmer, Model 2380, USA) was used to measure Mg, Mn, and Fe, while flame photometry (Corning 410, England) was used to quantify Na, K, and Ca. Using the phosphorus molybdate complex that Taussky and Shorr (1953) reported, phosphorus was measured photometrically.

Anti-nutritional factors

According to AOAC (1990), total tannins were measured calorimetrically. Wheeler and Ferrel (1971) technique were used to quantify the amount of phytic acid. Using the spectrophotometric approach described by Brunner (1994), the saponin content of samples of flour was measured. In addition to adding 100 ml of isobutyl alcohol, also known as But-2-ol, 2 g of the finely powdered material was weighed into a 250 ml beaker. To make sure the concoction was mixed evenly, it was shaken for five hours using a shaker. A 100 ml beaker containing 20 ml of a 40% saturated solution of magnesium carbonate (MgCo3) was filled with the combination after it had been filtered using No. 1 Whatman filter paper. After a second filtering using No. 1 Whatman filter paper, the combination was obtained with a clear, colorless solution. Using a pipette, transfer 1 ml of the colorless solution into a 50 ml volumetric flask. Add 2 ml of 5% iron (iii) chloride ($FeCl_3$) solution, and top up with distilled water. In order for the color to develop, it was let to stand for thirty minutes. At 380 nm, the absorbance was measured in relation to the blank.

The procedure for determining oxalate included digesting the sample in HCl, precipitating the oxalate using a solution of NH_4OH, 5% $CaCl_2$, and 10% H_2SO_4, and titrating permanganate (Onwuka 2005). The formula 1 ml of 0.05 m $KMnO_4$ solution = 0.00225 g oxalate was used to determine the oxalate content. Using the following formula, the oxalate content was determined:

$$\%\ \text{oxalate} \quad 100 \quad \frac{\text{Litre} \quad 0{:}00225 \quad W}{2}$$

Where, W = Weight of sample used

Determination of antioxidant properties

The extract's capacity to scavenge free radicals against DPPH (1,1-diphenyl-2-picrylhydrazyl) was assessed using the Gyamfi *et al.*, (1999) technique. After combining 1 ml of the extract with 1 ml of the 0.4 mM methanolic DPPH solution, the combination was exposed to the dark for 30 minutes. The absorbance at 516 nm was then measured. Using the following formula, the activity was represented as a percentage of DPPH scavenging in comparison to the control.

$$\text{DPPH Scavenging Activity (\%)} \quad \frac{\text{absorbance of control} - \text{absorbance of sample}}{\text{Absorbance of control}} \quad 100$$

Total phenol content was carried out according to the method described by Singleton et. Al., (1999). 2.5 ml of folic-calciocalteure agent (10%) and 2 ml of sodium carbonate (7.5%) were combined with about 0.2 ml of the extract. After incubating the reaction mixture for 40 minutes at 45 °C, the absorbance was measured in the spectrophotometer (Spectrum 23A Spectrophotometer, Gulfex Medical and Scientific, England) at 700 nm. Garlic acid equivalents (GAE)/g samples were utilized to indicate the total phenol concentration, with gallic acid serving as the reference phenol.

Statistical analysis

The trials were carried out in triplicate, and using Microsoft Excel 2007, the mean ± standard deviation (SD) of three independent replications was reported.

RESULTS AND DISCUSSION

Effect of germination on the Proximate Analysis of Green gram and chickpea flour

Table 1 shows the chemical compositions of green gram and chickpea seeds, both raw and germinated. The proximate composition of green gram flour and chickpea flour increased following germination, with the exception of fat and carbohydrates (Table 1). Protease biosynthesis during germination (Elobuike *et al.*, 2021; Sharma *et al.*, 2023A) and the loss of nutrients due to the hydrolysis of the protein-enzyme-mineral connection might be the cause of the protein's augmentation (Shah *et al.*, 2011). This result is consistent with the research conducted by several other writers, including Afam *et al.* (2016), Sharma *et al.* (2023B), Kaushik *et al.* (2010), and Shah *et al.* (2011).

As a result of its decline during sprouting, fat may be used as an energy source (Afam *et al.*, 2016; Sharma *et al.*, 2023C; Elobuike *et al.*, 2021; Shah *et al.*, 2011). Dietary fibre is crucial for controlling weight and bowel movements. Studies by Devi *et al.* (2015) and Elobuike *et al.* (2021) corroborate the flour's increased ash and crude fiber levels, respectively. As sprouting grew, the moisture content marginally rose as well. A rise in the number of hydrated cells within the seed might be the cause of the moisture content's gradual increase (Sharma *et al.*, 2023A).

However, the rate at which seeds absorb water during sprouting changes over time, resulting in a variation in moisture content (Devi *et al.*, 2015). Moisture increases during bean sprouting have also been recorded by Elobuike *et al.* (2021), Shah *et al.* (2011), and Devi *et al.* (2015). Ohtsubo *et al.*(2005), however, noticed a contrary outcome when brown rice was growing. The findings of Sharma *et al.* (2022), Mubarak *et al.* (2005), and Uppal and Bains (2012) are consistent with the flour samples' decreased carbohydrate levels. According to Shah *et al.* (2011), the catabolic activity of á-amylase may be the cause of the reduction in carbohydrates during sprouting. As to Kumar *et al.* (2020), during the sprouting process, developing seedlings use carbohydrates as a source of energy. The observed decrease in carbohydrates supports the use of chickpea and green Gram seeds as part of a helpful diet for managing weight or any other health problem connected to diet that necessitates low carbohydrate consumption.

Effect of germination on the Proximate Analysis of Green gram and chickpea flour

The calcium content of RGGF was shown to rise from 89.21 to 96.50 mg/100g during germination, however it fell from 96.50 to

Table 1: Effect of germination processes on the proximate composition of chickpea and green gram seeds (g/100 g dry weight basis)

S.No.	Moisture	Protein	Ash	Fat	Fiber	Carbohydrate
RCF	8.0±0.12	7.2±0.04	3.8±0.16	6.12±0.01	3.39±0.12	71.49±0.12
GCF	8.75±0.11	9.5±0.40	3.7±0.11	5.72±0.15	5.11±0.25	67.22±0.21
RGGF	9.37±0.32	6.9±0.18	3.88±0.09	1.82±0.18	3.85±0.02	74.18±0.18
GGGF	10.85±0.25	9.8±0.30	3.91±0.04	1.35±0.19	4.81±0.02	69.28±0.13

Note. Values represent the mean of triplicate ± standard deviation. Means with no common letters within a row differed (p = 0.05). RCF- raw chickpea flour, GCF- germinated chickpea flour, RGGF- raw green gram flour, GGGF- germinated green gram flour.

141.6 mg/100g in chickpea flour (Table 2). For raw green gram flour, Chauhan & Sarita (2018) found that the calcium concentration rose during germination, measuring 342.4 mg/100 g. As a result of oxalic acid levels decreasing during germination, green gram's calcium content appropriately increased since oxalic acid is known to impede the absorption of calcium (Ejike *et al.*, 2020). According to this finding, the germinated flour could be a useful calcium source. After germination, the amount of calcium dropped from 33.09 to 12.50 mg/100 g, according to Abd El-Moneim *et al.* (2012).

When the RGGF germinated, the magnesium level was found to rise from 65.5 to 68.2 mg/100g, however it fell from 161.5 to 155.2 mg/100g in the chickpea flour. Tarek, *et al.* (2002) observed a reduction in magnesium content during the germination of chickpeas, while Elobuike, *et al.* (2021) showed a rise in magnesium content on germinated green grammar flour.

During germination, it was discovered that the potassium content of green grams (5.28 to 5.65 mg/100g) and chickpeas (520.2 to 850.5 mg/100g) increased. For the body to receive these nutrients for proper operation, the processed chickpea flour's increased mineral content is essential. Shakirah *et al.* (2022) suggests that a decrease in ANFs during germination may be the cause of the bioprocess chickpea samples' notable rise (p=0.05) in mineral content.

After germination, raw green grams contain 3.62 to 3.95 mg/l00 g of potassium and 84.00 to 88.50 mg/100 g of calcium, according to Mubarak *et al.* (2005). The importance of potassium in the diet stems from its involvement in nerve function and blood sugar management.

For green gram flour, the iron level was 10.39 mg/100g, but for chickpea flour, it was 6.98 mg/100g. Iron concentration, however, dropped after germination; for chickpea flour, it was 6.23 mg/100g. Following germination, the iron content of green gram flour rose to 11.10 mg/100g, the highest value recorded (Table 2). Phytase enzyme activity may have increased during germination, which might account for this. The minerals will be released and made more readily available when the enzyme hydrolyzes the bond that holds the protein and the enzyme minerals together (Aserse *et al.*, 2022). Shakirah *et al.* (2022) found that the iron content of non-germinated green gram flour was 181.75 mg/100g while that of germinated green gram flour was 406.4 mg/100g. This result was comparable to their findings.

Minerals are necessary for immune system function, bone strength, and the proper operation of nerve and muscle cells. The presence of anti-nutritional substances may be the cause of the reduction in iron content during chickpea germination. According to Abd El-Moneim *et al.* (2012), chickpea germination resulted in a reduction in iron concentration. According to Sharma *et al.* (2023B), although chickpeas are high in minerals, their bioavailability is often limited because of anti-nutritional factors. Because phytate is soluble in water, additional minerals may be released after soaking as a result of the release of bounded minerals with phytate (Sharma *et al.*, 2023B).

Table 2. Effect of germination processes on the mineral composition of chickpea and green gram seeds (g/100 g dry weight basis)

S.No.	Calcium	Magnesium	Potassium	Phosphorus	Iron
RCF	156.2±0.02	161.5±0.125	520.2±0.25	225±0.214	6.98±0.14
GCF	141.6±0.36	155.2±0.11	850.5±0.21	240±0.21	6.23±0.78
RGGF	89.21±0.14	65.5±5.36	5.28±0.04	398±0.21	10.39±0.21
GGGF	96.50±1.25	68.2±0.15	5.65±0.5	420±0.14	11.10±0.14

Note. Values represent the mean of triplicate ± standard deviation. Means with no common letters within a row differed (p =

0.05). RCF- raw chickpea flour, GCF- germinated chickpea flour, RGGF- raw green gram flour, GGGF- germinated green gram flour.

Effect of germination on the Antinutritional factors of green gram and chickpea flour

The antinutritional characteristics of raw and germinated flours are displayed in Table 3. During germination, the tannin concentration in the raw flour (2.85 mg/g and 0.76 mg/g) for chickpea and green gram, respectively, was found to dramatically decrease to 2.21 mg/g and 0.34 mg/g. Increased enzymatic activity and polyphenol leaching in soaking water might be the cause of a reduction in tannin during germination (Jogihalli, et. al. 2017). These findings were more closely tied to the Aserse Yenasew *et al.* (2022) publication on finger millet. Mubarak *et al.* (2005) recorded a decrease in the tannin concentration of green Gram following germination, which is a comparable finding. Green Gram (42%) had the lowest percentage of tannin content reduction during germination, whereas Chickpea (64%) had the biggest reduction.

The highest amount of saponin was recorded during germination in GGGF, followed by GCF. The saponin content significantly increased in chickpea and green gram flour after germination . This increase was due to the displacement of stored phyto-chemicals from the germinated grains (Owheruo et. al.2018). Saponin is beneficial for human organ function and treating various diseases. , saponin for humans as it is an ant nutritional factor which is increasing in the study. Vegeterian human diet usually sums upto 200 mg of daily saponin in take by Bhosale *et at.* (2021)

The abundance of phyto-chemicals in legumes enhances nutraceutical potential, making them a reliable source of functional foods. The indigestion status of saponin content is related to a decrease in overall blood sugar.

Chickpea and green gram flours' respective phytochemical contents dropped dramatically (p=o.05) from 741.1 to 375.5 mg/g and 854.4 to 281.5 mg/g. Following germination, chickpeas had the lowest percentage decrease of phytic content (36.2%) while green gram flour had the largest percentage reduction (57.9%). Increasing the activity of phytase, which hydrolyzes phosphorus from phytate to inositol monophosphate, may be the cause of the decrease in phytic content following germination (Aserse Yenasew et.al. 2022). During the germination of green gram grains (Elobuike *et al.* 2021) and chickpea (Tarek *et al.* 2002), a comparable decrease in phytic content was noted. The decrease in phytic concentration during germination may be caused by phytase activation during germination as well as leaching away during hydration. Similar patterns in the phytic acid concentration of finger millet decreasing during germination were also documented by Sharma *et al.* (2022).

Oxalic acid is broken down into hydrogen peroxide and carbon (IV) oxide during sprouting, which leads to the release of calcium, according to Chauhan & Sarita (2018). Legumes' antinutrients reduced as the sprouting period grew, according to reports from a number of different researchers (Ejike *et al.*, 2020; Devi *et al.*, 2015; Uppal & Bains, 2012).

Effect of germination on the Antioxidant properties of green gram and chickpea flour

Table 4 displays the total phenol concentration and DPPH of the raw and germinating flour samples. In Fig. 2, the content of free radical scavenging activity (DPPH) rose considerably (p=0.05) from 25.25% to 38.42% and 18.34% to 30.0% for both the non-germinated and germinated chickpea and green gram. Enzymatic antioxidant activity is present in both raw and germinated grains; GCF was found to have the largest rise of DPPH (13.17%), followed by GGGF. A substance's capacity for reduction might account for some of its possible antioxidant action (Aserse Yenasew *et al.*, 2022). According to Owheruo *et al.* (2018), Table 4 indicates that green gram and chickpeas may be used as a source of antioxidants to stop undesirable compounds from building up in the body since they can DPPH. Comparable outcomes have been observed in pearl and finger millet, indicating an increase in antioxidant activities. This phenomenon may be explained by the actions of enzymes generated by microorganisms, the metabolism of phenolic compounds by fermenting microbes, and the release of bound phenols (Shikha 1 *et al.*, 2023).

Table 3. Effect of germination on the Ant nutritional factors of raw and germinated chickpea and green gram seeds

Antinutritional factors	RCF	GCF	RGGF	GGGF
Tannin (mg/g)	2.85±0.20	2.21±0.07	0.76±0.01	0.34±0.02
Saponin (mg/g)	33.16±0.44	48.51±0.01	37.53±1.02	53.70±1.21
Phytic acid (mg/g)	741.1±1.09	375.5±1.5	854.4±1.5	281.5±1.2
Oxalate (mg/g)	143.2±0.11	112.1±0.15	98.56±0.15	77.3±0.21

Note. Values represent the mean of triplicate ± standard deviation. Means with no common letters within a row differed (p = 0.05).

Following germination, the total phenol content (TPC) in the chickpea and green gram flour samples rose considerably (p=0.05) from 75.11 to 108.4 mg GAE/100g and 83.6 to 96.1 mg GAE/100g, respectively (Table 4). Similar findings were also reported by Singh *et al.* (2014), who found that the TPC rose as the pulses germinated. Similar results were found for green gram and chickpea during germination, wherein the active degrading enzymes in the cell wall of the grain changed its structure and resulted in an increase in phenolic compounds in the grain (Owheruo *et al.* 2018) suggest that the enzymatic release of bound phenolic chemical may be the cause of a rise in TPC upon germination. Phenols extend the shelf life of cereal, millet, and pulse products and add to the antioxidative capacity of grains. The methanol extractable TPC of finger millet increased with its germination and fermentation at varying temperatures, according to Shakirah *et al.* (2022). This phenomenon was linked to the synthesis of hydrolytic enzymes that altered the structure of the cell wall and produced new compounds with potential for bioactivity.

Note. Values represent the mean of triplicate ± standard deviation. Means with no common letters within a row differed (p = 0.05). RCF- raw chickpea flour, GCF- germinated chickpea flour, RGGF- raw green gram flour, GGGF- germinated green gram flour.

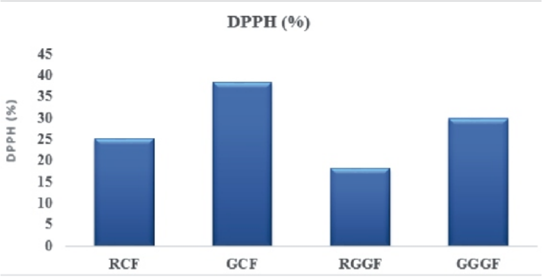

Fig 2: Graphical representation of Anti-oxidant analyses of raw and germinated chickpea and green gram flour.

Table 4. Effect of germination on the Antioxidant properties of raw and germinated chickpea and green gram seeds

Antioxidant	RCF	GCF	RGGF	GGGF
DPPH (%)	25.25±0.02	38.42±1.25	18.34±0.23	30.0±2.5
Total phenol (mg GAE/100g)	75.11±0.15	108.4±1.0	83.6±0.14	96.1±0.25

Note. Values represent the mean of triplicate ± standard deviation. Means with no common letters within a row differed (p = 0.05).

CONCLUSION

A conventional method of processing known as germination has been shown to improve the physicochemical, antioxidant, and antinutritional qualities of chickpea and green gram flour. The germination process was shown to enhance the amount of protein, fiber, and ash in the pulse flour in this study, but to dramatically reduce the amount of fat and carbohydrates. Germination of chickpea & green gram flour improves their protein, fiber and ash content while reducing fat and carbohydrates. It enhances antioxidant propesties increase calcious and iron levels and raise moisture content. This process can meet the nutritional needs of infants and young children supporting their growth & development. The moisture content rose. The maximum calcium and iron content pulses were found in germinated green grams. In order to promote an infant's or young child's early growth and development, it was determined that the germination process can boost the availability of minerals and help meet their nutritional demands. With the exception of saponin, the germination treatment considerably reduced the quantity of antinutritional factors while increasing the mineral content. Furthermore, germination raised the total phenolic content and DPPH in both flours. This increased antioxidant activity points to the possibility of creating a nutrient-rich product for therapeutic diet sand that uses germinated flours. This discovery will support the use of germinated flour in the production of gluten-free foods for celiac disease sufferers. Additionally, the results indicate that the development of baked goods, confections, fried foods, and foods with significant textural qualities will benefit from the use of germinated flour.

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EFFECT OF LIQUID BIOFERTILIZERS AND APPLICATION METHODS IN INCREASING PRODUCTIVITY AND PROFITABILITY OF FINGER MILLET

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ABSTRACT

A field study was conducted in finger millet to find out the effect of liquid bio fertilizer consortia and their methods of application (seed treatment, soil application, seed treatment+ soil application) in combination with graded levels of recommended dose of fertilizers (100% RDF, 85% RDF and 70% RDF and control) at Agricultural Research Station, Vizianagaram during *kharif*, 2020. The experiment was carried out in randomized bock design with three replications. 100% RDF + STLBF + SALBF resulted in higher grain yield, straw yield net returns and benefit cost ratio as compared to other treatments. The grain yield improvement in 100% RDF + STLBF + SALBF was around 14.75% compared to 100% RDF and 156.20% improvement over absolute control, however, it was found at par with 85% RDF + STLBF+SALBF and 100% RDF + SALBF. Soil application or seed treatment + soil application of liquid bio fertilizer were found superior among the application methods. From this study it was observed that upto 15% of RDF can be substituted with liquid bio fertilizer application in finger millet.

Key words: Finger millet; Liquid bio fertilizer; Soil application; Seed treatment; Yield; Economics

Finger millet is the major nutri-cereal widely grown in Asian and African countries as rainfed as well as irrigated crop. In India, it is being grown as rainfed crop under low input management by poor and marginal farmers in marginal soils. Hence, the actual productivity of finger millet obtained in India is much lesser than the potential productivity. Finger millet responds very well to the good management practices, particularly to the nutrient management. All the high yielding cultivars exhibit their maximum potential with the increased supply of fertilizer nutrients in the presence of other favorable conditions. However, the escalating cost of inorganic fertilizers, environmental hazards associated with them and failure in sustaining crop yields have given way for integrated use of organic and inorganic sources of nutrients, which would help to mitigate the soil fatigue and improving biological power of the soil. Liquid biofertilizers are the microbial preparations containing specific beneficial microorganisms which are capable of fixing or solubilizing or mobilizing plant nutrients by their biological activity (Chandra *et al*., 2005). Liquid biofertilizers (LBF) can reduce the chemical fertilizer requirement of crops by 15-40% in various types of soils. Further LBF protect the plants from soil borne diseases and enhances crop growth and development by producing plant growth promoting substances. Keeping these points in view, an experiment was taken up to find out the best method of application of liquid bio fertilizers and the best possible combination of LBF with chemical fertilizers to achieve maximum productivity as well as profitability of finger millet

MATERIALS AND METHODS

This study was conducted during *kharif*, 2020 at research farm of Agricultural Research Station, Vizianagaram, Andhra Pradesh, India. The site of the experiment was sandy loam in texture with neutral in soil reaction, low in organic carbon, soil available nitrogen, high in available phosphorus and low in available potassium. Experiment consisted of eleven treatments *viz.*, T_1- 100% RDF + Seed treatment with liquid bio fertilizer (STLBF) + soil application of liquid bio fertilizer (SALBF) , T_2- 100% RDF + STLBF , T_3- 100% RDF + SALBF, T_4- 85% RDF + STLBF + SALBF, T_5- 85% RDF + STLBF, T_6- 85% RDF + SALBF, T_7- 70% RDF + STLBF + SALBF,T_8- 70% RDF + STLBF, T_9- 70% RDF + SALBF, T_{10}- Recommended dose of fertilizer (100% RDF), T_{11}- Absolute control were laid out in randomized block design with three replications. Consortia of liquid bio fertilizer contain *Azospirillum lipoferum*, *Bacillus megaterium* and *Frateuria aurantia*. For seed treatment, 4-5 ml of liquid bio fertilizer per 1 kg seed was mixed with equal quantity of 10% jaggery solution and coated the mixture uniformly on the seed and shade dried for 10 minutes before sowing (Khandare *et al.,* 2020). For soil application in one-hectare area, 7.5 liters of liquid biofertilizer was diluted with 25 liters of water and then mixed with 500 kg of well decomposed farmyard manure then incubated overnight. Then the farm yard manure was applied in furrows at the time of sowing.

Finger millet variety Sri Chaitanya (VR-847) was sown on July 18 during 2020 with a row to row and plant to plant spacing of 30 cm × 10 cm. Recommended dose of NPK fertilizers (50-40-25 kg/ha) were applied in the form of urea, single super phosphate and murate of potash. Total quantity of P and K fertilizers were applied as basal at the time of last ploughing and N fertilizer was applied in two split doses at basal and at tillering stages.

Plant height and productive tillers/plant were measured randomly from five plants in each plot. For measuring the dry matter accumulation, five plants were selected randomly from each plot during the time of maturity and cut at the base and dried in oven until to get the constant weight. The 1000-filled grains, taken from sampled ear heads, were first counted and then weighed to compute the 1000-grain weight. After harvesting, threshing, cleaning and drying the grain yield was recorded. Cost of cultivation, gross returns, net monetary returns and benefit cost ratio were computed based on the prevailing market prices of the inputs, grain yield and straw yield during the respective crop season. All the data recorded were subjected to statistical analysis by adopting the method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of on growth attributes

Application of liquid bio fertilizer consortia through different methods showed significant variation among the growth parameters of finger millet. Among all the treatment combinations, 100% RDF+STLBF+ SALBF recorded longer days to maturity (116 days), which was significantly higher than other treatments except 100% RDF + SALBF, 85% RDF + STLBF + SALBF, 85% RDF + STLBF, 85% RDF + SALBF. As compared to absolute control, all other treatments showed significant improvement in plant height. Moreover, liquid bio fertilizer application along with 85% RDF-100% RDF had prominent influence on plant height as compared to 100% RDF alone. Combined application of inorganic, organic and biological nutrient sources not only increase the nutrient availability through atmospheric fixation, solubilization, mineralization processes but also induce the production of plant growth-promoting substances, which could resulting in increased plant height. These results are in accord with Deepti *et al.* (2022) and Sivamurugan *et al.* (2018). SPAD chlorophyll readings of all the treatments showed significant improvement over the absolute control. Liquid bio fertilizer application through various methods along with 85% RDF - 100 % RDF showed an extent of 4.4-35.6% improvement in the number of productive tillers per plant as compared to 100% RDF alone. Dry matter accumulation of 100% RDF +STLBF+SALBF was higher, however it was on par with all other treatments except absolute control. Higher plant height, more number of productive tillers coupled with increased assimilation due to prolonged growing period might have contributed to higher dry matter accumulation in 100% RDF + STLBF + SALBF and vice versa for absolute control. The test weight of finger millet also influenced positively with bio fertilizer application as compared to RDF alone. 100% RDF +STLBF+SALBF showed higher test weight, which was found on par with 100% RDF + SALBF, 100% RDF + STLBF, 85% RDF + STLBF + SALBF, 85% RDF + SALBF and 85% RDF + STLBF. The lowest test weight was recorded with absolute control.

Table 1: Effect of liquid biofertilizers and their mode of application on growth and yield of finger millet

Treatments	Days to maturity	Plant height (cm)	SPAD chlorophyll readings	Productive tillers/plant	Dry matter at harvest (kg/ha)	1000 seed weight (g)
T_1- 100% RDF + STLBF + SALBF	116.0	115.9	41.01	6.1	10000	3.30
T_2- 100% RDF + STLBF	114.3	113.3	39.98	5.4	9444	3.23
T_3- 100% RDF + SALBF	115.3	115.6	40.71	5.7	9778	3.27
T_4- 85% RDF + STLBF + SALBF	115.0	113.3	40.75	5.5	9444	3.23
T_5- 85% RDF + STLBF	113.7	112.1	38.63	4.7	8867	3.13
T_6- 85% RDF + SALBF	114.7	112.9	39.76	5.0	9244	3.20
T_7- 70% RDF + STLBF + SALBF	114.0	109.9	39.11	4.7	8567	3.00
T_8- 70% RDF + STLBF	112.3	103.0	37.86	4.0	7889	3.00
T_9- 70% RDF + SALBF	113.0	107.4	38.59	4.1	8333	2.97
T_{10}-100% RDF	113.7	109.5	39.78	4.5	8978	2.90
T_{11}- Absolute control	111.7	94.1	32.81	3.3	5778	2.67
S.Em±	0.63	3.3	1.08	0.5	729.9	0.06
C.D.(P=0.05)	1.85	9.7	3.18	1.6	2153.0	0.17

Table 2: Effect of liquid biofertilizers and their mode of application on yield and economics of finger millet

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha	Net return (Rs./ha)	B:C Ratio
T_1- 100% RDF + STLBF + SALBF	2380	6635	54822	2.32
T_2- 100% RDF + STLBF	2100	6253	47724	2.22
T_3- 100% RDF + SALBF	2186	6489	48422	2.05
T_4- 85% RDF + STLBF + SALBF	2192	6202	49185	2.13
T_5- 85% RDF + STLBF	2049	5765	46593	2.23
T_6- 85% RDF + SALBF	2111	5917	46517	2.02
T_7- 70% RDF + STLBF + SALBF	1970	5579	42423	1.89
T_8- 70% RDF + STLBF	1803	5171	39056	1.92
T_9- 70% RDF + SALBF	1872	5326	39192	1.74
T_{10}-100% RDF	2074	6212	46872	2.18
T_{11}- Absolute control	929	4253	-	-
S.Em±	108.6	211.7	-	-
C.D.(P=0.05)	320.4	624.5	-	-

Effect on Yield and Economics

Liquid bio fertilizer application in combination with NPK fertilizers increased the grain yield of finger millet to an extent 1.25- 14.75% as compared to 100% RDF alone. The method of application of liquid bio fertilizers also had a significant influence on grain yield at all the fertilizer levels. Seed treatment + soil application of liquid bio fertilizer was found more effective as against the seed treatment or soil application alone. The grain yield and straw yields of finger millet recorded with 100% RDF + STLBF + SALBF were found higher, however they were found on par with the grain yield and straw yields of 100% RDF + STLBF, 100% RDF + SALBF, 85% RDF + STLBF + SALBF, 85% RDF + STLBF + SALBF and 100% RDF treatments. As compared to the recommended dose of fertilizer, the grain yield increase in finger millet was 14.75%, 5.69% and 5.40% respectively with 100% RDF + STLBF + SALBF, 85% RDF + STLBF + SALBF and 100% RDF + SALBF. Addition of liquid bio fertilizer to the soil not only increases the plant absorbable nutrients but also improves the use efficiency of applied fertilizers. Sufficient nutrient availability throughout the crop growing period resulted in higher drymatter accumulation, more yield contributing characters and grain yield. These results corroborated with the results reported by Patil *et al.* (2022) in finger millet and Pagare *et al.* (2022) in little millet and Singh *et al.* (2016) in pearl millet. Absolute control recorded with the lowest grain and straw yield. Bhagchand and Gautam (2000) reported that the use of biofertilizers led to higher availability of nitrogen and phosphorus that promoted growth and development and ultimately resulting in higher yields. Considering the economics, highest net returns were registered with 100% RDF + STLBF + SALBF, however it was closely followed by 85% RDF + STLBF + SALBF and 100% RDF + SALBF. The lowest net returns were registered with absolute control. These results corroborated with the results reported by Pagare *et al.*, 2022; Upadhaya *et al.*, 2022, Latake *et al.*, 2009 and Choudhary and Gautam, 2007. Benefit cost ratio was higher for 100% RDF + STLBF + SALBF, but it was closely followed by 100% RDF + STLBF, 85% RDF + STLBF, 100% RDF and 85% RDF + STLBF + SALBF.

CONCLUSION

Experimental results revealed that application of 100% RDF + STLBF + SALBF or 85% RDF + STLBF + SALBF or 100% RDF + SALBF was found effective in increasing the grain yield and economics as against the 100% RDF alone. The use of biofertilizers may also have some positive effects on soil phyico-chemical properties

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