

**THE JOURNAL
OF
RURAL AND AGRICULTURAL RESEARCH**

Volume 25

Number 2

June 2025

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Biofortification: A long-term solution to improve global health: A review

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Introduction

Biofortified crops are staple foods (like rice, wheat, maize, sweet potato) bred to have higher levels of essential vitamins and minerals (iron, zinc, Vitamin A) using traditional breeding or biotechnology, providing a sustainable way to combat “hidden hunger” (micronutrient deficiencies) without changing diets or requiring extra processing, offering a long-term, cost-effective health solution for vulnerable populations. Nutritious diet is vital for proper growth and development in humans. It helps in preventing diseases, besides maintaining the body metabolism for physical- and mental- well-being. Food provides energy, protein, essential fats, vitamins, antioxidants and minerals to meet our daily metabolic requirement. Most of them cannot be synthesized in human body, therefore are to be supplemented through diet. Further, anti-nutritional factors present in edible parts of the food exert adverse effects on human health. Indian Council of Agricultural Research (ICAR) has improved the nutritional quality in high yielding varieties of cereals, pulses, oilseeds, vegetables and fruits using breeding methods. Special efforts were initiated during 12th Plan with the launching of a special project on Consortium Research Platform on Biofortification. Concerted efforts in collaboration with other national and international initiatives has led to the development of 87 varieties of rice (8), wheat (28), maize (14), pearl millet (9), finger millet (3), small millet (1), lentil (2), groundnut (2), linseed (1), mustard (6), soybean (5), cauliflower (1), potato (2), sweet potato (2), greater yam (2) and pomegranate (1). In addition, a

large number of advance elite materials are in pipelines and will be released in due course of time. These biofortified varieties assume great significance to achieve nutritional security of the country. Special efforts are being made to popularize these biofortified varieties among masses. Quality seeds of biofortified varieties are being produced and made available for commercial cultivation. Extension Division of ICAR has also launched two special programmes viz. Nutri-sensitive Agricultural Resources and Innovations (NARI) and Value Addition and Technology Incubation Centres in Agriculture (VATICA) for up-scaling the biofortified varieties through its Krishi Vigyan Kendra’s (KVK’s).

Types of Malnutrition

Malnutrition is caused by consumption of unbalanced diet. It affects most of the world’s population at some point in their lifecycle during infancy to old age. Every country experience one or the other form of malnutrition. It affects all geographies, age groups and people from rich to poor. Malnutrition exists in different forms:

- * Undernutrition: Lack of proper nutrition caused by not having enough food.
- * Stunting: Low height as per age in children under five years of age due to limited access to food, health and care.
- * Wasting: Thin for their height in children under five years of age because of acute food shortages or disease.
- * Micronutrient deficiencies: Suboptimal nutritional status

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caused by lack of intake, absorption or use of one or more vitamins or minerals.

- * Moderate and severe thinness or underweight.

Global Hunger Index

The Global Hunger Index (GHI) is a tool for comprehensively measuring and tracking hunger at global, regional, and national levels over recent years and decades. GHI score is based on a formula that involves three dimensions of hunger, viz., (i) insufficient caloric intake (undernourishment) in the population, (ii) undernutrition among children, and (iii) child mortality using four indicators:

Undernourishment: Share of the population that is undernourished, reflecting insufficient caloric intake.

Child wasting: Share of children (<5 years) who possess low weight for height, reflecting acute undernutrition.

Child stunting: Share of children (<5 years) who possess low height for age, reflecting chronic undernutrition.

Status of Malnutrition

Malnutrition contributes to increased morbidity, disability, stunted mental and physical growth, and reduced national socio-economic development. The extent of malnutrition worldwide as well as in India is presented below:

Global scenario

- * 2.37 billion do not have access to adequate food.
- * 768 million people are undernourished.
- * 118 million more people faced hunger in 2020 in comparison to 2019.
- * 20.5 million new-borns (14.6 % of all live births) have a low weight at birth.
- * 149.2 million (22.0%) children (12 million avoidable deaths among adults).
- * In Southern Asia, 30.7 % and 14.1 % of the children (<5 years) are stunted and wasted, respectively.

Indian scenario

- * 15.3 % of the population are undernourished.
Neonatal mortality rate (NNMR): 24.9 per 1,000 births.
- * Infant mortality rate (IMR): 35.2 per 1,000 births.
- * Child (< 5 years) mortality rate (U5MR): 41.9 per 1,000 live births.
- * 35.5 % of the children (<5 years) are stunted, 19.3 % wasted and 7.7 % severely wasted.

- * 32.1 % of the children (<5 years) are under-weight.

- * 3.4 % of the children (<5 years) are over-weight.

- * 18.7 % women and 16.2 % men possess BMI below normal (<18.5).

- * 24.0 % of women and 22.9 % of men are overweight or obese (BMI \geq 25.0).

- * 67.1 % of the children (6-59 months) are anaemic.

- * 57.2 % of non-pregnant, 52.2 % pregnant and 57.0 % of all women (15-49 years) are anaemic.

- * 59.1 % of all women (15-19 years) are anaemic.

- * 25.0 % of men (15-49 years) are affected due to anaemia.

- * 31.1 % of men (15-19 years) are anaemic.

- * 13.5 % of women and 15.6 % of men possess high or very high blood Sugar.

- * 21.3 % women and 24.0 % men possess elevated blood pressure.

- * India's GHI score is 27.5 (serious category).

- * India ranks 101 among 116 countries in relation to GHI.

- * India loses over US\$12 billion in GDP per year to vitamin and mineral deficiency.

Biofortification

Four avenues are generally practiced to alleviate malnutrition

Food fortification

It is a process of physically adding vital nutrients to the food in order to enrich it. For example, (i) iron, folic acid and vitamin B12 fortified wheat and rice flour, (ii) iron and iodine fortified salts, (iii) vitamin-A and vitamin-D fortified oil and milk, have been permitted by Food Safety and Standards Authority of India (FSSAI), Govt. of India.

Medical supplementation

It is a process of providing vital nutrients through pills. For example, Govt. sponsored programmes, (i) Weekly Iron Folic Acid Supplementation (WIFS) programme for school adolescent boys and girls (10- 19 years) and out of school girls (10-19 years) in urban and rural areas, and (ii) Vitamin-A Supplementation (VAS) programme for children under five, are in place India.

Dietary diversification

It is a process of including diverse cereals, pulses, oilseeds, vegetables and fruits in the diet in order to enhance the nutritional status.

Crop biofortification

It is a process of enhancing the nutritional quality of edible parts of the plants through genetic approach such as plant breeding. For example, iron and zinc rich wheat grains (ii) protein and zinc rich rice grains, and (iii) vitamin-A rich maize grains.

Merits of biofortification

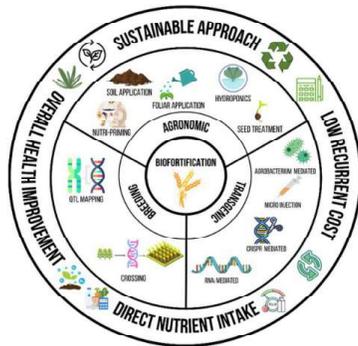
- * It is regarded as the most sustainable approach to alleviate malnutrition.
- * It provides nutrients in natural form; thus, nutrients enter the body as part of natural food matrix.
- * People can afford the ‘biofortified food’ as it does not involve any additional price.
- * ‘Biofortified varieties’ are as high yielding as ‘traditional varieties’, thus no loss is incurred to the farmers.
- * It does not require elaborate infrastructure facility as required in ‘food fortification’.
- * It does not need elaborate distribution system as required in ‘medical supplementation’.
- * It does not involve additional cost on preparing the enriched food grains.

How they work

Increased nutrient density: The plants naturally accumulate more micronutrients during growth.
 Simple mechanism: Eating more of these nutrient-dense crops means consuming and absorbing more essential vitamins and minerals.

Key benefits

- Sustainable: A one-time investment in breeding provides continuous nutritional benefits.
- Cost-effective: No extra cost for farmers or consumers during cultivation or consumption.



Addresses “hidden hunger”: Fights widespread micronutrient deficiencies impacting growth, immunity, and sight.

Common examples:

- Vitamin A: Golden Rice, sweet potato, cassava, maize.
- Iron: Beans, pearl millet, wheat, rice.
- Zinc: Maize, rice, wheat, pearl millet.

Breeding methods of development:

- * Conventional breeding: Selecting and crossing plants with desired traits.
- * Genetic engineering/biotechnology: Modifying genes (e.g., CRISPR) for enhanced nutrition.
- * Agronomic practices: Applying specialized fertilizers (e.g., zinc-enriched).

Why they matter

- * Unlike food fortification (adding nutrients during processing), biofortification enriches the food at the source.
- * They reach rural populations who may not access fortified foods, improving public health in resource-limited settings.

Releases of Biofortified Crops

Cumulatively, more than 400 biofortified varieties of 12 crops have been released in more than 40 countries, which includes all varieties facilitated by Harvest Plus plus orange sweet potato varieties developed independently by CIP. Candidate biofortified varieties across 12 crops are being evaluated for release in an additional 20 countries.

Conclusion

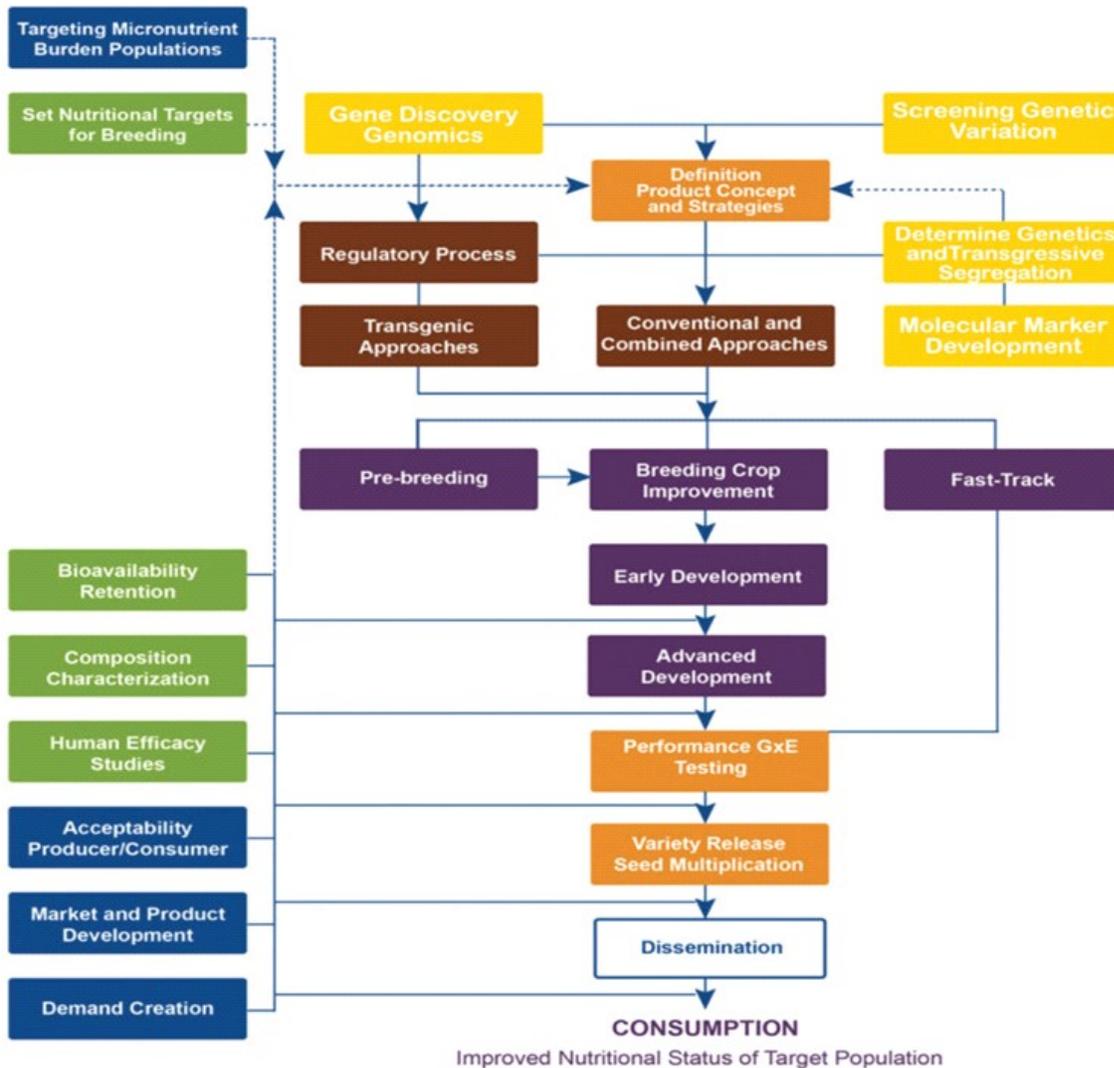
Current successes and impact

Proven Effectiveness: Randomized controlled trials have confirmed that biofortified crops, such as iron-rich beans in Rwanda and vitamin A-rich orange sweet potatoes in Mozambique, significantly improve nutritional status and cognitive performance in vulnerable populations.

Cost-Effectiveness: Biofortification is a highly economical intervention. Every \$1 invested can yield up to \$17 in economic benefits. Unlike traditional fortification, which requires recurring costs, biofortification utilizes a one-time investment in seed development that stays “fixed” in the germplasm.

Reach: It uniquely targets underserved rural populations who rely on home-grown staples and lack access to commercial supplements or processed fortified foods.

India’s Progress: India has emerged as a leader, developing over 70 nutrition-rich crop cultivars across staples like wheat, rice, maize, and pearl millet.



Future prospects and emerging frontiers

Multi-Nutrient “Stacked” Biofortification: The future is shifting from single-nutrient improvements to “multi-nutrient” or “combinatorial” biofortification. Researchers are using gene-stacking and genetic engineering (e.g., CRISPR-Cas9) to simultaneously increase iron, zinc, and provitamin A in a single variety.

Climate-Smart Traits: To combat declining nutrient densities caused by rising CO₂ levels, future varieties are being developed to combine high nutrition with climate-resilient traits like drought and pest resistance.

Precision Agronomy and Nanotechnology: Emerging “Nano-fertilizer-assisted biofortification” offers a way to precisely deliver nutrients to plants, increasing absorption efficiency and reducing environmental runoff compared to traditional fertilizers.

Microbe-Mediated Approaches: The use of beneficial soil microorganisms (like *Bacillus* and *Pseudomonas*) is a growing sustainable frontier to enhance nutrient solubility and uptake in the rhizosphere.

Mainstreaming Goals: A major strategic goal for 2030 is to “mainstream” biofortified traits into all public

Table 1: Varieties developed through conventional breeding

Crop	Variety	Trait	Country	Year release	
Rice	DRR Dhan 45	Zn	India	2016	
	DRR Dhan 48, DRR Dhan 49	Zn	India	2017	
	Saurbhi	Zn	India	2017	
	Fedearroz BIOZn 035	Zn	Colombia	2021	
	Inpara 11 Siam HiZInc	Zn	Indonesia	2022	
	BRR1 Dhan 64	Zn	Bangladesh	2014	
	CR 310, CR 311	Protein	India	2018	
	Zinco Rice MS	Zn	India	2018	
	WB 02, HPBW 01	Fe, Zn	India	2017	
	Pusa Tejas	Protein, Fe	India	2017	
	Pusa Ujala	Protein, Fe, Zn	India	2017	
	Wheat	HD 3171	Zn	India	2017
Nohely F2018		Zn	Mexico	2018	
TARNAB-REHBAR		Zn	Pakistan	2023	
TARNAB-GANDUM-I		Zn	Pakistan	2023	
Zinc Gahun-1		Zn	Nepal	2020	
HI 8777		Zn, Fe	India	2018	
MACS 4028		Protein, Zn and Fe	India	2018	
PBW 752		Protein	India	2018	
Maize		Vivek QPM 9	lysine and tryptophan	India	2008
		Pusa HM8 Improved, Pusa HM4	lysine and tryptophan	India	2017
	Pusa Vivek QPM9 Improved	provitamin-A, lysine and tryptophan	India	2017	
	ZS246A	Vitamin A	Africa	2016	
	ZS500A	Vitamin A	Africa	2019	
	ICTA HB-18ACP + Zn	Zinc	Guatemala	2018	
	Fortaleza 17	Zinc	Guatemala	2020	
	SGBIOH2	Zinc	Colombia	2019	
	Pusa HQPM 5 Improved, Pusa HQPM 7	provitamin-A, lysine and tryptophan	India	2020	
	Pearl-millet	Improved, IQMH 201	provitamin-A, lysine and tryptophan	India	2020
RHB 233, RHB 234		Iron and zinc	India	2019	
ICSR 14001, ICSH 14002		Iron	India		
VR 929		Iron	India	2020	
LCIC MV5		Iron	Nigeria	2023	
Chakti		Iron	Nigeria	2018	
Sorghum	CFMV1, CFMV 2	Calcium, iron and zinc	India	2020	
	CLMV1	Iron and zinc	India	2020	
	Parbhani Shakti	Zinc	India	2018	
Finger Millet	Pusa Ageti Masoor	Iron	India	2017	
Little Millet	IPL 220	Iron and zinc	India	2018	
	IPL 220	Iron and zinc	India	2018	
Lentil	Kufri Manik, Kufri Neelkanth	Anthocyanin	India	2020	
	Bhu Sona, Bhu Krishna	Provitamin-A, Anthocyanin	India	2017	
	Rasuwa black	Iron	Nepal	2020	
	Barimasur-4, B-5, B-6	Iron	Bangladesh	2010	
Cowpea	CBC6	Iron	Zimbabwe	2021	
	Pant Lobia-7	Iron	India	2019	
	BRS Araca	Iron	Brazil	2009	
Beans	RWR 2245; RWR 2154; MAC 42; MAC 44; CAB 2; RWV 1129; RWV 3006;				
	RWV 3316; RWV 3317; RWV 2887	Iron and zinc	Rwanda	2014	

Sweet Potato	Delvia	Vitamin A	Zimbabwe	2021
	Kokota, Chumfwa, Olympia	Vitamin A	Zambia	2014
	Gerald, Joweria	Vitamin A	Uganda	2013
Cassava	Slicass 12	Vitamin A	Sierra Leone	2014
	UMUCASS 44	Vitamin A	Nigeria	2014
	UMUCASS 52, UMUCASS 53, UMUCASS 54	Vitamin A	Nigeria	2022
Banana	Apantu, Bira, Pelipita, Lai, To'o	Vitamin A	Uganda	2022
Mango	Amarpali, Pusa Arunima, Pusa Surya, Pusa Lalima, and Pusa Shreshth	Beta-carotene, Vitamin C	India	2022
	Ataulfo	Beta-carotene, Vitamin C	Mexico	2022
Grapes	Pusa Navrang	Antioxidants	India	2022

plant breeding programs, making high mineral and vitamin content a standard requirement for all new variety releases.

Key challenges for the future

Consumer Acceptance: Visible traits, like the orange colour in vitamin A-rich maize or rice, require sustained social marketing to gain public trust.

Regulatory Barriers: Transgenic (GM) crops often face strict regulatory hurdles and political opposition, particularly in Europe, despite their potential for higher nutrient densities.

Scaling and Policy: Full impact depends on integrating biofortified crops into government programs like school feeding schemes and public distribution systems (e.g., India's PDS).

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Role of Women in Indian Agriculture (1950–2025): An Overview

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Abstract

Women play a central yet under acknowledged role in Indian agriculture. Over the last seven decades (1950–2025), structural changes in the agricultural sector, economic reforms, technology, migration, and education have reshaped their participation. This paper provides a comprehensive assessment of women’s contributions as cultivators and agricultural laborers, their educational progress, and implications for policy. Using historical data, national surveys, and projections, it charts trends in women’s agricultural participation, interprets shifts in roles, and analyzes key socio economic factors. The study also evaluates policy frameworks and recommends actionable measures to strengthen women’s position in Indian agriculture, emphasizing access to land, credit, mechanization, extension services, training, and social security. The findings underline that despite progress in education and empowerment, women continue to shoulder disproportionate unpaid work and face structural barriers that inhibit productivity, income, and agency in farming decisions.

Key words: Women, Indian Agriculture, empowerment, agricultural sector, economic reforms

Introduction

Agriculture has long been the backbone of the Indian economy, employing a significant share of the workforce and contributing to food security and rural livelihoods. Within this sector, women form a substantial, yet frequently invisible, component of the labor force. Historically, Indian women have engaged in sowing, weeding, harvesting, livestock care, post-harvest processing, and household food security tasks. However, patriarchal land ownership norms, limited access to resources, and measurement biases in official workforce statistics have often underreported their contributions.

Since India’s independence in 1947, the agricultural landscape has evolved through the Green Revolution, liberalization in the 1990s, and technological advancement in the 21st century. These transformations have had mixed impacts on

women’s roles. Mechanization reduced drudgery for certain operations but also displaced women in tasks like sowing and harvesting. Meanwhile, male out migration from rural areas increased women’s responsibilities on family farms.

Understanding women’s roles in agriculture is critical for designing gender responsive policies that enhance productivity, ensure equity, and promote rural development. This paper examines changes in women’s agricultural participation from 1950 to 2025, identifies trends, explores drivers of change, and offers policy recommendations.

Objective

The primary objectives of this research are:

1. To document trends in women’s participation in Indian agriculture from 1950 to 2025.

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2. To analyze changes in roles as cultivators, laborers, and contributors to farm and allied activities.
3. To assess socio economic factors influencing women's agricultural engagement, including education, mechanization, and migration.
4. To interpret implications of these trends for productivity, income, and gender equity in agriculture.
5. To propose policy recommendations for strengthening women's participation and welfare in agricultural systems.

Methodology

Data Sources:

This research uses secondary data from:

- * Census of India rural workforce statistics
- * National Sample Survey Office (NSSO) employment surveys
- * National Family Health Survey (NFHS)
- * Ministry of Agriculture & Farmers Welfare reports
- * FAO and World Bank gender and labor reports
- * Published research articles and journals on gender in agriculture

Time Frame:

The study covers 1950–2025, divided into decadal intervals to capture long term trends.

Indicators Used

Indicator	Definition
Female Share of Agricultural Workforce (%)	Proportion of female agricultural workers within total agricultural workforce
Women Cultivators (%)	Women engaged in land cultivation
Women Agricultural Laborers (%)	Women working as hired agricultural labor
Female Literacy in Rural Areas (%)	Percentage of rural women who can read and write

Data Analysis

Descriptive statistical techniques were used to analyze trends. A multibar graph was created to visually compare changes across key indicators over time. Interpretation focused on socio economic drivers, gender norms, and policy context.

Results and Discussion

Trends in Women's Participation (1950–2025)

The table 1 shows a steady rise in women's participation in Indian agriculture from 1950 to 2025.

The female share of the agricultural workforce increased from 32% in 1950 to 44% in 2025, reflecting the growing feminization of agriculture. However, the proportion of women cultivators declined from 27% in the 1970s–1980s to 22% in 2025, indicating reduced land ownership and decision-making roles. In contrast, women agricultural laborers rose sharply from 35% to 46%, highlighting increasing dependence on wage labor. This trend underscores gender inequality in access to land, assets, and secure livelihoods within Indian agriculture.

Socio economic factors influencing women's agricultural Food Production

Table 2. highlights the strong influence of socio-economic factors particularly land ownership and education on women's contribution to agricultural food production in India from 1950 to 2025. In 1950, women owned only 5% of land and rural female literacy was extremely low (8%), yet women already contributed 35% to food production, reflecting their heavy involvement as unpaid family labor. Over time, gradual improvements in women's land ownership from 5% in 1950 to 15% in 2025 have enhanced their decision-making power, access to credit, and adoption of improved farming practices.

A sharp rise in rural female literacy, especially after 1990, has further strengthened women's skills, productivity, and awareness of modern agricultural techniques. Consequently, women's contribution to food production steadily increased to 52% by 2025. Overall, the table shows that expanding women's land rights and education are crucial for boosting agricultural productivity, food security, and inclusive rural development.

Table 1: Women in Indian Agriculture (1950–2025)

Year	Female Share of Agricultural Workforce (%)	Women Cultivators (%)	Women Agricultural Laborers (%)
1950	32	25	35
1960	34	26	36
1970	35	27	36
1980	36	27	37
1990	38	26	39
2000	40	25	41
2010	42	24	43
2020	43	23	45
2025*	44	22	46

Sources: Government reports and FAO

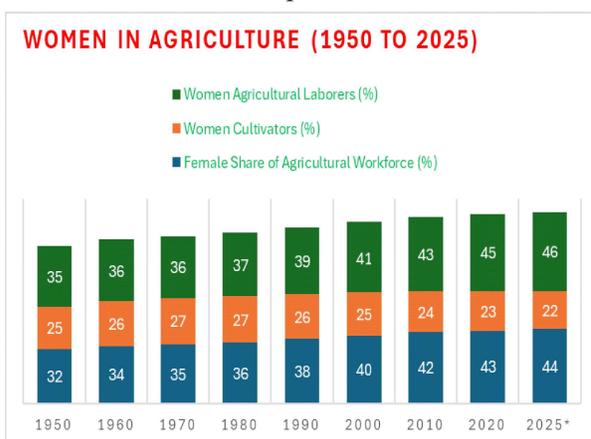


Figure: 1

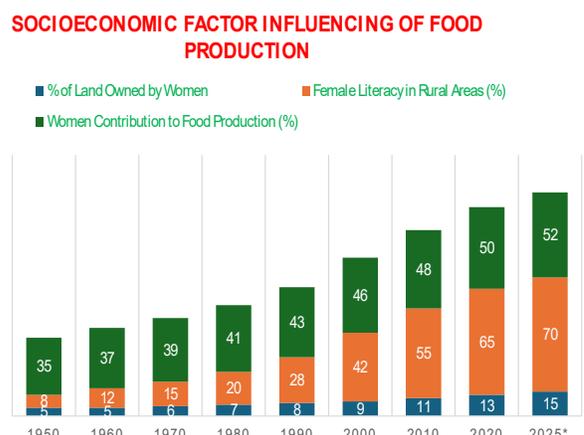


Figure: 2

Table 2: Socio economic factors influencing women’s agricultural Food Production, including education & land holding

Year	% of Land Owned by Women	Female Literacy in Rural Areas (%)	Women Contribution to Food Production (%)
1950	5	8	35
1960	5	12	37
1970	6	15	39
1980	7	20	41
1990	8	28	43
2000	9	42	46
2010	11	55	48
2020	13	65	50
2025*	15	70	52

Sources: Government reports, FAO & Census of India

*Projections based on 2020 trends and national education goals

Women's participation in allied agricultural sectors

The table 3 highlights the extensive participation of women across India's agricultural and allied sectors, underscoring their central role in rural livelihoods. Women constitute about 65% of the agricultural workforce, reflecting their dominance in crop-related activities. Their involvement is even higher in dairy farming (70–85%) and livestock management (around 70%), where they handle daily animal care, feeding, and processing. In fisheries, women's participation reaches about (44–72%), particularly in inland and post-harvest activities. Horticulture shows a variable but significant share (33–64%), indicating growing engagement in high-value crops. Overall, the data reveals women as the backbone of allied agriculture, though often under-recognized and under-supported.

Table 3: Women's participation in allied agricultural sectors (India)

Sector	Approximate women's share (%)
Agriculture	65%
Dairy farming	70–85%
Livestock (other)	70%
Fisheries	44–72%
Horticulture	33–64%

Sources: Government reports, FAO, Industry surveys & Census of India

Policy and Recommendations

1. Land Rights and Ownership

- * Issue: Women often act as de facto farm managers but are not recorded as landowners.
- * Recommendation: Reform land titling so spouses are joint landowners, thereby increasing access to credit and investments.

2. Access to Credit and Inputs

- * Issue: Women face limited access to formal credit, mechanization, and quality inputs.
- * Recommendation: Expand women centric credit schemes and subsidized access to machinery (e.g., seeders, transplanters) and climate resilient technologies.

3. Agricultural Extension and Training

- * Issue: Extension services are male biased in delivery and timing.
- * Recommendation: Recruit and train gender aware extension agents, provide flexible training schedules, and launch digital platforms targeting women farmers.

4. Social Protection and Safety Nets

- * Issue: Women laborers lack social security and predictable incomes.
- * Recommendation: Strengthen programs like Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) with dedicated quotas for women and integrate pension and insurance benefits.

5. Education and Skill Development

- * Issue: Though literacy is rising, technical agricultural education for women remains low.
- * Recommendation: Promote agriculture vocational training centers for women, integrating business skills and market linkages.

6. Recognition and Data Inclusion

- * Issue: Official data underreports women's contribution, especially in unpaid work.
- * Recommendation: Revise labor surveys to include time use data and recognize women as farm decision makers.

Conclusion

The role of women in Indian agriculture has evolved significantly from 1950 to 2025. While their share in the agricultural workforce has increased, the nature of participation reflects structural challenges. Women continue to be key contributors, especially as laborers and de facto managers, but have limited access to land, resources, and decision making authority. Improvements in literacy and education bring promise for future empowerment, yet institutional barriers persist.

Addressing these requires a gender responsive agricultural strategy that ensures equitable access to land, credit, technology, training, and social protections. Reimagining agriculture policy with gender at its core will not only improve women's livelihoods but will enhance productivity and sustainability in Indian agriculture as a whole.

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A Comparative Study of Association between Different Variables of Two District of Haryana State

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Abstract

Adolescence refers to the period of development and adjustment during the transitional period between childhood and adulthood. The term adolescent means 'to emerge' or 'achieve identity.' India has largest adolescent population in the world. Family being the first and major agency of socialization has great influence and bearing on the development of the child. It is the home which sets the pattern for the Childs' attitude towards people and society, aids intellectual growth in the child and supports his achievements. Next to family, school is the most important experience process of child development. These two environments not only affect the educational aspiration of adolescents but also affect directly or indirectly on the academic achievement of children. The present study was done in Hisar and Bhiwani districts of Haryana State. For the study 200 girls and 200 parents (200 fathers and 200 mothers) were selected randomly from the selected schools and villages. The present work was done to find the association between different variables of school and family environment. It was found from the results that in urban area, majority of girls with functional environment somewhat preferred jobs (32%) followed by least preferred jobs (30%), while only 14 percent most preferred for jobs. It can be observed in rural area that majority of adolescent girls with bottom level (20%), mediocre level (22%) and top level (16%) self-managing had somewhat preferences for jobs.

Key words: Adolescence, rural, urban, association, environment, school

Introduction

Adolescence refers to the period of development and adjustment during the transitional period between childhood and adulthood. The term adolescent means 'to emerge' or 'achieve identity.' India has largest adolescent population in the world. According to the UNICEF's flagship (1987) 'World's Children report stated that country's adolescent constituted 20.0% of the world's 1.2 billion adolescents.

Adolescents carve out ambitious plans for their future. During this critical stage in the life cycle, a young person's social, economic, legal and political

status is transformed. Adolescence is a time of preparation for the adult roles of worker, citizen and community participant, spouse, parent, and household manager. Adolescence is also a time of gender differentiation.

Two environments, home and school share an influential space in individual's life and there exists a unique combination between the two. The family environment and the school environment have regularly been linked in the scientific literature to psychosocial and behavioural adjustment/problems in the adolescent period (Este'vez, *et al.* 2005;

Murray and Murray, 2004; Stevens *et al.* 2002). The quality of adolescent-parent, adolescent-peer and adolescent-teacher interactions influence and may determine, the way adolescents perceive themselves in relation to others, their attitudes and their behaviours (Lila *et al.* 2006; Werner, 2004).

Family being the first and major agency of socialization has great influence and bearing on the development of the child. It is the home which sets the pattern for the Childs' attitude towards people and society, aids intellectual growth in the child and supports his achievements. A highly significant positive relationship between the variables of academic achievement and family scores had been assessed.

Next to family, school is the most important experience process of child development. These two environments not only affect the educational aspiration of adolescents but also affect directly or indirectly on the academic achievement of children. Pupils immediate environment is the classroom where unique face-to-face group interaction marked by interpersonal relationships among its members. These interpersonal relationships essentially include teacher-student relationship and peer relationship. The general atmospheres within the academic activities that take place influence the social relationships. Two types of social interactions occur in the classroom Teacher vs. Students and students vs. students. First one is the most referred one in educational context. However, the interaction going on amongst students is equally significant from a psycho-social view point. The success or the failure of the students also depends on the quality of classroom's social climate (Sunitha, 2005).

Research shows a significant positive association between healthy school and family environments and adolescents' well-being and academic success, with studies indicating that positive family environments, strong parental involvement, and supportive school climates contribute to better emotional, social, and educational adjustment. Negative aspects in either environment can lead to challenges like poor self-esteem, anxiety, and impaired social functioning, highlighting the interconnected nature of these influential spheres in adolescent development.

Adolescence is a period of transition between childhood and adulthood. Individuals getting into adolescence undergo several changes. A young person should develop robust skills to manage these developmental changes. Resilience has been outlined as an individual's ability to perform aptly in the face of adversity or stress. Teens face daily challenges like unsatisfying test scores, sports losses, or relationship problems. A resilient adolescent is likely to bounce back from their life challenges and develop better ways of coping. It is widely known that the family environment has a greater influence on an individual's personality. Thus, this paper focuses on examining the relationship between adolescent family environment and their resilience. (Fernandez and Varghese, 2023)

Research consistently shows a strong, positive association between supportive family and school environments and adolescent well-being, including better academic achievement, emotional adjustment, and social functioning. A positive family environment, characterized by high parental involvement and emotional support, is a crucial factor for academic success, while a supportive school climate also plays a significant role in promoting positive outcomes. Studies demonstrate that supportive environments, whether at home or in school, can mitigate negative factors and foster overall positive development in adolescents. The foundation of many associated elements in the educational process, the home environment serves as an external support resource to guarantee teenagers' academic achievement. It serves as the foundation for children's socialization and the source of successful academic development.

Methodology

The study was conducted in Haryana state purposively. Two districts, Hisar and Bhiwani were selected randomly from Haryana state on the basis of rural female literacy rate i.e. in between 65%. The total sample of 200 adolescent girls and 200 parents (200 mothers & 200 fathers) were selected for the study, thus making a total sample of 600. Two variables were taken for the study i.e. Dependent and independent. Parents were taken as dependent variable and parent-child relationship was taken as

dependent variable. Association between dependent, situational and psychological variables was calculated with the help of structured performance.

Results and Discussion

Association between dependent, situational and psychological variables Association of adolescent girls' preference for job opportunities with family environment in Hisar district

Association of family environment with preference of job opportunities has been depicted in both the areas of Hisar district from Table 1. It can be observed that majority of adolescent girls with abusive environment, most preferred (36%) followed by somewhat preferred (22%) for jobs. Majority of distressed adolescent girls from rural Hisar least preference (16%) followed by somewhat preference (12%) for jobs, while all the adolescent girls belonging to functional environment in both the areas had least preference (14%) for jobs. The reason behind these findings might be that from functional family environment children feel more secure than distressed and abusive family environment. The calculated chi-square (χ^2) values were found to be significant (39.05* for rural and 39.2* for urban areas). Thus, indicating that family environment was positively associated with preferences of jobs.

The result could be supported by Chope (2006) stated that supportive family environments with high expectations were associated with "high level educational and occupational aspirations". This could be supported by Navin (2009) found that parental attachment, defined as the extent to which one feels emotionally close to and supported by one's parents,

was positively related to career exploration. Positive correlation was of education and income with knowledge about job opportunities and job preferences for parents. Printed booklet on job opportunities for adolescent girls was found to be effective. Further, it revealed that media changed knowledge and job preferences of the respondents at a great extent. Positive relationship with education, income and material possession was observed while age, occupation, family environment etc. was negatively associated with knowledge and job preferences.

Scholars have focused on issues related to adolescents' cognitive and non-cognitive abilities (Adams, 2021), prosocial and problem behavior (Karmakar, 2017; Padilla et al., 2018), social development (Walters, 2013), and academic achievement (Zhang et al., 2020). One study found that successful and informed families support children's social and non-cognitive development, and that a positive family environment and parent-child relationships support the development of physical and mental health (Marcenaro and Lopez, 2017; Obimakinde et al., 2019). Parents may help children build their information literacy, raise their reading and arithmetic scores, and directly promote cognitive growth by talking to them, taking them to museums, or documenting their everyday experiences (Sibley and Dearing, 2014; Choe, 2020).

Association of adolescent girls' preference for job opportunities with family environment in Bhiwani district

Association of family environment with preference of job opportunities has been depicted in

Table 1: Association of adolescent girls' preference for job opportunities with family environment in Hisar district (n=200)

Family Environment	Preference for Job Opportunities							
	Rural				Urban			
	Least preferred	Somewhat preferred	Most preferred	Total	Least preferred	Somewhat preferred	Most preferred	Total
Abusive	0(0.00)	11(22.0)	18(36.0)	29(58.0)	0(0.00)	11(22.0)	19(38.0)	30(60.0)
Distressed	8(16.0)	6(12.0)	0(0.00)	14(28.0)	8(16.0)	5(10.0)	0(0.00)	13(26.0)
Functional	7(14.0)	0(0.00)	0(0.00)	7(14.0)	7(14.0)	0(0.00)	0(0.00)	7(14.0)
Total	15(30.0)	17(34.0)	18(36.0)	50(100.0)	15(30.0)	16(32.0)	38(38.0)	50(100.0)
		$\chi^2 = 39.05^*$				$\chi^2 = 39.2^*$		

Table 2: Association of adolescent girls' preference for job opportunities with family environment in Bhiwani district (n=200)

Family Environment	Preference for Job Opportunities							
	Rural				Urban			
	Least preferred	Somewhat preferred	Most preferred	Total	Least preferred	Somewhat preferred	Most preferred	Total
Abusive	8(16.0)	10(20.0)	6(12.0)	24(48.0)	0(0.00)	0(0.00)	5(10.0)	5(10.0)
Distressed	0(0.00)	0(0.00)	12(24.0)	12(24.0)	0(0.00)	0(0.00)	7(14.0)	7(14.0)
Functional	0(0.00)	0(0.00)	14(28.0)	14(28.0)	15(30.0)	16(32.0)	7(14.0)	38(76.0)
Total	8(16.0)	10(20.0)	32(64.0)	50(100.0)	15(30.0)	16(32.0)	19(38.0)	50(100.0)
	$\chi^2=11.6^*$		$\chi^2=27.4^*$					

both the areas of Bhiwani district from table 2. It can be observed that in rural area, majority of adolescent girls with abusive environment had somewhat preference (20%) followed by least preference (16%), while adolescent girls with distressed environment (24%) and 28 percent with functional environment most preferred jobs.

In urban area, majority of girls with functional environment somewhat preferred jobs (32%) followed by least preferred jobs (30%), while only 14 percent most preferred for jobs. The calculated chi-square (χ^2) values were found to be significant (11.6* for rural and 27.4* for urban areas). Thus, indicating that family environment was positively associated with preferences of jobs.

Association of adolescent girls' preference for job opportunities with school environment in Hisar district

Association of school environment with preference of job opportunities has been depicted in both the areas of Hisar district from table 3. It can be observed in rural area that equal number of adolescent girls with bottom level and top-level self managing had most preference (20%) for jobs followed by somewhat preferences (6%). Majority of adolescent girls with mediocre level self managing had somewhat preferences (20%) followed by least preferences (14%) for jobs.

In urban area, majority of girls with bottom level (20%) and mediocre level (28%) self managing had most preferences for jobs while top level self managing had somewhat preferences (16%) followed by least preferences (16%) for jobs.

The calculated chi-square (χ^2) values were found to be significant (12.45* for rural and 14.83* for urban areas). Thus, indicating that school environment was positively associated with preferences of jobs.

Association of adolescent girls' preference for job opportunities with school environment in Bhiwani district

Association of school environment with preferences of job opportunities has been depicted in both the areas of Bhiwani district from table 4. It can be observed in rural area that majority of adolescent girls with bottom level (20%), mediocre level (22%) and top level (16%) self managing had somewhat preferences for jobs.

In urban area, similar trend was observed i.e. majority of girls with mediocre level (30%), bottom level (18%) and top level (14%) self managing had somewhat preferences for jobs. The calculated chi-square (χ^2) values were found to be significant (5.04* for rural and 8.27* for urban areas). Thus, indicating that school environment was positively associated with preferences of jobs.

Kaur and kalaramna (2004) conducted a study to assess the existing levels of inter-relationship between family environment and socio-economic status and found that socio-economic status and family environment affected social environment. Study revealed that with the increase in socio-economic status, the level of recognition of social environment (0.324***), tactfulness (0.293***), sense of humour (0.254**) and memory (0.544****) also increased in males and the relationship was found

Table 3: Association of adolescent girls' preference for job opportunities with school environment in Hisar district (n=200)

Family Environment	Preference for Job Opportunities							
	Rural				Urban			
	Least preferred	Somewhat preferred	Most preferred	Total	Least preferred	Somewhat preferred	Most preferred	Total
Bottom level self managing	0(0.00)	03(6.00)	10(20.0)	13(26.0)	0(0.00)	0(0.00)	09(18.0)	09(18.0)
Top level self managing	0(0.00)	10(20.0)	10(20.0)	20(40.0)	0(0.00)	8(16.0)	04(8.00)	12(24.0)
Mediocre level self managing	7(14.0)	10(20.0)	0(0.00)	17(34.0)	7(14.0)	8(16.0)	14(28.0)	24(48.0)
Poor level self managing	0(0.00)	0(0.00)	0(0.00)	0(0.00)	0(0.00)	05(10.0)	0(0.00)	05(10.0)
Total	07(14.0)	23(46.0)	20(40.0)	50(100.0)	02(4.00)	21(42.0)	27(54.0)	50(100.0)
	$c^2 = 12.45^*$						$c^2 = 14.83^*$	

Table 4: Association of adolescent girls' preference for job opportunities with school environment in Bhiwani district (n=200)

Family Environment	Preference for Job Opportunities							
	Rural				Urban			
	Least preferred	Somewhat preferred	Most preferred	Total	Least preferred	Somewhat preferred	Most preferred	Total
Bottom level self managing	0(0.00)	10(20.0)	07(14.0)	17(34.0)	0(0.00)	09(18.0)	0(0.00)	09(18.0)
Top level self managing	0(0.00)	8(16.0)	05(10.0)	13(26.0)	0(0.00)	07(14.0)	04(8.00)	11(22.0)
Mediocre level self managing	0(0.00)	11(22.0)	0(0.00)	11(22.0)	7(14.0)	15(30.0)	05(10.0)	27(54.0)
Poor level self managing	0(0.00)	09(18.0)	0(0.00)	9(18.0)	0(0.00)	03(6.00)	0(0.00)	03(6.00)
Total	0(0.00)	38(76.0)	12(24.0)	50(100.0)	07(14.0)	34(68.0)	09(18.0)	50(100.0)
			$c^2 = 5.04^*$				$c^2 = 8.27^*$	

significant. Similar was the case as far as females were concerned but there was an inverse and significant relationship between socio-economic status and patience in females (-0.247**) and it was non-significant patience with socio-economic status of males. The other dimensions i.e. cooperativeness, confidence and sensitivity were non-significantly related with socioeconomic status of both males and females.

Conclusion

Adolescence is a time of preparation for the adult roles of worker, citizen and community participant, spouse, parent, and household manager.

Adolescence is also a time of gender differentiation. Two environments, home and school share an influential space in individual's life and there exists a unique combination between the two. The family environment and the school environment have regularly been linked in the scientific literature to psychosocial and behavioural adjustment/problems in the adolescent period. It is concluded from the results that majority of adolescent girls with abusive environment had somewhat preference (20%) followed by least preference (16%), while adolescent girls with distressed environment (24%) and 28

percent with functional environment most preferred jobs in Hisar District. In urban area, association of adolescent girls' preference for job opportunities was found that the majority of girls with mediocre level (30%), bottom level (18%) and top level (14%) self managing had somewhat preferences for jobs of Bhiwani district.

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Growth and yield of okra as influenced by organic manures and bio-fertilizers

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Abstract

Okra (Abelmoschus esculentus L. Moench) is an economically important vegetable crop valued for its nutritional, medicinal, and industrial applications. With increasing concerns over the high cost and negative environmental effects of inorganic fertilizers, organic nutrient management has emerged as a sustainable alternative for enhancing soil fertility and okra productivity. A field experiment was conducted during the Kharif season of 2024 at the Campus for Research and Advanced Studies, Dhablan, to evaluate the effect of planting methods and various organic manures and biofertilizers on the growth and yield of okra. The study was laid out in a split-plot design with two planting methods (plain and ridge) in the main plots and six organic treatments control, farmyard manure (25 t ha⁻¹), poultry manure (10 t ha⁻¹), vermicompost (5 t ha⁻¹), Azotobacter (3 kg ha⁻¹), and phosphate-solubilizing bacteria (3 kg ha⁻¹) in the subplots. Results revealed that ridge planting significantly improved vegetative traits, including plant height, canopy spread, and number of leaves, as well as yield parameters such as fruit length, fruits per plant, and total fruit yield compared to plain planting. Among the organic treatments, vermicompost proved most effective, producing the highest plant height (91.1 cm), plant spread (79.1 cm), number of leaves (18.5), fruit length (13.7 cm), fruits per plant (15.2), and yield (194.57 q ha⁻¹). Azotobacter and poultry manure were also highly effective, outperforming farmyard manure, phosphate-solubilizing bacteria, and the control. The superior performance of vermicompost and biofertilizers may be attributed to improved nutrient availability, soil structure, and microbial activity. Overall, the study demonstrates that ridge planting in combination with high-quality organic amendments particularly vermicompost offers a sustainable and efficient strategy for enhancing okra growth, yield, and soil health under semi-arid agroclimatic conditions.

Keywords: Inorganic fertilizers, Azotobacter, poultry manure, farmyard manure, biofertilizers

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a widely cultivated vegetable crop of considerable agronomic and economic importance across tropical, subtropical, and warm temperate regions of the world. Okra is valued primarily for its tender green pods, which contains a characteristic mucilaginous

substance used to thicken soups and stews. Beyond its pods, the leaves are consumed as leafy vegetables and possess medicinal properties, being traditionally used for treating ulcers and haemorrhages (Martin & Ruberte, 1978). Okra seeds also serve as a source of edible oil and have industrial applications in soap

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production (Oyolu, 1983). Enhancing okra yield has long been associated with the application of inorganic fertilizers, particularly NPK, which increases soil fertility and productivity (Donahue et al., 1990). However, the high cost, declining soil health, and negative environmental impacts associated with chemical fertilizers (Ullysses, 1982) have necessitated the search for sustainable alternatives. Previous investigations have demonstrated the efficacy of integrating organic and inorganic fertilizer sources for improved okra growth. For example, Okwuagwu *et al.* (2003) reported enhanced growth and yield when cattle manure was combined with NPK, while Akande *et al.* (2010) found significant increases in growth parameters with integrated applications of poultry manure and organic-based fertilizers.

In recent years, attention has shifted toward organic fertilizers, which are derived from decomposed plant or animal residues (Buob, 2008). Common organic sources including cow dung, poultry manure, rabbit manure, goat manure, and composts improve soil organic matter, enhance nutrient availability, and promote better physical and biological soil conditions (Bhata & Shukla, 1982). Organic manures have been shown to increase soil carbon, nitrogen, pH, cation-exchange capacity, and essential nutrients such as calcium, magnesium, and potassium, all of which contribute to higher crop productivity. Several studies highlight the positive effects of vermicompost and poultry manure in increasing growth and yield attributes of okra (Sameera *et al.*, 2005; Tihamiyu *et al.*, 2012). Despite the advantages, the nutrient release rate from organic manures is often slow and inconsistent (Miah, 1994), creating uncertainty in achieving optimal yields. Therefore, evaluating different organic fertilizer sources is essential for identifying the most effective manure type for improving okra productivity while reducing dependency on chemical inputs. In response to these concerns, the present study aims to assess the effects of various organic manures, particularly poultry and cattle manures, on the growth and yield performance of okra.

Materials and Methods

A field experiment was conducted during *Kharif* season 2024 at the Campus for Research

and Advanced Studies, Dhablan. The experimental site is situated at about 30°-20' N latitude and 76°-28' E longitude at an altitude of 249 m above the mean sea level. Patiala falls under a semi-arid climatic zone, characterized by distinct seasonal variations. The region experiences hot and dry conditions from April to June, transitioning to hot and humid weather during the monsoon period from July to September, and turning cold from November to February. At the Campus for Research and Advanced Studies, Dhablan, Patiala, the climate remains subtropical throughout the year, marked by dry summers, a humid monsoon phase, and chilly winters. After the preparation of the field, the experiment was laid out in split plot design with 12 treatments and three replications. Okra variety Samarth was sown on 5th April, 2024 with spacing 45x15cm and plot size of 4.0x 3.25 meters. All manures were applied as per the requirement. The required quantity of FYM at 25 t ha⁻¹, poultry manure at 10 t ha⁻¹, and vermicompost at 5 t ha⁻¹ were applied before sowing. Azotobacter (3 kg ha⁻¹) and phosphate solubilizing bacteria (3 kg ha⁻¹) were also applied. The plots were maintained weed free throughout the growth period of crop. To reduce the crop weed competition, three weeding were done.

Main plots = Planting methods:

P1: Plain

P2: Ridge

Sub plots = Organic manure and bio-fertilizers:

M1: Control

M2: Farm yard manure 25t ha⁻¹

M3: Poultry manure 10t ha⁻¹

M4: Vermicompost 5t ha⁻¹

M5: Azotobacter 3kg ha⁻¹

M6: Phosphate solubilizing bacteria 3kg ha⁻¹

Results and Discussion

Growth parameters

The results clearly demonstrate that both planting methods and organic nutrient sources significantly influenced the vegetative growth of okra, as reflected in plant height, plant spread, and number of leaves per plant. Ridge planting (P₂) produced taller plants (90.4 cm), wider canopy spread (78.2 cm), and more leaves (18.1) compared to plain

Table 1: Growth parameters of okra as influenced by organic manure and bio-fertilizers

Treatment	Plant height (cm)	Plant spread (cm)	No. of leaves per plant
Main Plot (Planting methods)			
P1 : Plain	85.7	73.5	16.3
P2 : Ridge	90.4	78.2	18.1
SEm±	0.82	0.95	0.31
CD (5%)	2.50	2.81	0.90
Sub Plot (Type of organic treatments)			
M1 : Control	64.6	68.1	14.1
M2 : FYM 25t ha ⁻¹	87.6	75.3	17.2
M3 : PM 10t ha ⁻¹	89.4	76.8	17.7
M4 : VC 5t ha ⁻¹	91.1	79.1	18.5
M5 : Azotobacter 3kg ha ⁻¹	90.2	78.1	18.3
M6 : PSB 3 kg ha ⁻¹	88.6	75.9	17.4
SEm±	1.12	1.18	0.41
CD (5%)	3.22	3.43	1.23

planting (P_1), indicating that improved soil aeration and drainage under ridge conditions enhanced root development and nutrient uptake. Among the organic treatments, the untreated control (M_1) recorded the lowest growth performance across all parameters, confirming the insufficiency of inherent soil fertility. In contrast, all organic amendments improved vegetative growth, with vermicompost at 5 t ha⁻¹ (M_4) resulting in the greatest plant height (91.1 cm), plant spread (79.1 cm), and leaf production (18.5), followed closely by Azotobacter (M_5) and poultry manure (M_3). Farmyard manure (M_2) and PSB (M_6) also enhanced growth but to a comparatively lesser extent. Overall, the findings suggest that ridge planting combined with high-quality organic inputs, particularly vermicompost, substantially enhances vegetative performance in okra.

Ridge planting produced taller and more vigorous plants, which aligns with the reports of Adekunle (2013) who noted enhanced vegetative growth of okra under improved soil aeration and drainage conditions associated with suitable land preparation. Organic treatments, especially vermicompost, poultry manure, and Azotobacter, significantly increased plant height and canopy spread, reflecting the nutrient-enriched environment described by Khandaker *et al.* (2017), who emphasized that organic manures improve soil

carbon content, nutrient availability, and biological activity. Similarly, Kumar *et al.* (2017) found significant increases in plant height and leaf production with the application of vermicompost and FYM, attributing these effects to enhanced nutrient mineralization and soil structure. Meena *et al.* (2019) further confirmed vermicompost as the most effective organic source for promoting vigorous vegetative growth in okra due to its high humus content, microbial activity, and slow but steady nutrient release.

Yield parameters

The results indicate that both planting methods and organic nutrient sources exerted a significant influence on fruit length, number of fruits per plant, and overall fruit yield in okra. Ridge planting (P_2) consistently outperformed plain planting (P_1), producing longer fruits (13.4 cm), a higher number of fruits per plant (14.6), and greater fruit yield (183.35 q ha⁻¹), whereas plain planting recorded comparatively lower values (12.6 cm, 13.2 fruits, and 170.86 q ha⁻¹). This suggests that ridge planting facilitated better soil aeration, moisture distribution, and nutrient uptake, which translated into improved reproductive efficiency and yield. Across the organic treatments, the control (M_1) presented the lowest fruit length (11.2 cm), fruit number (11.6), and yield (157.34 q ha⁻¹), confirming the necessity of external

Table 2: Yield parameters of okra as influenced by organic manure and bio-fertilizers

Treatment	Fruit length (cm)	Fruit plant ⁻¹	Fruit yield (q ha ⁻¹)
Main Plot (Planting methods)			
P1 : Plain	12.6	13.2	170.86
P2 : Ridge	13.4	14.6	183.35
SEm±	0.14	0.17	4.75
CD (5%)	0.42	0.52	9.54
Sub Plot (Type of Organic components)			
M1 : Control	11.2	11.6	157.34
M2 : FYM 25t ha ⁻¹	12.9	13.8	169.93
M3 : PM 10t ha ⁻¹	13.2	14.3	177.39
M4 : VC 5t ha ⁻¹	13.7	15.2	194.57
M5 : Azotobacter 3kg ha ⁻¹	13.5	14.6	190.18
M6 : PSB 3 kg ha ⁻¹	13.1	14.1	184.84
SEm±	0.19	0.23	5.64
CD (5%)	0.58	0.68	14.51

nutrient supplementation for optimal okra productivity. All organic amendments enhanced yield parameters, with vermicompost at 5 t ha⁻¹ (M₄) recording the maximum fruit length (13.7 cm), highest fruit number (15.2), and greatest fruit yield (194.57 q ha⁻¹). This was closely followed by Azotobacter (M₅) and poultry manure (M₃), both of which showed substantial improvements over the control. FYM (M₂) and PSB (M₆) also improved yield attributes but to a lesser degree than vermicompost. Overall, the findings demonstrate that ridge planting combined with nutrient-rich organic amendments particularly vermicompost, Azotobacter, and poultry manure enhances fruit development and yield potential in okra.

Ridge planting produced longer fruits, more fruits per plant, and higher yield, which supports the findings of Adekunle (2013), who reported improved pod development and yield when soil conditions favour nutrient uptake and root expansion. Among organic treatments, vermicompost recorded the highest fruit length and yield, agreeing with the observations of Khandaker *et al.* (2017) and Meena *et al.* (2019), who both found vermicompost superior in enhancing reproductive traits and final yield due to its balanced nutrient profile and high microbial population. Poultry manure and Azotobacter also

produced significantly higher fruit yields, similar to the results of Kumar *et al.* (2017), who reported that organic sources, especially vermicompost and poultry manure, increase flowering, fruiting efficiency, and pod size. The lowest fruit yield recorded in the control plot parallels all four referenced studies, where the absence of organic amendments consistently resulted in poor fruit development.

Conclusion

The present study clearly demonstrates that both the method of planting and the application of organic nutrient sources plays a decisive role in determining the vegetative growth and yield performance of okra. Ridge planting consistently proved superior to plain planting, as it enhanced soil aeration, drainage, and nutrient uptake, ultimately resulting in improved growth attributes such as plant height, canopy spread, and number of leaves, as well as better reproductive parameters including fruit length, number of fruits per plant, and overall yield. Among the organic nutrient sources, vermicompost (5 t ha⁻¹) emerged as the most effective treatment, producing the highest values for both growth and yield parameters, followed closely by *Azotobacter* and poultry manure. These findings highlight the capacity of high-quality organic inputs to supply

balanced nutrients, stimulate microbial activity, and improve soil structure, thereby contributing to enhanced plant vigour and productivity. The consistently poor performance of the control confirms that inherent soil fertility alone is insufficient to support optimal okra growth and yield. This integrated approach not only boosts yield but also enhances soil health, making it a viable option for environmentally conscious and resource-efficient okra cultivation.

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Impact of Phosphorus and Zinc on Yield, Quality and Nutrient Content of Lentil (*Lens culinaris* (L)) crop

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Abstract

A plot experiment was conducted to study the effect of phosphorus and zinc on the yield and nutrient content of lentil crop. The experiment was laid out in a randomized block design with phosphorus (0, 30, 60 and 120 kg ha⁻¹) and four levels of zinc (0, 0.5, 1 and 2 mg ha⁻¹) with three replications. The results revealed that increasing dose of phosphorus up to 120 kg/ha and Zn up to 0.5/ha enhanced the lentil yield significantly. Protein yield was also improved by the application of both of these two (P and Zn) nutrients. Phosphorus and zinc addition had a beneficial effect on absorption and utilization of (N, P and Zn) of lentil.

Key words: Phosphorus, zinc, yield, nutrient content, lentil

Introduction

Lentil is an important annual leguminous crop which is locally called “Masoor” belongs to the family Fabaceae. Human diet consists of vegetable protein in good amount. Lentil is a legume crop and plays a great role in crop rotation for maintaining soil fertility and through root nodules, lentil can fix atmospheric nitrogen by symbiotic rhizobia therefore fertilizers and soil fertility has a major role for obtaining higher yield. Phosphorus plays a remarkable role in plant physiological processes. It is an essential constituent of majority of enzymes which are of great importance in the transformation of energy in carbohydrate metabolism in different types of plants and is closely related in cell division and grain development. In micro-nutrients, zinc is very important in reproductive phase like fertilization and pollen grain formation as pollen grain contains a high amount of zinc. Most of the zinc is trans-located to seeds during fertilization and lower application of zinc causes deficiency of zinc in the seed and also the seed yield is quietly reduced.

Materials and Methods

A field experiment was conducted in the field of Agriculture (Department of Soil Science & Agricultural Chemistry), Nehru Mahavidyalaya Lalitpur (Uttar Pradesh) during the winter season of 2023-24. The soil had EC 0.20 dSm⁻¹, pH 7.9, organic carbon 4.68 g kg⁻¹, and available N 84.67, P 5.13, K 96.45 kg ha⁻¹ and zinc 5.84 mg kg⁻¹. The experiment was laid out in a randomized block design with four levels of phosphorus (0, 30, 60 and 120 kg ha⁻¹) and four levels of zinc (0, 0.5, 1 and 2 mg ha⁻¹) with three replications. The recommended dose of nitrogen and potassium were applied as urea and MOP. Phosphorus and zinc were supplied through phosphorus penta oxide and zinc sulphate as per treatments. Lentil was sown on October 25, 2023 and irrigated at appropriate times based on soil and crop appearance. Weeds were removed periodically. The crop was harvested at maturity. Grain and straw samples were analysed for N content by the Kjeldahl method (Jackson, 1973). Grain and straw

samples were digested in di-acid (HNO_3 : HClO_4) and the digest was analyzed for phosphorus by the vanadomolybdo phosphoric acid yellow color method, for K by flame photometer, and for Mn by atomic absorption spectrophotometer (Jackson, 1973). Nutrient uptake was calculated using yield data in conjunction with their respective contents.

Results and Discussion

Yield studies

The data given in to table 1 reveals that phosphorus application have a marked effect on seed yield and stover yield of lentil. P application had a significant response on seed yield and stover yield production of lentil. All the higher doses of P significantly enhanced the seed yield and stover yield production. The percent enhancement were 5.55, 9.80 and 14.37% (seed yield) and 4.87, 8.78 and 13.59% (stover yield) over control (due to 30, 60 and 120 kg P/ha) of lentil, respectively. All the higher doses of zinc clearly significantly superior over control enhancing the seed and stover yield production of lentil. The lowest average value of seed yield and stover yield were recorded in control treatment. The seed yield 1.31, 2.55 and 3.55% and stover yield 1.00, 2.12 and 3.49% increased of lentil due to 0.5, 1.0, 2.0 ppm Zn/ha. Similar results

have been reported by Kumari, et al. (2024) and Munna, et al. (2016)

Protein content

A study of Table 1 reveals that the P application has a significant effect on the protein content in seed and stover yield of lentil crop. P application caused significant enhancements in protein content 3.37, 6.37 and 6.51% in seed and 2.44, 6.12 and 8.77% in stover due to 30, 60 and 120 kg P/ha. All the higher doses of phosphorus 30, 60 and 120 kg/ha application were found significantly superior over control in enhancing the protein content in seed and stover of lentil. Application of zinc increased the protein content in seed and stover of lentil and this effect was significant with each level of zinc. All the levels of zinc significantly increased the protein content. The percent enhancement were 0.088, 5.12 and 8.17% in seed and 2.61, 6.15 and 9.51 in stover of lentil due to 0.5, 1.0 and 2.0 ppm Zn/ha over control, respectively. Similar results have been reported by Kumari, et al. (2024) and Munna, et al. (2016)

Nutrients composition

Nitrogen content

Application of phosphorus significant effect on the N content in seed and stover yield of lentil

Table 1: Effect of phosphorus and zinc on seed and stover yield (gram/plot) and protein content (%) of lentil crop

Treatments	Grain yield	Straw yield	Protein content (%) in seed	Protein content (%) in stover
Phosphorus (kg ha ⁻¹)				
P ₀	306	1375	21.03	4.90
P ₁	323	1442	21.74	5.02
P ₂	336	1496	22.37	5.20
P ₃	350	1562	22.40	5.33
SEm±	1.05	1.45	0.09	0.01
CD @ 5%	2.15	2.96	0.20	0.03
Zinc (mg ha ⁻¹)				
Zn ₀	323	1445	22.64	5.36
Zn ₁	327	1459	22.62	5.22
Zn ₂	331	1475	21.48	5.03
Zn ₃	334	1495	20.79	4.85
SEm±	1.05	1.45	0.09	0.01
CD @ 5%	2.15	2.96	0.20	0.03

Table 2: Effect of phosphorus and zinc on N, P and Zn content (%) in seed and stover of lentil crop

Treatments	N content (%) in grain	N content (%) in straw	P content (%) in grain	P content (%) in straw	Zn content (%) in grain	Zn content (%) in straw
Phosphorus (kg ha ⁻¹)						
P ₀	3.36	0.782	0.281	0.143	36.82	25.31
P ₁	3.47	0.802	0.312	0.144	38.42	26.14
P ₂	3.58	0.832	0.339	0.163	40.02	27.25
P ₃	3.58	0.852	0.372	0.179	41.36	28.40
SEm±	0.015	0.11	0.04	0.02	0.21	0.16
CD @ 5%	0.032	0.24	0.09	0.04	0.43	0.33
Zinc (mg ha ⁻¹)						
Zn ₀	3.62	0.80	0.355	0.169	37.50	24.75
Zn ₁	3.62	0.83	0.354	0.170	38.79	26.18
Zn ₂	3.43	0.80	0.316	0.148	39.84	27.47
Zn ₃	3.32	0.77	0.278	0.142	40.49	28.71
SEm±	0.015	0.11	0.04	0.02	0.21	0.16
CD @ 5%	0.032	0.24	0.09	0.04	0.43	0.33

crop. Application of phosphorus caused a significant enhancement in N content 3.27, 6.54 and 6.54% in seed and 2.55, 6.38 and 8.94% in stover due to 30, 60 and 120 kg P/ha. All the higher doses of phosphorus 30, 60 and 120 kg/ha application were found significantly superior over control in enhancing the N content in seed and stover of lentil (table-2). Zinc application has a significant effect on nitrogen content in seed and stover of lentil plant. All higher doses of Zn application were found significantly increased N content 0, 5.24 and 8.28% in seed and 2.62, 6.41, 9.62% in stover of lentil over control due to 0, 0.5, 1.0, 2.0 Zn ppm/ha respectively. Similar results have been reported by Kumari, et al. (2024) and Munna, et al. (2016).

Phosphorus content

The data given in Table 2 clearly indicate that the P application has a significant effect on the phosphorus content in seed and stover yield of lentil crop. P application caused a significant enhancements in P content 10.97, 20.42 and 32.32% in seed and 0.83, 13.63 and 25.19% in stover yield due to 30, 60 and 120 kg P/ha. Zinc application has a significant effect on phosphorus content in seed

and stover of lentil. All higher doses of Zn application were found significantly increased P content 0.28, 11.04 and 21.78% in seed and 0.52, 12.71 and 15.89% in stover of lentil over control. Similar results have been reported by Kumari, et al. (2024) Singh, et al. (2020) and Munna, et al. (2016).

Zinc content

The data given in Table 2 clearly indicate that the phosphorus application has a significant effect on the Zn content in seed and stover yield of lentil crop. P application caused significant enhancements in Zn content 4.34, 8.69 and 12.33% in seed and 2.35, 5.49 and 8.75 in stover due to 30, 60 and 120 kg P/ha. All the higher doses of phosphorus 30, 60 and 120 kg/ha application were found significantly superior over control in enhancing the Zn content in lentil. Zinc application has a significant effect on zinc content in seed and stover of lentil. All higher doses of Zn application were found significantly increased Zn content 3.44, 6.24 and 7.97% in seed and 4.11, 7.82 and 11.39% in stover of lentil over control. Similar results have been reported by Kumari, et al. (2024), Singh, et al. (2020) and Singh, et al. (2024).

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Effect of organic and inorganic sources of nutrients on soil properties in alluvial soils of the Agra region

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Abstract.

This field experiment, conducted over two rabi seasons (2023–24 and 2024–25) at R.B.S. College, Bichpuri, Agra (India), evaluated the impact of integrated nutrient management (INM) combining inorganic fertilizers (RDF: recommended dose of fertilizers) with sulphur (S) and zinc (Zn) on post-harvest soil properties in sandy loam alluvial soil. The experiment was layout in randomized block design with nine treatments of T1 - 100 % RDF, T2 - 75 % RDF + Sulphur, T3 - 75 % RDF + Zinc, T4 - 75 % RDF + Vermicompost, T5 - 75 % RDF + Sulphur + Zinc + Vermicompost, T6 - 50 % RDF + Sulphur, T7 - 50 % RDF + Zinc, T8 - 50 % RDF + Vermicompost and T9 - 50 % RDF + Sulphur + Zinc + Vermicompost with three replications. The study found that applying 75% recommended dose of fertilizers (RDF) + Sulphur + Zinc + Vermicompost (T5) significantly improved soil organic carbon, available nutrients (N, P, K, S, Zn), and other properties compared to other treatments. Application of T5: @ 75% RDF + Sulphur + Zinc + Vermicompost recorded significantly higher EC, pH, soil organic C, available nitrogen, phosphorus, potassium, sulphur and zinc over T6: 50% RDF + Sulphur treatment. Similarly, the increase in soil organic C, available nitrogen, phosphorus, potassium, sulphur and zinc 17.0, 23.1, 39.1, 19.0, 29.9 and 25.9% with the application of T5: 75% RDF + Sulphur + Zinc + Vermicompost compared to T6: 50% RDF + Sulphur.

Key words: INM, SOC, Nitrogen, Phosphorus, Potassium, Sulphur, Zn

Introduction

The alluvial soils of the Agra region are vital for agricultural productivity, but their fertility and sustainability are challenged by intensive farming practices. Inorganic fertilizers provide rapid nutrient availability, boosting crop yields, but long-term use can degrade soil health by reducing organic carbon, impairing soil structure, and contributing to environmental pollution. Organic amendments, such as farmyard manure, compost, and green manures, offer a sustainable alternative by enhancing soil organic carbon, improving water retention, and promoting beneficial microbial activity. This study

investigates the effect of integrating organic and inorganic nutrient sources on soil properties in the alluvial soils of the Agra region, aiming to identify balanced nutrient management practices that sustain soil health and productivity.

Materials and Methods

The field experiments were conducted at the Agricultural Research farm of R.B.S. College Bichpuri, Agra located in semi arid or gray steppe arid region of South-Western Uttar Pradesh during two consecutive rabi seasons of 2023-24 and 2024-25 on sandy loam soil. The soil had EC 0.28 dSm⁻¹,

pH 8.2, organic carbon 4.6 g kg⁻¹, available N 190.6, P 13.8 and K 218.6 kg ha⁻¹. The soil had CaCl₂ extractable sulphur content of 14.2 kg ha⁻¹ and DTPA extractable zinc 0.59 mg kg⁻¹. The experiment was laid out in randomized block design with three replications. The treatments were comprised of T1 - 100 % RDF, T2 - 75 % RDF + Sulphur, T3 - 75 % RDF + Zinc, T4 - 75 % RDF + Vermicompost, T5 - 75 % RDF + Sulphur + Zinc + Vermicompost, T6 - 50 % RDF + Sulphur, T7 - 50 % RDF + Zinc, T8 - 50 % RDF + Vermicompost and T9 - 50 % RDF + Sulphur + Zinc + Vermicompost.

Soil sampling and analysis

Soil samples were collected during 2023 from the plow layer (0-20 cm depth) from the experimental plot after the crop harvest. These samples were partitioned and passed through standard prescribed sieves for further use in a different kind of analysis. The soil samples that passed through the 0.2-mm sieve were used for estimating soil organic carbon. For the rest of the soil quality parameters such as chemical (pH, EC), available N, P, K, S, and Zn parameters, soil samples that passed through 2-mm sieves were used. Soil pH and EC were measured in a 1:2 soil/water suspension (Richards, 1954), organic carbon by wet oxidation with sulfuric acid (H₂SO₄) + potassium dichromate (K₂Cr₂O₇) (Walkley and Black, 1934), available N by alkaline-KMnO₄ oxidizable N method (Subbiah and Asija, 1956), available P by 0.5 M sodium bicarbonate (NaHCO₃) extraction method (Olsen et al., 1954), available K (Hanway and Heidel, 1952), available sulfur by 0.15% CaCl₂ (Williams and Steinbergs, 1959), and Available Zn by DTPA method (Lindsay and Norvell, 1978).

Results and discussion

EC and pH

The application of T5 (75% RDF + Sulphur + Zinc + Vermicompost) resulted in a significantly higher EC value of 0.35 dSm⁻¹, compared to T6 (50% RDF + Sulphur) which had an EC value of 0.28 dSm⁻¹. Although T5 recorded a higher pH value of 8.51, the difference was not significant compared to T6 (pH 8.20). These findings are consistent with the results of (Sharma et al. 2022 and 2024).

Soil organic carbon

The soil organic carbon (SOC) content

increased significantly across treatments, with T5 (75% RDF + Sulphur + Zinc + Vermicompost) recording the highest SOC content of 5.08 g/kg, representing a 17.0% increase compared to T6 (50% RDF + Sulphur) which had the lowest SOC content of 4.35 g/kg. The SOC content in other treatments was: T4 (4.96 g/kg), T9 (4.89 g/kg), T8 (4.79 g/kg), T3 (4.71 g/kg), T2 (4.60 g/kg), T1 (4.55 g/kg), and T7 (4.49 g/kg). These results are consistent with the findings of (Sharma et al. 2021, 2022 and 2024) and Bhama et al. (2017).

Available Nitrogen

The available nitrogen content in soil was significantly influenced by the nutrient management treatments. The highest available nitrogen content was recorded in T5 (75% RDF + Sulphur + Zinc + Vermicompost) with 222.4 kg/ha, representing a 23.1% increase compared to T6 (50% RDF + Sulphur) which had the lowest available nitrogen content of 180.6 kg/ha. The available nitrogen content in other treatments was: T4 (215.2 kg/ha), T9 (210.6 kg/ha), T8 (204.9 kg/ha), T3 (199.3 kg/ha), T2 (195.5 kg/ha), T1 (191.6 kg/ha), and T7 (186.5 kg/ha). These findings are in agreement with the results of (Sharma et al. 2022 and 2024) and Bhama et al. (2017).

Available Phosphorus

The available phosphorus content in soil increased significantly across treatments, with T5 (75% RDF + Sulphur + Zinc + Vermicompost) recording the highest available phosphorus content of 20.4 kg/ha, representing a 38.8% increase compared to T6 (50% RDF + Sulphur) which had the lowest available phosphorus content of 14.7 kg/ha. The available phosphorus content in other treatments was: T4 (19.4 kg/ha), T9 (18.7 kg/ha), T8 (17.9 kg/ha), T3 (17.4 kg/ha), T2 (16.5 kg/ha), T1 (15.9 kg/ha), and T7 (15.3 kg/ha). These findings are consistent with the results of (Sharma et al. 2022 and 2024) and Indoria et al. (2024).

Available Potassium

The available potassium content in soil increased significantly across treatments, with T5 (75% RDF + Sulphur + Zinc + Vermicompost) recording the highest available potassium content of 244.3 kg/ha, representing a 19.0% increase

Table 1: Effect of organic and inorganic sources of nutrients on EC, pH, SOC, available N, P, K, S and Zn in alluvial soil of Agra region

Treatments	EC (dS/m)	pH	SOC (g/kg)	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Zn (mg/kg)
T1	0.29	8.24	4.55	191.6	15.9	221.0	14.3	0.58
T2	0.30	8.28	4.60	195.5	16.5	224.2	14.8	0.59
T3	0.31	8.30	4.71	199.3	17.4	227.9	15.1	0.60
T4	0.35	8.44	4.96	215.2	19.4	240.2	16.5	0.66
T5	0.35	8.51	5.08	222.4	20.4	244.3	17.1	0.68
T6	0.28	8.20	4.35	180.6	14.7	205.3	13.1	0.54
T7	0.29	8.22	4.49	186.5	15.3	216.1	14.0	0.56
T8	0.32	8.37	4.79	204.9	17.9	232.9	15.3	0.62
T9	0.33	8.43	4.89	210.6	18.7	236.2	15.7	0.64
SEm±	0.020	0.12	0.14	7.45	1.04	9.17	0.62	0.02
CD @ 5%	0.042	NS	0.30	15.37	2.15	18.93	1.28	0.05

compared to T6 (50% RDF + Sulphur) which had the lowest available potassium content of 205.3 kg/ha. The available potassium content in other treatments were: T4 (240.2 kg/ha), T9 (236.2 kg/ha), T8 (232.9 kg/ha), T3 (227.9 kg/ha), T2 (224.2 kg/ha), T1 (221.0 kg/ha), and T7 (216.1 kg/ha). These findings are consistent with the results of (Sharma et al. 2022 and 2024).

Available Sulphur

The available sulphur content in soil increased significantly across treatments, with T5 (75% RDF + Sulphur + Zinc + Vermicompost) recording the highest available sulphur content of 17.1 kg/ha, representing a 30.5% increase compared to T6 (50% RDF + Sulphur) which had the lowest available sulphur content of 13.1 kg/ha. The available sulphur content in other treatments were: T4 (16.5 kg/ha), T9 (15.7 kg/ha), T8 (15.3 kg/ha), T3 (15.1 kg/ha), T2 (14.8 kg/ha), T1 (14.3 kg/ha), and T7 (14.0 kg/ha). These findings are consistent with the results of (Sharma et al. 2022 and 2024).

Available Zinc

The available zinc content in soil increased significantly across treatments, with T5 (75% RDF + Sulphur + Zinc + Vermicompost) recording the highest available zinc content of 0.68 mg/kg, representing a 25.9% increase compared to T6 (50%

RDF + Sulphur) which had the lowest available zinc content of 0.54 mg/kg. The available zinc content in other treatments were: T4 (0.66 mg/kg), T9 (0.64 mg/kg), T8 (0.62 mg/kg), T3 (0.60 mg/kg), T2 (0.59 mg/kg), T1 (0.58 mg/kg), and T7 (0.56 mg/kg). These findings are consistent with the results of (Sharma et al. 2022 and 2024), Munna, et al. (2020) and Indoria et al. (2024).

Conclusion

The study revealed that the application of T5 (75% RDF + Sulphur + Zinc + Vermicompost) was the most effective treatment in improving soil fertility and nutrient availability. The integrated use of organic and inorganic sources of nutrients can be recommended for sustainable soil management and crop production. The findings of this study can be used to develop nutrient management strategies that enhance soil health and fertility.

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Influence of organic manures on the growth of radish (*Raphanus sativus* L.)

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Abstract

*A field experiment was conducted during Rabi 2023-24 at the Campus for Research and Advanced Studies, Dhablan, to evaluate the effect of different organic manures on the growth and yield of radish (*Raphanus sativus* L.). The experiment was laid out in a Randomized Block Design with eight treatments comprising farmyard manure, vermicompost, poultry manure, goat manure, and their combinations. Results revealed significant variation among treatments for all growth and yield parameters. The integrated treatment T₇ (25% FYM + 25% VC + 25% PM + 25% GM) consistently outperformed all other treatments, recording the highest plant height (28.32 cm), number of leaves (11.88), leaf length (23.55 cm), leaf width (13.48 cm), root length (24.29 cm), root diameter (4.96 cm), and root yield (286.43 q ha⁻¹). Among single-source manures, vermicompost (T₃) showed superior performance, followed by poultry manure (T₁), indicating the importance of nutrient-rich and rapidly mineralizing organic inputs. The enhanced vegetative vigour and root development under integrated and high-quality organics align with previous findings highlighting the effectiveness of vermicompost and poultry manure in improving soil fertility and crop productivity. The study concludes that integrated organic nutrient management offers synergistic benefits, providing a balanced nutrient supply and improved soil conditions, and can be recommended as an efficient and sustainable strategy for maximizing radish growth and yield under subtropical conditions.*

Keywords: Integrated nutrient management, Organic manures, Poultry manure, Randomized Block Design, Vermicompost

Introduction

Radish (*Raphanus sativus* L.) is an important root vegetable of the family Brassicaceae, cultivated widely across tropical and temperate regions. It is primarily valued for its napiform edible root, although the entire plant, including the foliage, is consumed as a leafy vegetable (Kiran et al., 2016). Radish holds considerable nutritional significance, being rich in carbohydrates, proteins, and vitamins A and C, which contributes to its rising demand as a dietary

component in developing countries (Singh and Bhandari, 2015). To meet this demand, farmers often apply high doses of chemical fertilizers and pesticides, particularly nitrogen (N). While high N levels can enhance vegetative growth and yield (Brintha and Seran, 2009), continuous reliance on inorganic fertilizers can deteriorate soil health and negatively impact environmental quality. Radish is also valued for its medicinal attributes. It has a cooling

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effect and is used traditionally to relieve digestive disorders, jaundice, liver problems, and urinary issues (Kushwah et al., 2020). Nutritionally, radish contains 93.7% water, 4.2% carbohydrates, 1.1% fat, vitamin C (15–40 mg per 100 g), and minerals such as calcium, manganese, fluorine, iodine, and silicon. Its characteristic pungency is due to volatile isothiocyanates (Bose et al., 2000). Radish leaves are rich in minerals and vitamins A, B, and C. The rat-tailed radish, however, does not form fleshy roots (Dhaliwal, 2018). Despite its nutritional and medicinal value, declining produce quality and reduced economic returns have been linked to excessive chemical fertilizer use.

Organic and integrated nutrient management approaches have gained attention as sustainable alternatives to chemical fertilizers. Organic manures such as farmyard manure (FYM), vermicompost, and neem cake help maintain soil productivity, improve organic carbon levels, and support long-term soil health (Kumar et al., 2013; Mahokar et al., 2007). As a short-duration winter crop with rapid physiological growth, radish responds strongly to nutrient availability, especially nitrogen (Khatri et al., 2019). Chemical N sources like urea, although effective, contribute to nutrient losses, higher production costs, and environmental degradation (Oad et al., 2004). In contrast, organic inputs including FYM, poultry manure, goat manure, and biogas slurry enhance soil physicochemical properties, improve nutrient retention, and ensure slow and sustained nutrient release suitable for diversified agroecosystems (Kale et al., 1991; Delate and Camberdella, 2004). Rising consumer preference for chemical-free vegetables has further encouraged the adoption of organic production systems. Though variable in composition, organic manures are vital sources of plant nutrients and significantly improve soil health (Gyewal et al., 2020; Bhatta et al., 2009). Given radish's short growth cycle and high nutrient demand for rapid root development, efficient organic nutrient management is crucial to achieving high yield and quality. Therefore, a field experiment was conducted to evaluate the effects of different organic manures on the growth of radish.

Materials and Methods

A field experiment was conducted during *Rabi* season 2023-24 at the Campus for Research and Advanced Studies, Dhablan. The experimental site is situated at about 30-20 p N latitude and 76-28 p E longitude at an altitude of 249 m above the mean sea level. Patiala falls under a semi-arid climatic zone, characterized by distinct seasonal variations. The region experiences hot and dry conditions from April to June, transitioning to hot and humid weather during the monsoon period from July to September, and turning cold from November to February. At the Campus for Research and Advanced Studies, Dhablan, the climate remains subtropical throughout the year, marked by dry summers, a humid monsoon phase, and chilly winters. Five plants were randomly picked and tagged from each plot for the purpose of documenting various observations at different growth stages. Organic manures viz., FYM, vermicompost, goat manure and poultry manure were incorporated as per treatment to respective plots. The nitrogen content in FYM, vermicompost, goat manure and poultry manure was 0.5, 2.5, 1.3 and 3%, respectively. Optimum soil moisture was maintained in the field by regular irrigation. Observations were recorded on plant growth parameters of radish roots. The data obtained on various observations for each treatment were statistically analysed as per standard procedures.

Details of layout

Experimental design	Randomised block design (RBD)
No. of replications	03
No. of treatments	8
Total no. of plots	24
Gross plot size	4.2 x 3.2 m
Net plot size	3.15 × 2.5 m
Spacing	45 x 10 cm
Seed rate	4 kg ha ⁻¹
Variety	Scarlet Red Globe
Date of sowing	5 December 2023

Details of Treatments

- T₁ Control
 T₂ 100% Farmyard Manure (FYM)
 T₃ 100% Vermicompost (VC)
 T₄ 100% Poultry Manure (PM)
 T₅ 100% Goat Manure (GM)
 T₆ 50% FYM + 25% VC + 25% PM
 T₇ 25% FYM + 25% VC + 25% PM + 25% GM
 T₈ 75% FYM + 25% VC

Results and Discussion*Growth parameters*

The Table 1 shows clear variation in radish growth due to different organic manures. The integrated treatment T₇ (25% FYM + 25% VC + 25% PM + 25% GM) recorded the highest values for all parameters, with plant height 28.32 cm, 11.88 leaves, leaf length 23.55 cm, and leaf width 13.48 cm, indicating superior nutrient availability from combined organic sources. Among single manures, vermicompost (T₃) performed strongly with 27.85 cm height, 11.22 leaves, 22.36 cm leaf length, and 12.93 cm width, closely followed by poultry manure (T₄) with 27.39 cm height, 10.73 leaves, 21.65 cm leaf length, and 11.78 cm width.

The present findings on plant height are supported by earlier studies, as Kushwah *et al.* (2020) reported maximum height, longer leaves, leaf width to improved nutrient supply under

vermicompost, while Gyewali *et al.* (2020) observed plant height and shoot growth with poultry manure-based combinations, both highlighting the strong influence of nutrient-rich organic sources on vegetative vigour.

Trends in the number of leaves and leaf length agree with Khatri *et al.* (2019), who recorded the maximum leaf breadth, highest leaf numbers under poultry manure./

Yield parameters

The Table 2 indicates that root growth and yield of radish varied significantly among the organic manure treatments. The integrated treatment T₇ (25% FYM + 25% VC + 25% PM + 25% GM) produced the greatest root length (24.29 cm), root diameter (4.96 cm), and the highest root yield (286.43 q ha⁻¹), demonstrating the advantage of combining different organic sources for improved nutrient availability and root development. Among single manures, vermicompost (T₃) showed the best performance with 22.73 cm root length, 4.36 cm diameter, and 273.80 q ha⁻¹ yield, followed by poultry manure (T₄) and goat manure (T₅), which also enhanced root traits compared to FYM alone.

These results closely correspond with Khatri *et al.* (2019), who reported the highest root length and root diameter under poultry manure, demonstrating its rapid mineralization and superior nutrient supply. The similarity between the two

Table 1: Effect of different organic manures on growth parameters of radish

Treatment	Plant height (cm)	No. of leaf plant ⁻¹	Leaf length (cm)	Leaf width (cm)
T ₁ : Control	21.14	7.26	17.85	4.22
T ₂ : 100% Farm Yard Manure (FYM)	26.18	9.18	20.35	7.84
T ₃ : 100% Vermi Compost (VC)	27.85	11.22	22.36	12.93
T ₄ : 100% Poultry Manure (PM)	27.39	10.73	21.65	11.78
T ₅ : 100% Goat Manure (GM)	26.42	9.67	20.97	9.15
T ₆ : 50% FYM + 25% VM + 25 % PM	25.19	7.74	18.62	5.86
T ₇ : 25% FYM + 25% VC + 25% PM + 25% GM	28.32	11.88	23.55	13.48
T ₈ : 75% FYM + 25% VC	25.60	8.43	19.48	7.14
SE (m)	0.58	0.43	0.51	0.23
CD (0.05)	1.65	1.26	1.42	0.68

Table 2: Effect of different organic manures on yield parameters of radish

Treatment	Root length (cm)	Root diameter (cm)	Root yield q ha ⁻¹
T ₁ : Control	11.61	2.34	228.90
T ₂ : 100% Farm Yard Manure (FYM)	17.41	3.26	245.14
T ₃ : 100% Vermi Compost (VC)	22.73	4.36	273.80
T ₄ : 100% Poultry Manure (PM)	21.84	3.79	265.39
T ₅ : 100% Goat Manure (GM)	19.95	3.14	254.61
T ₆ : 50%FYM +25%VM + 25 % PM	14.35	2.62	233.25
T ₇ : 25% FYM+25% VC+25%PM+25%GM	24.29	4.96	286.43
T ₈ : 75%FYM+ 25%VC	16.69	2.93	242.74
SE (m)	0.65	0.22	6.85
CD (0.05)	1.85	1.04	17.45

studies lies in the clear advantage of high-quality organics particularly poultry manure and vermicomposting enhancing root elongation, thickening, and yield, while the lowest values consistently occurred under control treatments in both cases. However, unlike Khatri *et al.* (2019), where poultry manure alone was the best performer, the present study showed that a balanced combination of FYM, VC, PM, and GM (T₇) surpassed all single-source manures, suggesting a synergistic effect of integrating multiple organics for better nutrient release, improved soil structure, and optimal root growth and yield.

Conclusion

The study clearly demonstrated that the application of organic manures significantly influenced both growth and yield attributes of radish. Among all treatments, the integrated organic formulation T₇ (25% FYM + 25% VC + 25% PM + 25% GM) proved superior, producing the highest plant height, leaf number, leaf size, root length, root diameter, and overall yield. This indicates that combining diverse organic sources ensures a more balanced nutrient supply, improved soil structure, and enhanced microbial activity, resulting in vigorous vegetative growth and optimal root development. Among the single organic amendments, vermicompost (T₃) consistently performed best, followed by poultry manure (T₄), highlighting their rapid mineralization and higher nutrient density. The

trends in growth parameters and yield closely align with earlier findings that emphasize the effectiveness of nutrient-rich organics such as vermicompost and poultry manure in promoting plant vigour and superior root traits. Overall, the results suggest that integrated organic nutrient management offers a synergistic advantage over individual manures and can be recommended as an efficient and sustainable approach for enhancing radish growth and productivity.

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Effect of Potassium and Manganese on Yield, Quality, and Nutrient Uptake by Pea (*Pisum sativum* L.)

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Abstract

*A pot experiment was conducted to study the effect of potassium and manganese on yield, quality, and nutrient uptake by pea (*Pisum sativum* L.). The experiment was laid out in a randomized block design with four levels of potassium (0, 30, 60, and 90 kg K₂O ha⁻¹) and four levels of manganese (0, 0.5, 1.0, and 2.0 mg kg⁻¹) with three replications. The results revealed that increasing doses of potassium up to 90 kg ha⁻¹ significantly enhanced pea yield, while manganese application tended to decrease the yield. Protein content was improved by the application of both potassium and manganese. Potassium addition had a beneficial effect on the uptake of N, P, K, and Mn by the pea crop, while manganese addition had a significant but adverse effect on yield, quality, and nutrient uptake, except for Mn uptake.*

Key words: Potassium, manganese, yield, nutrient uptake, pea

Introduction

Pea is commonly grown in temperate areas of all continents. It has many uses: immature pods and seeds are used as green vegetables, either fresh or frozen; it is used as green forage for grazing animals, in situ or as hay or silage; and it is grown for its mature seed, which itself has many uses. If the crop is managed properly, green pods are produced continuously for several months. Application of balanced fertilizer increases vegetative growth and improves yield and quality of the produce. As a grain legume, field peas are capable of fixing most of the required nitrogen from environment. Among the mineral elements, potassium plays a major role on the plant growth. Potassium (K) is key element for crop productivity and soil fertility. Potassium (K) is the vital nutrient involved in many essential physiological processes in plants; it can increase crop productivity and quality, and capability of plants to survive adverse conditions. Potassium deficiency is a world-wide problem,

although cropping intensity and improved variety enhance K deficiency in soil. The crop is grown on such soil show potassium deficiency (Akter et al., 2020). Micronutrients like manganese play an important role in increasing crop yield through their effect of plant itself and also help in nitrogen fixing process. Manganese (Mn) plays an important role in Nitrogen metabolism and forms several compounds needed or plant metabolism. Mn also acts as co- factor for several plant enzymes, where it activates about 35 different enzymes. Manganese, one of the essential micronutrients though involved in respiratory process such as oxidation of carbohydrates to carbon dioxide and water, also participates in the metabolism of nitrogen. It activates the enzymes, directly involved in the synthesis of chlorophyll.

Materials and Methods

A pot experiment of this investigation was carried out at Agriculture experimental field were

undertaken in the (Department of Soil Science and Agricultural Chemistry), Nehru Mahavidyalaya, Lalitpur (U.P.) during winter season 2024-2025. Lalitpur district is a part of Bundelkhand plateau. Betwa River is the boundary between Jhansi and Lalitpur in the north. Most of the area is under the average elevation of 300m-450m from the Sea level. Its latitudinal extension is from 24°10' to 25°15' (north) and longitudinal extension is from 78°10' and 79°0' (East). The experimental station is 44 situated at 1.5-2.00 km in the Southern of center of Lalitpur city on Sagar-Road. The soil had EC 0.21 dSm⁻¹, pH 7.8, organic carbon 4.7 g kg⁻¹, available N 80.5, P 6.0, K 95.0 kg ha⁻¹, and manganese 1.68 mg kg⁻¹. The experiment was laid out in randomized block design with four levels of potassium (control, 30, 60 and 90 kg K₂O ha⁻¹) and four levels of manganese (control, 0.5, 1.0 and 2.0 mg kg⁻¹) with three replications. The recommended doses of N and P @ 25 and 60 kg P₂O₅ ha⁻¹, respectively were applied as urea and single super phosphate. Potassium and manganese were supplied through MOP and MnSO₄ as per treatments. The pea was sown on November 13, 2024 and irrigated at the proper time as judged by the appearance of soil and crop. The weeds were eradicated time to time from the crop. The crop was

harvested on maturity. The grain and straw samples were analyzed for N content by Kjeldahl method (Jackson 1973). Grain and straw samples were digested in di-acid (HNO₃, HClO₄) and the digest were analyzed for phosphorus by vanado molybdo phosphoric acid yellow color method, K by flame photometer and Mn by atomic absorption spectrophotometer (Jackson 1973). The uptake of nutrients was calculated using the yield data in conjunction with their respective contents.

Results and discussion

Potassium application had a significant response on seed yield and straw yield of garden pea. All the higher doses of potassium significantly engaged the seed yield and straw yield. The percent enhancements were 1.27, 6.01, 11.4% in seed and 19.11, 28.0, 35.9% in stover over control due to the application of @ 30, 60, and 90 kg K/ha of pea, respectively (table-1). These results were reported by Hussain et al. (2011) and Ahmed et al. (2015). All the higher level of manganese tended to decreased 2.23, 4.48, 7.57% in seed and 3.85, 9.10, 14.69% in stover due to application of @ 0.5, 1.0, 2.0 ppm/ha. These results were reported Lal, et al. (2012) and Deep Chandra et al. (2024).

Table 1: Effect of potassium and manganese on seed and stover yield (gram/pot) and protein content (%) of pea crop

Treatments	Seed yield	Stover yield	Protein (%) in seed	Protein (%) in stover
Potassium (kg ha ⁻¹)				
K ₀	36.08	21.61	17.84	3.98
K ₁	36.54	25.74	18.42	4.33
K ₂	38.25	27.66	18.79	4.41
K ₃	40.21	29.37	18.84	4.44
SEm±	0.28	0.25	0.07	0.001
CD @ 5%	0.61	0.50	0.16	0.002
Manganese (mg kg ⁻¹)				
Mn ₀	36.16	28.03	18.72	4.53
Mn ₁	38.29	26.95	18.58	4.18
Mn ₂	37.41	25.48	18.38	4.30
Mn ₃	36.2	23.91	18.20	4.16
SEm±	0.28	0.25	0.07	0.001
CD @ 5%	0.61	0.50	0.16	0.002

Protein content

Application of potassium increased the protein content in seed and also in stover of pea and this effect was significant with each level of potassium. The increase protein content with K applied @ 30 kg ha⁻¹, 60 kg ha⁻¹ and 90 kg ha⁻¹ level of potassium over control was tone of extent 3.29, 5.37, 5.62% in seed and 8.76, 10.56, 11.37% in stover of pea respectively as compared to control (Table 1). Application of manganese has a non-significant effect on the protein content in seed and stover yield of pea crop. Application of manganese caused a significant decrease in protein content 0.71, 1.76, 2.75% in seed and 7.82, 5.19, 8.28% in stover due to 0.5, 1.0 and 2.0 ppm Mn/ha. All the higher doses of manganese @ 0.5, 1.0 and 2.0 ppm Mn/ha application were found non-significant on the protein content of seed and stover of pea. The similar result also found by Tiwari et al. (2012) and Farhad et al. (2010).

Nutrients uptake studies

Nitrogen uptake

The data given in table 2 clearly indicate that potassium application have a significant effect on

nitrogen uptake by pea. The percent enhancement was 4.61, 12.45, 17.73% in seed and 21.10, 33.17, 42.37% in stover by the pea due to @ 30, 60 and 90 kg K/ha over control respectively. These findings were similar to those Mali et al. (2000) and Gupta, et al. (2020). Application of manganese had a significant response on N uptake in seed and stover yield by pea. The percent decreases were 3.54, 6.77, 10.67% in seed and 6.19, 13.81, 21.79% in stover yield over control due to @ 0.5, 1.0 and 2.0 ppm Mn/ha. A similar effect of manganese application on pea and other pulses crop production has also been reported by Lal, et al. (2012), Gupta, et al. (2020) and Deep Chandra et al. (2024).

Phosphorus uptake

The data given in table 2 clearly indicate that potassium application have a significant effect on phosphorus uptake in seed and stover yield by pea. The percent enhancement of phosphorus was 15.51, 39.98, 63.08% in seed and 41.54, 76.18, 100.09% in stover by pea with the application of @ 30, 60 and 90 kg K/ha over control respectively. Application of manganese has a significant effect on P uptake in seed and stover yield of pea

Table 2: Effect of potassium and manganese on N, P, K, and Mn uptake (mg/pot) by seed and stover of pea crop

Treatments	N uptake in seed	N uptake in stover	P uptake in seed	P uptake in stover	K uptake in seed	K uptake in stover	Mn uptake in seed	Mn uptake in stover
Potassium (kg ha ⁻¹)								
K ₀	103.00	14.68	9.30	2.29	25.81	31.46	529.31	155.53
K ₁	107.75	17.89	10.75	3.24	29.65	41.62	572.00	205.02
K ₂	115.83	19.54	13.02	4.03	33.92	47.92	638.24	242.58
K ₃	121.27	20.89	15.17	4.75	37.12	53.24	679.92	285.27
SEm±	0.92	0.23	0.20	0.05	0.35	0.52	7.31	2.86
CD @ 5%	1.86	0.47	0.41	0.12	0.71	1.08	14.93	5.85
Manganese (mg kg ⁻¹)								
Mn ₀	118.16	20.38	13.62	4.19	33.95	48.25	581.56	222.97
Mn ₁	113.98	19.13	12.61	3.76	32.42	45.36	599.56	225.96
Mn ₂	110.16	17.56	11.53	3.30	30.84	42.01	616.61	222.73
Mn ₃	105.55	15.93	10.48	2.86	29.28	38.61	621.74	216.73
SEm±	0.92	0.23	0.20	0.05	0.35	0.52	7.31	2.86
CD @ 5%	1.86	0.47	0.41	0.12	0.71	1.08	14.93	5.85

Potassium uptake

The data given in table 2 reveals that the application of potassium increased the K utilization in seed and stover by pea and this effect was significant with each level of potassium. The percent enhancement of K uptake was 14.91, 31.42, 43.83% in seed and 32.31, 52.35, 69.25% in stover by pea with the application of @ 30, 60 and 90 kg K/ha over control, respectively. Application of manganese had a significant response on K utilization by pea. The percent decreases of K uptake were 4.50, 9.15, 13.76% in seed and 5.99, 12.94, 19.97% in stover by pea over control due to the application of @ 0.5, 1.0 and 2.0 ppm Mn/ha of pea, respectively Gupta, et al. (2020) Lal, et al. (2012) and Gupta, et al. (2020).

Manganese uptake

The data given in table 2 clearly indicate that the potassium application have a significant effect on manganese uptake by pea. The percent enhancement of manganese uptake was 8.06, 20.58, 28.45% in seed and 31.82, 55.96, 83.41% in stover by pea due to the application of 30, 60 and 90 kg K/ha over control, respectively. Application of manganese had a significant response on its uptake by pea. The percent enhancement of manganese uptake was 3.10, 6.03, 6.91% in seed and 1.34, 0.11, 2.80% in stover by pea over control due to the application of manganese @ 0.5, 1.0 and 2.0 ppm Mn/ha, respectively. The same resulted by Gupta, et al. (2020) and Lal, et al. (2012).

Conclusion

The study revealed that potassium application up to 90 kg ha⁻¹ significantly improved pea yield, quality, and nutrient uptake, while manganese application had a negative impact on most of the parameters studied.

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The Effect of phytohormones sprays to 55 days old black gram plants on photosynthetic efficiency of upper and lower leaves and flower opening in plants

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Abstract

This work was performed at the Hindu P.G. College Moradabad. Moradabad is placed in the interior of subtropical continental region. Its climate is typically monsoon. The material data for Moradabad for the years 23-24. There is a seasonal rhyme of the weather seasonal variation in temperature and moisture condition govern the distribution pattern, growth and phenology of plants in the region. Data for photosynthetic efficiency [Expressed as $\text{cpm gm}^{-1} \text{ wt.}$] of upper and lower leaves of plants receiving various and ethephon (10 and 50 ppm) increased photosynthetic efficiency of lower leaf by 55.4 and 52.3% respectively. Higher concentration of GA3 (100 ppm) decrease photosynthetic efficiency by 43.3%. The seeds contain approximately 9.7% moisture, 23.4% proteins, 1.0% fat, 57.3% carbohydrates, 3.8% fibre and 4.8 % ash. It is rich in phosphoric acid to be 5-10 times more than other pulses. Dry stems and leaves after threshing are used as cattle feed. Seed are also given to animals.

Keywords: Carbohydrates, photosynthetic, phenology, phosphoric acid, pulses

Introduction

The black gram or urad bean is a bean grown in South Asia. Like its relative the mung bean, it has been reclassified from the genus *Phaseolus* to *Vigna*. The produced sold as black gram is usually the urad bean, whereas the split bean is called white lentil.

Black gram is believed to be a native of India and mainly grown in M.P., U.P., Punjab, Maharashtra, W.B. A.P. and Karnataka States. It is erect, fast growing annual herb up to 0.8m in height and grown as winter and summer crop both after as mixed crop. Leaves are large, trifoliate having ovate to lanceolate, entire 5-10 cm long leaflets subtended by short stipules. Flower is small, yellow and cluster in short hairy penduncle. Keel is spirally coiled. Pods are narrow, cylindrical with 6-10 seeds. Seeds are

oblong having flat or square ends, up to 4mm long and mostly black with smooth seeds coat. Hilum is protuberant white with concave surface. Cotyledons are white. Seeds contain approximately 9.7% moisture 23.4 proteins, 1.0% fat, 57.3% carbohydrate, 3.8 fibre and 4.8% ash. It is rich in phosphoric acid to be 5-10 times more than other pulses. Seeds are consumed whole, split pulse (dual husked or DE husked or parched). It is also used for making other dishes like idli, dosa, etc or in confectionary. Green pods are eaten as vegetable whole plant is also used as fodder for livestock it is also sometimes as a green manure.

Nutritional Value in Urad Dal

It has high nutritional content, including protein, fat, Carbohydrate, Vitamins and minerals

Nutritional Content	Amount Per 100gm
Carbohydrate	58.99
Energy	341 kgal
Protein	25.21
Total Fat	1.64
Dietary Fibre	18.3
Niacin	1.447
Fats	216
Sodium	38
Potassium	983
Iron	7.57
Zinc	3.35
Phosphorus	379
Calcium	138
Magnesium	267

You can use it to prepare various food dishes, curries soup, vada etc. and also make masks and oils to pamper your hair and skin. However one must consume it's in moderation as it can lead to negative health consequences.

Regulation of flowering by growth hormones is of great economic importance in plants as it directly determines the yield (Audus, 1959; Weaver, 1972; Hedden et al., 1978).

1. Cycocel abbreviated to CCC, a quaternary ammonium compound was reported by Tolebert in 1962, Higher doses of cycocel was found more effective as compared to lower doses in bajra (Yadava et al, 1980) and in sunflower (Kumari, 1981).
2. Ethephon abbreviated to CEA is being manufactured under the trade name "Ethrel" was introduced as plant growth regulator by Amchem products Inc. Ambler Pennsylvania, U.S.A. releases ethylenes in plant tissue. Amchem 1967, foliar application of Ethephon induce many changes in composition of fruits of cucurbitaceous vegetables (Shanmugavela et al: 1975), tomato (Williams et al., 1999) and in Rice (Bainka and Sauter, 2005).
3. Gibberellins are of isoprenoid nature and belongs to the class of compound called Diterpenes. Several workers have reviewed the physiology effects of Gibberellins in different plants (Cleland, 1969; Yadava and Pahl, 1980; Sreen, 1985, Alexander et al., 1994; Chauhan and Bashist, 2000; Mahavir Singh, 2002,

Sankaran et al, 2004; Rakesh et al; 2005.

Methods and Materials

Moradabad is placed in the interior of subtropical continental region. Its climate is typically monsoonal. The meteorological data for Moradabad for the year 23-24. There is a seasonal rhythm of the weather seasonal variation in temperature and moisture condition governs the distribution pattern, growth and phenology of plants in the region. The terrain is also characterized by heavy rain-fall and periodic inundation of its vast area by the over flooding and shifting of rivers flowing through through its. There are three well marked season i.e. summer, rainy and winter.

Rainy Season

It begins from middle of June and continues up to end of September about 80 to 900 of the total annual rainfall occurs in this season. July and August are the months when heavy precipitation take place. During these months, the mean maximum temperature ranges b/w 31.5 and 33.5°C and mean maximum temperature ranges 23.4°C. Mean diurnal fluctuation in temperature during these months ranges from 18.3°C to 10.2°C relative humidity during the season is very high (about 71.6 to 85.7%).

Selection of Plant Material

The details of the materials used and experimental proceeding and techniques followed for the various experiments during the course of this investigation are describe below; Seeds of Urad cultivars, PU-31, COTA-4, P.U-35 were obtained from agronomy Department of G.B. Pant University of agriculture and technology, Pantnagar seeds show large variation in seed morphology among genotypes and hybrids with respect to seed colour, seed surface characteristics test and kernel texture and colour.

Source of Chemicals

All chemicals employed in this investigation were of analytical grade supplied by BDH (India) unless specified otherwise. Dehydrated absolute ethyl alcohol was supplied by Bega Chemical Company, India. Ethrel was supplied by Duchem, U.S.A.

Gibberellic acid supplied by CDH (Central Drug house) (P) Ltd. post Box No. New Delhi-110002.

Fertilizer and other Chemical

Urea single super phosphate mature of potash (Gujrat fertilizer were obtained from crop research central G.B. Pant University of Agriculture and Technology Pantnagar. Diathane-N-45 and sandovit were also obtained from crop research centre, Pantnagar.

Apparatus

1. All glassware used was either of coming India L.t.d. or Pyrez, U.S.A.
2. Vaccum Pump (Metrez, India)
3. Spekal (Carl Zelis Jena-DDR)
4. Luxmeter (Research-Luxomete-300, atlantis, India.
5. Blender (Metrax, India)
6. Measuring Slender
7. Air Hand Sprayer.

Field Culture

For exposure to estimate photosynthesis efficiency of individual leaves, a plot (19.20x12.75m) was select. Anormal dose of N.P.K was applied to the soul. About 100 seeds were sown by keeping normal distance recommended for Urad. After 10 days seedily were then to twenty.

Preparation of Hormones Solutions

To prepare stock solution of different hormones the following addition was made per litre. Deionized water was used for solution preparations.

Hormones	Amount added/ litter(mgs)	Concentration (ppm)
GA3	100	100
Cycocel 50 50		
Ethephon (1 = m= 400 mg)	1.25 ml	500

Gibberellic acid & Ethephon were directly dissolved in water. Cycocel was first a few drops of absolute ethyl alcohol and required volume was made by deionized water 0.22 ml of "Sandovit" per litre of hormone solution was added as a surfactant.

Chemical Analysis

Chemical analysis was conducted in the plants physiology lab of Botany Department Hindu College, Moradabad and college of basic science, G.B. Pantnagar University, Pantnagaer (U.A.).

Foliar Spray of Hormones

1. 55 days after seedling emergence (Bud initiation Stage)
2. 90 days after seedling emergence (Flowering Stage)

Concentrations of phytohormones used

Seven concentrations of each hormone 10, 25, 50 100, 200, 400, 800 ppm as given below were sprayed at every stage of development.

Treatment	Concentration (ppm)
Control	10, 25, 50, 100, 200, 400, 800 ppm
GA3	10, 25, 50, 100, 200, 400, 800 ppm
Ethephon	10, 25, 50, 100, 200, 400, 800 ppm

Thirty plants were sprayed for each concentration.

Measurement of flowering

Days required for required for opening of buds were recorded.

1. Seed setting and yield- At maturity, heads were harvested and were derived in oven at 750c for 5 days. After drying head dimeter, filling percentage, hundred seed wt. (for filled seeds only) and seed yield per plant (filled seeds only) were recorded.
2. Number of seed- No of seeds were carried out harvest of matured head and counts the seeds and find out the average value of no. of seeds in for each treatment.
3. Seed yield- The economic yield of each net at harvest was recorded and expressed in kg/ha. The three components of seed yield is number of heads per acre, no. of seeds per head and average seed weight.

Seed yield =

No. of head x no. of seed per hand x Average seed wt.

Results and Discussion

The following observation are recorded in the present investigation. Effect of phyto-hormones sprayed 55-days after seedling emergence (bud-initiation stage). Effect of phytohormone sprayed 90 days after seedling emergence (Flowering stage).

Data for photo-synthetic efficiency (expressed) as cpm gm^{-1} twt. of upper and lower leaves of plants receiving various treatments show that lower concentration of cycocel and ethephon

(10 and 50 ppm) increased photosynthetic efficiency of lower leaf the by 55.4 and 52.3%, respectively. Higher concentration of GA3 (100 ppm) decreased photosynthetic efficiency by 43.0%. Photo-synthetic efficiency of upper leaf also increased by 95% with ethrel 50 ppm treatment. Data obtained for photo-synthetic efficiency (Expresser as cpm-cm² leaf area) of lower of upper also show that ethephen (5 and 50 ppm) increased the photosynthetic efficiency of lower leaf by treatment to the extent of 44.5% photo-synthetic efficiency of upper leaf increase by 152 and 34% with 50 and 500 ppm ethenol, while 10 ppm GA3 decreased it by 26 and 25.3% (Table 1).

II. Flower Morphology

Flowers formed in the plants receiving different treatments were normal (similar to control) in most cases. However, the flowers of plants

treatment with GA3 (100 ppm) Showed the following abnormal features.

- I. The flower shape changed from flat (disc-shoped) to slightly elongated
- II. Sepals and petals (ray-florets) becomes elongated (lanceolated shaped).
- III. The mature heads were completely open.
- IV. Flower are small, yellow and clustered at short hairy peduncle. Keep is spirally coiled.
- V. Pods are narrow, cylindrical with 6-10 seeds. Seeds are oblong having flat or square ends up to 4mm long and mostly black with smooth seed coat. Hilum is protuberant with concave surface. Cotyledon are white.
- VI. Seeds contain approximately 97% moisture, 23.4% protein, 1.0% fat, 57.3% Carbohydrate, 3.8% fibre and 4.8% ash. It is rich in phosphoric acid to be 5-10 times more than other pulses.

Table 1: Photo-synthetic efficiency of upper and lower leaves

Treatments Phyto-hormones Conc. (ppm)	cpm gm ⁻¹ dry wt.		cpm cm ⁻² leaf area	
	Low leaf	Upper leaf	Low. leaf	Upper leaf
Water (Control) -	17598±98.0	13999±83.8	92.0±7.6	73.0±6.9
Cycocel				
10	2750±80.0	13999±80.7	66.4±6.7	83.0±7.3
25	12860±80.2	13112±82.6	78.6±5.8	84.2±7.8
50	15979±89.5	13299±81.6	80.5±7.3	78.0±7.1
100	15999±88.2	13170±92.4	82.6±7.4	78.0±8.2
200	16000±89.7	13050±90.6	86.4±7.6	79.4±8.3
400	16080±90.2	12000±90.7	88.3±7.8	80.6±6.7
800	17170±90.6	12970±97.2	90.7±6.2	82.4±7.4
GA3				
10	16349±90.5	12949±80.5	94.0±7.7	78.0±7.1
25	15.270±90.4	13100±82.3	96.2±7.6	70.2±6.8
50	13.227±87.4	13800±83.6	65.4±7.4	60.5±6.7
100	10049±71.5	14449±85.1	51.0±6.1	54.5±6.2
200	10000±72.5	14700±86.2	50.0±7.2	53.1±8.2
400	09981±80.2	14925±87.1	45.2±6.2	51.2±8.1
800	9900±86.7	15000±86.1	44.6±6.8	51.6±7.1
Ethephon				
10	27349±117.0	27399±117.1	175.0±9.9	184.0±10.2
25	25280±116.0	25412±126.2	140.0±8.9	170.2±10.3
50	21360±127.5	20320±135.4	135.0±9.2	150.6±9.4
100	20412±120.2	19721±130.6	130.0±8.8	130.4±9.7
200	19623±110.4	16220±120.7	125.0±7.9	115.0±9.8
400	18850±97.2	12599±79.5	123.0±8.5	98.0±7.8
800	18860±98.1	12602±80.5	122.0±8.3	97.0±7.0

VII. Seeds are consumed whole, split pulse (dol, husked or parched). It is also used for making other dishes like idle, dosa, paper, bari etc. or in confectionary.

VIII. Green pods are eaten as vegetable whole plant is also used as fodder for livestock. It is also used some times as a green manure.

Table 2: Effect of foliar sprays of phyto-hormones on flower opening in black gram.

Treatments	Days required for flowering (bud opening) plant age (day) at which hormones were applied		
Phyto-hormones	Conc.	40	55
Water (Control)	-	67	70
Cycocel	10	64	70
	25	67	71
	50	68	72
	100	69	73
	200	73	74
	400	75	76
	800	78	77
	GA3	10	63
25		62	64
50		60	64
100		58	64
200		59	65
400		58	65
800		57	66
Ethephon		10	60
	25	61	64
	50	62	64
	100	63	65
	200	62	65
	400	64	65
	800	69	66

*Average values 6 plants (3 plate) each.

Conclusion

The lower concentration of cycocel and Ethephon (10 and 50 ppm) increased photosynthetic efficiency of lower leaf the by 55.4 and 52.3% respectively. Higher concentration of GA3 100 ppm decreased photosynthetic efficiency by 43.0.

Photosynthetic efficiency of upper leaf also increased by 95% with ethereal 50 ppm treatments. Data obtained for photosynthetic efficiency (expressed as cpm^{-2} leaf area) of lower of upper also, that ethephon (5 and 50 ppm) increased the photosynthetic efficiency of lower leaf by treatment to the extent of 44.5%. Photosynthetic efficiency of upper leaf increase by 152 and 34% with 50 and 500 ppm ethereal while 10 pp, GA3 decreased it by 26 and 25.3%.

Effect of Phytohormones sprayed 55 days after seedling emergence (bud initiation stage) and 90 days after seedling emergence (flower stage).

The flower is small yellow and clustered at short hairy peduncle. Keep is spirally coil. Pods are narrow cylindrical with 6-10 seeds. Seeds are oblong having flat or square ends up to 4 mm long and mostly black with smooth seed coat. Hilum is protuberant with concave surface.

Cotyledon is white.

Dry stems and leaves after threshing are used as cattle feed. Seeds are also given to animals. It is also sometimes as a green manure.

The data show that both the concentration of GA3 (10 and 100 ppm brought about an early flowering by 4 and 9 days respectively, as compared to control. Cycocel (10 ppm) and ethrel (50 ppm) also has tened flowering by 3, 4 and 4 days respectively. On the other hand cycocel (50 ppm) are ethrel (400 ppm) delayed flowering by 1 and 2 days respectively.

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Effect of Organic and Inorganic Nutrient Sources on the Availability of Micronutrients in Inceptisols of Agra Region

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Abstract

A field experiment was conducted at the Agricultural Research Farm, R.B.S. College, Bichpuri, Agra, during the rabi seasons of 2023–24 and 2024–25 to evaluate the effect of integrated application of organic and inorganic nutrient sources on the availability of micronutrients (Zn, Mn, Fe, and Cu) in soil. The experiment was laid out in a randomized block design with eleven treatments and three replications: T_1 (control), T_2 (100% NPK), T_3 (75% NPK), T_4 (50% NPK), T_5 (50% NPK + 20 kg $ZnSO_4$ ha^{-1}), T_6 (50% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}), T_7 (75% NPK + 20 kg $ZnSO_4$ ha^{-1}), and T_8 (75% NPK + 5 t FYM ha^{-1} + 20 kg $ZnSO_4$ ha^{-1}). Combined data of two years revealed that treatment T_7 (75% NPK + 20 kg $ZnSO_4$ ha^{-1}) was significantly superior and recorded the highest available Zn (0.71 mg kg^{-1}), Mn (16.5 mg kg^{-1}), Fe (11.46 mg kg^{-1}), and Cu (1.65 mg kg^{-1}) in soil. Compared to the control, T_7 increased available Zn, Mn, Fe, and Cu by 36.5%, 42.2%, 50.0%, and 33.1%, respectively. The results highlight the beneficial role of integrated nutrient management in enhancing micronutrient availability in calcareous Inceptisols.

Keywords: Integrated nutrient management, Zinc, Manganese, Iron, Copper, FYM, Inceptisols

Introduction

Continuous use of only chemical fertilizers often leads to deterioration of soil health and micronutrient deficiencies, particularly in calcareous soils of semi-arid regions. Integrated use of organic manures (FYM, vermicompost, poultry manure, etc.) along with inorganic fertilizers not only reduces environmental pollution but also sustains soil fertility by improving physical, chemical, and biological properties. Farmyard manure (FYM) is a valuable source of both macro- and micronutrients and helps maintain soil productivity for a longer period compared to sole inorganic fertilizers. The organic matter in FYM enhances chelation of micronutrients, thereby increasing their availability in soil. The present investigation was therefore undertaken to

study the effect of combined application of inorganic fertilizers and FYM on the status of available Zn, Mn, Fe, and Cu in Inceptisols of the Agra region.

Materials and Methods

The field experiment was conducted during the kharif seasons of 2023–24 and 2024–25 at the Agricultural Research Farm, R.B.S. College, Bichpuri, Agra (Uttar Pradesh), India. The experimental soil was sandy loam (Typic Ustochrept) with initial available Zn, Mn, Fe and Cu of 0.82, 9.86, 8.75 and 0.64 mg kg^{-1} , respectively. The experiment was laid out in a randomized block design with three replications and eight treatments viz. T_1 (control), T_2 (100% NPK), T_3 (75% NPK), T_4 (50% NPK), T_5 (50% NPK + 20 kg

ZnSO₄ ha⁻¹, T₆ (50% NPK + 5 t FYM ha⁻¹ + 20 kg ZnSO₄ ha⁻¹, T₇ (75% NPK + 20 kg ZnSO₄ ha⁻¹, and T₈ (75% NPK + 5 t FYM ha⁻¹ + 20 kg ZnSO₄ ha⁻¹. Combined data of two years revealed that treatment T₈ (75% NPK + 5 t FYM ha⁻¹ + 20 kg ZnSO₄ ha⁻¹. Nitrogen, phosphorus, potassium and zinc were applied through urea, diammonium phosphate, muriate of potash and zinc sulphate (ZnSO₄) accordance with treatments at the time of sowing respectively.

Soil Sampling and Analysis

Soil Sampling and Analysis Post-harvest soil samples (0–20 cm depth) were collected in March 2025 from each plot, air-dried, ground, and passed through a 2-mm sieve. Available micronutrients (Zn, Mn, Fe, and Cu) were extracted using DTPA extractant (Lindsay and Norvell, 1978) and determined by atomic absorption spectrophotometer (AAS).

Results and discussion

Available Zinc (Zn)

Application of integrated nutrient management practices significantly influenced available Zn in soil (Table 1). The highest available Zn (0.71 mg kg⁻¹ was recorded with T₈ (75% NPK + 5 t FYM ha⁻¹ + 20 kg ZnSO₄ ha⁻¹, which was significantly superior to all other treatments. It was followed by T₂ (0.66 mg kg⁻¹ and T₆ (0.64 mg kg⁻¹. Compared to control (0.52 mg kg⁻¹, the increase

in available Zn ranged from 5.8% (T₄) to 36.5% (T₈). The higher Zn availability under combined application of FYM and ZnSO₄ may be attributed to the chelating effect of organic matter, which reduces Zn fixation in calcareous soils. These findings are in close agreement with Singh and Chauhan (2020), Munna et al. (2020), and Sharma et al. (2022, 2024).

Available Manganese (Mn)

All treatments significantly increased available Mn over control (11.6 mg kg⁻¹. Treatment T₈ recorded the highest value (16.5 mg kg⁻¹, representing a 42.2% increase over control. The beneficial effect of FYM on Mn availability is due to the reduction of Mn oxides to more soluble Mn⁺⁺ forms under the influence of organic acids released during decomposition. The results corroborate the findings of Pandey et al. (2020) and Sharma et al. (2022, 2024).

Available Iron (Fe)

The highest available Fe (11.46 mg kg⁻¹ was observed in T₈, which was 50.0% higher than control (7.64 mg kg⁻¹. Organic matter forms stable complexes with Fe, preventing its precipitation as insoluble oxides/hydroxides in high-pH soils. Similar positive effects of integrated nutrient management on Fe availability have been reported by Sharma et al. (2022, 2024).

Table 1: Effect of organic and inorganic nutrient sources on available Zn, Mn, Fe, and Cu (mg kg⁻¹) in soil after harvest of crop (pooled data of 2023–24 and 2024–25)

Treatments	Zn (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Cu (mg kg ⁻¹)
T1	0.52	11.6	7.64	1.24
T2	0.66	15.4	10.66	1.60
T3	0.61	13.5	8.86	1.46
T4	0.55	12.5	8.03	1.31
T5	0.58	13.1	8.43	1.38
T6	0.64	14.8	10.17	1.55
T7	0.62	14.1	9.49	1.51
T8	0.71	16.5	11.46	1.65
SEm±	0.039	1.11	1.02	0.055
CD @ 5%	0.084	2.37	2.19	0.117

Available Copper (Cu)

Treatment T₈ registered the maximum available Cu (1.65 mg kg⁻¹, which was 33.1% higher than control. Organic matter enhances Cu solubility by forming organo-metallic complexes. These results are consistent with Sharma et al. (2022, 2024).

Conclusion

Integrated application of 75% recommended NPK along with 5 t FYM ha⁻¹ and 20 kg ZnSO₄ ha⁻¹ (T₈) proved most effective in enhancing the availability of Zn, Mn, Fe, and Cu in calcareous Inceptisols. This practice can be recommended for sustainable crop production and preventing micronutrient deficiencies in the Agra region.

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Effect of Nitrogen and Phosphorus on Yield, Quality and Nutrient Uptake by Pea (*Pisum sativum* L.)

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Abstract

*A pot experiment was conducted to study the effects of nitrogen and phosphorus on yield, quality, and nutrient uptake by pea (*Pisum sativum* L.). The results of this pot experiment clearly demonstrate that application of nitrogen up to 120 kg ha⁻¹ and phosphorus up to 80 kg ha⁻¹ significantly enhanced the productivity and quality of pea (*Pisum sativum* L. cv. Arkel). Higher levels of both nutrients led to substantial improvements in seed and stover yields, with the maximum seed yield (35.16 g/pot) recorded at 120 kg N ha⁻¹ and stover yield (36.22 g/pot) at 80 kg P₂O₅ ha⁻¹. Protein content in seeds and stover also increased markedly with rising doses of N and P, reaching peak values of 31.19% and 5.46% (seeds and stover, respectively) at the highest nitrogen level, and 24.25% and 5.54% at the highest phosphorus level. Nitrogen application progressively increased both N and P uptake in seeds and stover, while phosphorus fertilization dramatically boosted P uptake (particularly in stover) and also improved N uptake, indicating a synergistic interaction between the two nutrients.*

Keywords: Nitrogen, phosphorus, yield, nutrient uptake, pea

Introduction

Pea is commonly grown in temperate areas of all continents. It has many uses: immature pods and seeds are used as green vegetables, either fresh or frozen; it is used as green forage for grazing animals, in situ or as hay or silage; and it is grown for its mature seed, which has many uses. If the crop is managed properly, green pods are produced continuously for several months. Application of balanced fertilizers increases vegetative growth and improves yield and quality of the produce. As a grain legume, field peas are capable of fixing most of their required nitrogen from the environment. Fertilizer use is essential for the production of high yields of good-quality seed. The yield of pea is influenced by numerous agronomical, ecological, and biotic factors, such as environment, soil fertility, and cultural practices. Among these, soil fertility is the prime consideration for increasing crop production. Indian

soils are known to be nitrogen-deficient because of the tropical climate. Therefore, application of nitrogenous fertilizers and manures becomes imperative for obtaining increased yields. It has been reported that nitrogen fertilization of legumes has a positive effect on growth attributes. The nutrient phosphorus is an essential constituent of every living cell of the plant and of the majority of enzymes; it is also a structural component of the membrane systems of the cell, the chloroplasts, and the mitochondria. It takes an active part in all types of metabolism in the plant. It stimulates root development and growth in the seedling stage, and stimulates flowering, fruit setting, and seed formation. Along with a special action on leguminous crops, it induces nodule formation and rhizobial activity in the roots

Materials and Methods

The pot experiment was carried out at the agricultural experimental field (Department of Soil Science & Agricultural Chemistry), Nehru Mahavidyalaya, Lalitpur (U.P.) during 2023–24. Lalitpur district is part of the Bundelkhand plateau. The Betwa River forms the boundary between Jhansi and Lalitpur in the north. Most of the area is at an average elevation of 300–450 m above sea level. Its latitudinal extension is from 24°10' N to 25°15' N and longitudinal extension is from 78°10' E to 79°00' E. The experimental station is situated 1.5–2.00 km south of the Centre of Lalitpur city on the Sagar Road. The soil had EC 0.20 dSm⁻¹, pH 7.9, organic carbon 4.68 g kg⁻¹, and available N 84.67 kg ha⁻¹, P 5.13 kg ha⁻¹, and K 96.45 kg ha⁻¹. The experiment was laid out in a randomized block design with four levels of nitrogen (0 (control), 30, 60, and 120 kg N ha⁻¹) and four levels of phosphorus (0 (control), 20, 40, and 80 kg P₂O₅ ha⁻¹) with three replications. Pea variety Arkel was sown on October 15, 2023, and irrigated as needed based on soil and crop appearance. Grain and stover samples were analyzed for N content by the Kjeldahl method (Jackson, 1973). Grain and stover samples were digested in a di-acid mixture (HNO₃ + HClO₄), and the digests were

analyzed for phosphorus by the vanadomolybdophosphoric acid yellow color method, for K by flame photometer, and for Mn by atomic absorption spectrophotometer (Jackson, 1973). Nutrient uptake was calculated using yield data in conjunction with their respective concentrations.

Results and Discussion

Yield studies

The data presented in Table 1 reveal that nitrogen application had a marked effect on seed and stover yields of pea, and higher doses of nitrogen were significantly superior to the control. Significantly higher seed and stover yields of pea (35.16 and 37.41 g/pot) were observed with the application of nitrogen @ 120 kg ha⁻¹, followed by @ 60 kg ha⁻¹ (33.41 and 35.72 g/pot) and @ 30 kg ha⁻¹ (31.49 and 33.77 g/pot), compared to the control (28.33 and 31.05 g/pot). Significantly higher seed and stover yields of pea (34.49 and 36.22 g/pot) were observed with the application of phosphorus @ 80 kg ha⁻¹, followed by @ 40 kg ha⁻¹ (33.49 and 35.05 g/pot) and @ 20 kg ha⁻¹ (31.49 and 33.69 g/pot), compared to the control (29.41 and 33.12 g/pot). These findings are similar to those of Munna et al. (2012) and Sahu et al. (2024).

Table 1: Effect of nitrogen and phosphorus on seed and stover yield (g/pot) and protein content (%) of pea crop

Treatments	Seed yield	Stover yield	Protein (%) in seed	Protein (%) in stover
Nitrogen (kg ha ⁻¹)				
N ₀	28.33	31.05	19.37	4.94
N ₁	31.49	33.77	27.73	5.05
N ₂	33.41	35.72	30.29	5.41
N ₃	35.16	37.41	31.19	5.46
SEm±	0.51	0.51	0.81	0.06
CD @ 5%	0.86	0.86	1.65	0.12
Phosphorus (kg ha ⁻¹)				
P ₀	29.41	33.12	20.63	4.88
P ₁	31.49	33.69	20.74	5.04
P ₂	33.49	35.05	21.50	5.39
P ₃	34.49	36.22	24.25	5.54
SEm±	0.51	0.51	0.81	0.06
CD @ 5%	0.86	0.86	1.65	0.12

Protein content

The data in Table 1 reveal that the application of nitrogen increased the protein content in pea seed and stover. Significantly higher protein content in seed and stover (31.19% and 5.46%) was observed with the application of nitrogen @ 120 kg ha⁻¹, followed by @ 60 kg ha⁻¹ (30.29% and 5.41%) and @ 30 kg ha⁻¹ (27.73% and 5.05%), compared to the control (19.37% and 4.94%). Significantly higher protein content in seed and stover (24.25% and 5.54%) was observed with the application of phosphorus @ 80 kg ha⁻¹, followed by @ 40 kg ha⁻¹ (21.50% and 5.39%) and @ 20 kg ha⁻¹ (20.74% and 5.04%), compared to the control (20.63% and 4.88%).

Nutrients uptake studies

Nitrogen uptake

The data presented in Table 2 clearly indicate that nitrogen application had a significant effect on nitrogen uptake in pea seed and stover. Significantly higher nitrogen uptake in seed and stover (133.95 and 32.85 mg/pot) was observed with the application of nitrogen @ 120 kg ha⁻¹, followed by @ 60 kg ha⁻¹ (121.05 and 27.85 mg/pot) and @ 30 kg ha⁻¹ (106.21 and 27.19 mg/pot), compared to the control

(89.64 and 24.57 mg/pot). Significantly higher nitrogen uptake in seed and stover (125.44 and 32.26 mg/pot) was observed with the application of phosphorus @ 80 kg ha⁻¹, followed by @ 40 kg ha⁻¹ (121.02 and 30.32 mg/pot) and @ 20 kg ha⁻¹ (106.40 and 27.49 mg/pot), compared to the control (73.88 and 26.60 mg/pot). These results are similar to those obtained by Munna et al. (2012, 2016), Kumari et al. (2024), and Sahu et al. (2025).

Phosphorus uptake

The data presented in Table 2 clearly indicate that nitrogen application had a significant effect on phosphorus uptake in pea seed and stover. Significantly higher phosphorus uptake in seed and stover (15.18 and 8.15 mg/pot) was observed with the application of nitrogen @ 120 kg ha⁻¹, followed by @ 60 kg ha⁻¹ (14.05 and 7.45 mg/pot) and @ 30 kg ha⁻¹ (12.78 and 6.85 mg/pot), compared to the control (11.33 and 5.83 mg/pot). Significantly higher phosphorus uptake in seed and stover (14.37 and 20.40 mg/pot) was observed with the application of phosphorus @ 80 kg ha⁻¹, followed by @ 40 kg ha⁻¹ (14.13 and 11.06 mg/pot) and @ 20 kg ha⁻¹ (12.95 and 7.53 mg/pot), compared to the control (11.92 and 2.66 mg/pot). These results are similar

Table 2: Effect of nitrogen and phosphorus on nitrogen and phosphorus uptake (mg/pot) by seed and stover of pea crop

Treatments	N uptake in seed	N uptake in stover	P uptake in seed	P uptake in stover
Nitrogen (kg ha ⁻¹)				
N ₀	89.64	24.57	11.33	5.83
N ₁	106.21	27.19	12.78	6.85
N ₂	121.05	27.85	14.05	7.45
N ₃	133.95	32.85	15.18	8.15
SEm±	7.19	0.69	0.80	0.10
CD @ 5%	14.69	1.41	1.70	0.30
Phosphorus (kg ha ⁻¹)				
P ₀	73.88	26.60	11.92	2.66
P ₁	106.40	27.49	12.95	7.53
P ₂	121.02	30.32	14.13	11.06
P ₃	125.44	32.26	14.37	20.40
SEm±	7.19	0.69	0.80	0.10
CD @ 5%	14.69	1.41	1.70	0.30

to those obtained by Munna et al. (2016), Kumari et al. (2024), and Singh et al. (2024).

Conclusion

In conclusion, for achieving higher yield, better seed quality, and efficient nutrient utilization in pea under similar edaphic conditions, application of 120 kg N ha⁻¹ combined with 80 kg P₂O₅ ha⁻¹ is recommended. However, field-level validation and consideration of Rhizobium inoculation are advised to optimize nitrogen use efficiency and minimize reliance on high fertilizer inputs.

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Effect of nitrogen and potassium on yield and nutrient content of wheat (*Triticum aestivum* L.) crop

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Abstract

A pot experiment was conducted to study the effect of nitrogen and potassium on the yield and nutrient content of wheat crop. The experiment was laid out in a randomized block design with four levels of nitrogen (0, 20, 40 and 80 kg ha⁻¹) and four levels of potassium (0, 25, 50 and 100 kg ha⁻¹) with three replications. The results revealed that increasing doses of nitrogen up to 80 kg ha⁻¹ and potassium up to 100 kg ha⁻¹ significantly enhanced the grain and straw yield of wheat crop. The N, P and K contents were improved by the application of both nutrients. The addition of nitrogen and potassium had a beneficial effect on the uptake of N, P and K by the wheat crop.

Key words: Nitrogen, potassium, yield, nutrient content, wheat

Introduction

Wheat (*Triticum aestivum* L.) is the most important winter-season food crop in India, and improvements in its productivity have played a key role in making the country self-sufficient in food grains. The crop occupies an area of about 28.5 million hectares with a total production of 80.70 million tonnes and productivity of 2.83 tonnes ha⁻¹, contributing 12.43% of total world production. The major wheat-producing states in the country are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, Karnataka, West Bengal, Uttarakhand, Himachal Pradesh and Jammu & Kashmir. These states contribute about 99.5% of the total wheat production in the country. Nitrogen is the most important plant nutrient required for crop production and is needed in the greatest quantities among fertilizer nutrients. Although N plays a vital role in the good growth and development of wheat, over-fertilization is often harmful as it results in lodging, increased susceptibility to insect pests and diseases, and thus reduced yield and

quality. After N, potassium is absorbed in larger amounts than any other element and plays a leading role in increasing crop yield and improving product quality. Potassium is the third most important macronutrient after nitrogen and phosphorus. It has an important osmotic role, activates enzymes, and is involved in carbohydrate and protein synthesis, energy relations and assimilate translocation. Potassium supply is often considered a limiting factor due to its high accumulation in cereals.

Materials and Methods

The pot experiment was carried out at the agricultural experimental field (Department of Soil Science & Agricultural Chemistry), Nehru Mahavidyalaya, Lalitpur (U.P.) during 2023–24. Lalitpur district is part of the Bundelkhand plateau. The soil had EC 0.21 dSm⁻¹, pH 7.8, organic carbon 4.7 g kg⁻¹, and available N 80.5, P 6.0 and K 95.0 kg ha⁻¹. The experiment was laid out in a randomized block design with four levels of nitrogen (0, 20, 40 and 80 kg ha⁻¹) and four levels of potassium (0, 25,

50 and 100 kg ha⁻¹) with three replications. The recommended dose of P at 80 kg P₂O₅ ha⁻¹ was applied as single superphosphate. Nitrogen and potassium were supplied through urea and muriate of potash (MOP) as per treatments. Wheat was sown on October 15, 2023 and irrigated at appropriate times based on soil and crop appearance. Weeds were removed periodically. The crop was harvested at maturity. Grain and straw samples were analysed for N content by the Kjeldahl method (Jackson, 1973). Grain and straw samples were digested in di-acid (HNO₃:HClO₄) and the digest was analyzed for phosphorus by the Vanadomolybdo phosphoric acid yellow colour method, for K by flame photometer, and for Mn by atomic absorption spectrophotometer (Jackson, 1973). Nutrient uptake was calculated using yield data in conjunction with their respective contents.

Results and discussion

Yield studies

Nitrogen application had a significant effect on grain and straw yield of wheat crop. Higher doses of nitrogen significantly increased grain and straw yield. The percentage increases were 17.62%, 34.46% and 49.70% in grain yield and 13.24%, 15.11% and 34.36% in straw yield over control due

to 20, 40 and 80 kg N ha⁻¹, respectively. Higher levels of potassium also increased grain and straw yield of wheat. The percentage increases were 15.55%, 29.75% and 41.07% in grain yield and 10.83%, 19.92% and 31.95% in straw yield due to 25, 50 and 100 kg K ha⁻¹, respectively. Similar results have been reported by Gupta et al. (2020), Deep Chandra et al. (2024) and Sahu et al. (2024).

Nutrients composition

Nitrogen content

The data in Table 1 indicate that N application had a significant effect on nitrogen content in grain and straw of wheat crop. Higher doses of N significantly increased N content by 10.53%, 17.54% and 25.00% in grain and 10.91%, 20.00% and 41.82% in straw over control, respectively. Potassium application also had a significant effect on N content in grain and straw. It caused significant increases of 7.69%, 12.39% and 20.94% in grain and 3.28%, 8.20% and 13.11% in straw due to 25, 50 and 100 kg K ha⁻¹, respectively. Higher doses of K (25, 50 and 100 kg ha⁻¹) were significantly superior to control in enhancing N content in grain and straw of wheat. Similar results have been reported by Munna et al. (2012) and Sahu et al. (2025).

Table 1: Effect of nitrogen and potassium on grain and straw yield (gram/pot) and nitrogen content (%) of wheat crop

Treatments	Grain yield	Straw yield	N content (%) in grain	N content (%) in straw
Nitrogen (kg ha ⁻¹)				
N ₀	5.05	7.48	2.28	0.55
N ₁	5.94	8.47	2.52	0.61
N ₂	6.79	8.61	2.68	0.66
N ₃	7.56	10.05	2.85	0.78
SEm±	0.06	0.15	0.06	0.04
CD @ 5%	0.13	0.32	0.12	0.08
Potassium (kg ha ⁻¹)				
K ₀	5.21	7.48	2.34	0.61
K ₁	6.02	8.29	2.52	0.63
K ₂	6.76	8.97	2.63	0.66
K ₃	7.35	9.87	2.83	0.69
SEm±	0.06	0.15	0.06	0.04
CD @ 5%	0.13	0.32	0.12	0.08

Phosphorus content

As shown in Table 2, application of N increased P content by 7.14%, 14.29% and 17.86% in grain and 0%, 8.33% and 16.67% in straw over control. Higher levels (20, 40 and 80 kg N ha⁻¹) registered significant increases in P content in grain, while effects in straw were variable. The maximum P concentration in wheat was recorded at 80 kg N ha⁻¹. Potassium application caused increases in P content by 10.71%, 14.29% and 17.86% in grain and 4%, 12% and 16% in straw due to 25, 50 and 100 kg K ha⁻¹, respectively. Higher doses of K were significantly superior to control in enhancing P content in wheat (particularly in grain). Similar results have been reported by Munna et al. (2012) and Sahu et al. (2025).

Potassium content

The data in Table 2 indicate that N application had a significant effect on potassium content in grain and straw of wheat crop. Higher doses of N increased K content by 5.41%, 9.46% and 10.81% in grain and 4.64%, 6.19% and 6.19% in straw over control. Potassium application significantly affected its own content in grain and straw. The percentage increases were 2.63%, 5.26% and 6.58% in grain

and 4.26%, 12.77% and 13.30% in straw due to 25, 50 and 100 kg ha⁻¹, respectively. Higher doses of potassium were significantly superior to control in enhancing K content in grain and straw of wheat. Similar results have been reported by Munna et al. (2012) and Sahu et al. (2025).

Conclusion

Increasing levels of nitrogen up to 80 kg ha⁻¹ and potassium up to 100 kg ha⁻¹ significantly improved grain and straw yields as well as N, P and K contents in wheat. Application of both nutrients showed positive interactions in enhancing nutrient concentrations and overall crop performance.

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Table 2: Effect of nitrogen and potassium on phosphorus and potassium content (%) of wheat crop

Treatments	P content (%) in grain	P content (%) in straw	K content (%) in grain	K content (%) in straw
Nitrogen (kg ha⁻¹)				
N ₀	0.28	0.24	0.74	1.94
N ₁	0.30	0.24	0.78	2.03
N ₂	0.32	0.26	0.81	2.06
N ₃	0.33	0.28	0.82	2.06
SEm±	0.002	0.01	0.012	0.015
CD @ 5%	0.004	0.02	0.026	0.075
Potassium (kg ha⁻¹)				
K ₀	0.28	0.25	0.76	1.88
K ₁	0.31	0.26	0.78	1.96
K ₂	0.32	0.28	0.80	2.12
K ₃	0.33	0.29	0.81	2.13
SEm±	0.002	0.01	0.012	0.015
CD @ 5%	0.004	0.02	0.026	0.075

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Factor productivity, nutrient and harvest status of rice in farmers' fields of Ghagraghat

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Abstract

Rice is the lifeline of food security in Asia, feeding billions and sustaining rural economies. Yet, productivity in farmers' fields often lags behind research station yields due to constraints in factor efficiency, nutrient management, and harvest practices. Understanding these dimensions is critical for bridging yield gaps, improving resource-use efficiency, and ensuring sustainability. This paper explores factor productivity, nutrient dynamics, and harvest status of rice in farmers' fields, drawing insights from field surveys and agronomic studies. Temporal and spatial variability of the major nutrients in farmers field are the important factors leading to skewed paddy productivity in the farmers' fields. The results of this exploratory study organized in 40 farm sites around Ghagraghat representing Indo gangetic plains indicated variability among farm sites for productivity, soil nutrient supply and nutrient use efficiency by genotypes. Rice productivity across different agro ecosystems varied widely. Nutrient harvest index calculated across farmers' field at these sites indicated steep variation for all the nutrients due to poor nutrient concentration in the grain and straw. To find out the contribution of a single fertilizer factor in the productivity of rice, the partial factor productivity was calculated. At Ghagraghat PFP was found to be 44.86% for N, 115.53% for P₂O₅. At Mandya, the values of IE and nutrient ratios indicated sharp differences among farm sites with regard to nutrient uptake, genotypes indicating highly imbalanced nutrition which do not match with the crop nutrient requirements. This suggests for refinement of the current fertilizer practice being followed by the farmer.

Key words: Factor Productivity, Nutrient, Harvest, Rice, Farmers' Fields, Ghagraghat

Introduction

Rice productivity in farmers' fields is shaped by the interplay of factor efficiency, nutrient dynamics, and harvest management. Field surveys across diverse agro-ecological zones reveal wide variability in factor productivity, largely influenced by soil fertility, irrigation practices, and varietal choice. Imbalanced input use—particularly

excessive nitrogen with limited phosphorus and potassium—has led to declining nutrient use efficiency and widening yield gaps. Genotypic differences among rice varieties further determine nutrient uptake and conversion efficiency, underscoring the need for site-specific nutrient management. Nutrient assessments highlight

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deficiencies in phosphorus, potassium, and micronutrients, while nitrogen remains over-applied, creating skewed nutrient profiles. Integrated nutrient management (INM), combining balanced fertilizers, organic amendments, and biofertilizers, emerges as a sustainable pathway to restore soil health and enhance productivity. Harvest status surveys indicate yield gaps of 1–2 t/ha between research station trials and farmers' fields, attributed to nutrient imbalances, pest incidence, and suboptimal agronomic practices. Post-harvest inefficiencies—such as delayed harvesting, poor threshing, and inadequate storage—further reduce effective productivity. Mechanization and improved post-harvest handling can significantly minimize losses.

Materials and Methods

In about 40 farmer sites out of the identified farms including the frontline demonstrations representing the region / rice ecosystem in the district fields were selected among the survey sites and farmers fertilizer practice (FFP) were recorded for estimating soil nutrient supply and fertilizer efficiency parameters. These field sites truly represented the district/rice growing region covering major and dominant rice ecosystem / soil types and representing all strata of farmers (Small, marginal and large) and crop management levels recording low to high productivity levels. GPS coordinates (longitude, latitude and altitude data) of the selected farm sites were also collected for use in mapping. Bulk/composite soil sample (0-15 cm) from each of the selected farm holdings before land preparation and analyse for all physico chemical characters (available N, P₂O₅, K₂O, pH and organic carbon content) on air dried, processed soil were performed. Recorded

all package of practices followed by the farmer particularly with regard to manures applied (quantity/ha), nutrient (NPK) contents in the manures, fertilizer practices, timing, and plant protection measures followed by each farmer. Information were collected regarding the variety planted/sown, date of sowing nursery, nursery management, date of planting, age of seedlings at transplanting, 50% flowering, harvest date and duration of the crop in each farmer's field.

Results and Discussion

Important soil fertility characteristics (pH, SOC, available N, P and K) analysed prior to planting from the farmers' fields is presented in the Table 1. The parameters assessed showed a fairly wide range of variability. Soils at Ghagraghat were sandy loam in texture with pH 7.2 to 8.6, 0.23-0.55% soil organic carbon, 165-291 kg/ha available N, 19.30-54.60 kg/ha available P and 123 to 285 kg/ha available K. Hybrids, in general, recorded higher yields than HYVs. Earlier studies have been reported by (Sharma, et al. 2020, 2022, Brajendra et al. 2022, Tuti, et al. 2022).

The yields ranged from 3.47 t/ha to 7.50t/ha at Ghagraghat indicating substantial variability among the farm (Table 2). Grain and straw nutrient concentration varied considerably at the test locations. Higher nutrient concentration in grain and straw were recorded in the samples at Ghagraghat, indicating wide variations in the nutritional status of the crop as also reflected by low soil nutrient availability and highly imbalanced fertilizer use by the farmers. Nutrient accumulation in grain indicated an average harvest index (translocation) of 85.09, 82.59 and 19.25 per cent at Ghagraghat, broadly reflecting the dry matter yields (Table 3). Nutrient

Table 1: Soil characteristics in the farmers field prior to planting during Kharif 2012

Parameters	Min	Max	Average	Sd
Ghagraghat, UP				
pH	7.20	8.60	7.92	0.39
SOC%	0.23	0.55	0.35	0.08
Avail. N (kg/ha)	165.00	291.00	202.40	32.08
Avail. P ₂ O ₅ (kg/ha)	19.30	54.60	36.65	9.81
Avail. K ₂ O (kg/ha)	123.00	285.00	191.98	36.67

Table 2: Grain and straw yield, % variations during Kharif 2012

Parameters	Min	Max	Average	Sd
Ghaghraghat, UP				
Grain(t/ha)	3.47	7.50	4.96	1.28
Straw(t/ha)	4.23	9.78	6.27	1.79
Parameters	N (%)	P (%)	K (%)	Sd
Ghaghraghat, UP				
Grain	1.23	0.39	0.33	0.05
Straw	0.40	0.06	1.14	0.06

harvest index calculated across farmers' field at Ghaghraghat, indicated steep variation for all the nutrients. Unlike the grain yields, the nutrient harvest index recorded at Ghaghraghat was substantially higher.

Table 3: Nutrient uptake and harvest index

Parameters	Grain	Straw	NHI	Sd
Ghaghraghat, UP				
N(kg/ha)	62.11	26.41	85.09	25.56
P ₂ O ₅ (kg/ha)	20.24	4.26	82.59	41.38
K ₂ O (kg/ha)	17.41	72.99	19.25	31.57

Internal efficiency (IE, kg grain/kg nutrient accumulation) varied between the sites and genotypes. Average IE for hybrids at Ghaghraghat was 79.99, 241.45 and 285.41 kg grain/kg N, P₂O₅ and K₂O respectively (Table 4). This works out to a nutrient accumulation ratio of 17.82 kg N at Ghaghraghat, 4.93 kg P₂O₅ at Ghaghraghat per ton of

Table 4: Internal efficiency of nutrients in hybrids and HYVs Kharif 2012

Parameters	Internal efficiency	Soil efficiency (%)	Fertilizer use efficiency (%)	Partial factor productivity	Nutrient requirement
Ghaghraghat, UP					
N	79.99	43.73	87.72	44.86	17.82
P ₂ O ₅	241.45	66.86	23.94	115.63	4.93
K ₂ O	285.41	47.01	88.14	124.22	18.19
SD	31.18	12.51	36.94	43.55	7.55

grain. Soil efficiency worked out at Ghaghraghat varied from 43.73% for nitrogen to 66.66% for phosphorus and 47.01% for potassium. At Ghaghraghat FUE was found to be 87.72% for N, 23.94% for P₂O₅ and 88.14% for K₂O respectively. To find out the contribution of a single fertilizer factor in the productivity of rice, the partial factor productivity was calculated. At Ghaghraghat PFP was found to be 44.86% for N, 115.53% for P₂O₅. At Mandya, the values of IE and nutrient ratios indicated sharp differences among farm sites with regard to nutrient uptake, genotypes indicating highly imbalanced nutrition which do not match with the crop nutrient requirements. This suggests for refinement of the current fertilizer practice being followed by the farmer. Earlier studies have been reported by Vishwakarma, et al. (2012), Kumar, et al. (2014), Pushpalatha et al. (2015), Sharma et al. (2022) Padbhusan et al. (2022) Madhusudan, et al. (2022) and Ondrasek, et al. (2022).

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Influence of Milk Fat Content on Yield and Quality of Paneer

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Abstract

In an attempt to study the quality of paneer, there were four fat levels i.e. 1.5 %, 3.0%, 4.5% and 6.0% maintained in the buffalo milk to manufacture paneer. The paneer samples thus prepared were analyzed for sensory evaluation and chemical analysis in terms of moisture, fat, protein, lactose, ash and titratable acidity. Investigation was replicated thrice. The data thus obtained were statistically analyzed using CRD and tested at 5% level of significance. The fat content of milk had a significant effect on all above characteristics of study. This study was concluded as milk must contain at least 6.0% fat for getting well accepted quality paneer and to meet the legal standards.

Key Words: SNF, legal standards, sensory evaluation, fat on dry matter, ash

Introduction

Paneer is an Indian soft cheese manufactured by the combined action of heat and acid in coagulation of milk. This is used as a base material for the preparation of a large number of culinary dishes and is highly nutritious and wholesome (Sachdeva and Singh 1990). It contained almost all the fat, casein complexed with denatured and a portion of salts and lactose as reviewed by Kumar et. al. 2014. Paneer is an ideal food for expectant mother, infants, growing children, adolescents and adults. Being rich source of animal protein, it is good source of all essential amino acids to the vegetarians. Its fat content renders the fat-soluble vitamins A and D, all essential fatty acids and energy. With its high protein and low sugar content, it is recommended to the diabetic patients. It has also particular value for those who possess the problem of lactose intolerance. Without standardization of milk, uniformity in the composition of the finished product cannot be obtained. Simultaneously, it is also necessary to get the product conforming the legal standard

Materials and Methods

Buffalo milk was received from the source aseptically, tested and standardized to 1.5, 3.0, 4.5 and 6.0 percent milk fat with a SNF level of 9.0 percent by adding water / fresh buffalo skim milk. The additional requirement of SNF content was made up through spray dried skim milk powder. The paneer was prepared by the method suggested by Sachdeva and Singh (1987) and Aneja (1997). The yield (%) of paneer was reported on the weight basis of same milk used for the purpose. Paneer samples were taken as per procedure described in SP18 Part XI (1981). Sensory evaluation was done by 100-point scale as given by Patil and Gupta (1986). The moisture content determined by Gravimetric method as described in IS: 1479, Part II 1961. Fat content was determined by the Gerber's method. The protein content of Paneer was determined by the Kjeldahl's method. The lactose content of paneer was estimated by Fehling's solution method as described in Lab. Mann. in Agriculture Chemistry (1960). Ash Content determined by the procedure given in S.P. 18 Part XI (1981), BIS New Delhi. Titratable acidity

in paneer was determined as per the procedure adopted by Rajorhia et al., (1984). This study was replicated thrice and data thus obtained were analyzed by CRD and tested at 5% level of significance.

Results and Discussion

It is evident from the data depicted in the table that fat levels of milk had a significant effect on every parameter of quality of paneer in the study (Table 1).

The yield of paneer was increased with the increase in fat level of milk. The increase in yield of paneer at higher fat level of milk might be attributed to increase in the recovery of total solids and higher fat content in milk. Similarly, the recovery of total solids in paneer also increased at higher fat levels of milk. The hike in recovery of total solids with increasing fat levels in milk might be attributed to the increase in fat-protein complexes during heating of milk (Chauhan et al. 1917). The overall sensory score of paneer samples increased with the increase in fat levels of milk. It is particularly due to improvement in flavour and body and texture of paneer with increase in fat content of paneer samples. It is well established that milk fat contributes most pleasing taste and odour to the milk products (Kumar 2021). Moisture content in paneer samples was significantly reduced with the increase in each

level of fat in milk. The reason could be hydrophobic nature of fat which reduces the moisture content of paneer at higher fat levels. Similar trend was also reported by Roy (1994). All fat levels of milk conformed the legal requirement of moisture in paneer samples which is maximum 70%. The fat content of paneer samples increased significantly with increase in each level of fat. Pal and Yadav (1992) also reported the milk with greater fat content produced paneer with more fat. The analysis of data shows that there must be at least 6.0% fat in milk to get paneer of corresponding legal standard which is 50 % fat on dry matter basis.

The protein content of paneer samples decreased significantly with increase in each level of fat. Chawla et al. (1987) also reported as inverse relationship between protein content of paneer and fat level of milk. The lactose content of paneer was significantly reduced with increase in each level of fat. It is well established that lactose, being water soluble and have no association with any other constituents, remains in the whey (Kumar 2021). So, paneer samples which retains higher amount of whey, contained higher lactose. This view get support from the results of Pal et al. (1991). The ash content of paneer was significantly decreased with increase in each level of fat. There is intimate association between protein and ash content in milk

Table 1: Effect of fat content of milk on the yield, recovery of total solids and quality of paneer

Characteristics	Fat Levels				Effect	SE (Diff)	CD at 5%
	1.5%	3.0%	4.5%	6.0%			
Yield (%)	18.40	19.19	20.80	22.91	Significant	0.11	0.22
Recovery of total solids (%)	58.09	59.72	63.29	66.35	Significant	0.25	0.50
Overall sensory score out of 100	74.68	80.42	85.47	88.52	Significant	1.13	2.24
Moisture (%)	66.84	62.65	58.92	56.55	Significant	0.25	0.50
*Fat (%)	7.83	14.80	20.43	24.36	Significant	0.09	0.19
	(23.61)	(39.63)	(49.73)	(56.06)			
Protein (%)	17.18	16.52	15.34	14.01	Significant	0.09	0.17
Lactose (%)	3.12	2.94	2.84	2.73	Significant	0.02	0.03
Ash (%)	2.23	2.14	1.97	1.79	Significant	0.01	0.02
Titrateable acidity (lactic acid %)	0.350	0.338	0.329	0.320	Significant	0.003	0.005

*Values in the parentheses are fat on dry matter basis

system. So, paneer samples higher in protein would also be higher in ash content and vice versa. Pal and Yadav (1992) also reported similar results in this regard. The titratable acidity of paneer samples progressively decreased with the increase in fat levels of milk. The relatively higher acidity in low fat paneer might be due to its higher level of protein and greater retention of colloidal phosphate. Protein and phosphate contribute maximum acidity of milk products Chawla et.al. (1987).

Conclusion

It is finally, concluded that 6.0 % fat in milk can produce paneer of well accepted quality conforming legal standards, and is being recommended for the commercial production of paneer.

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Effect of Different Growing Environments on available Macro and Micro Nutrient in soil under Various Establishment Methods

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Abstract

This study investigates the impact of different growing environments on available macro (N, P, K) and micro (Fe, Mn, Cu, Zn) nutrient content in soil under various establishment methods, including transplanted rice (TP), direct seeded rice (DSR), and system of rice intensification (SRI). The results showed that different rice establishment methods significantly affected the available macro and micro nutrient content in the soil. TP generally had higher available N and P content, while control had higher K content. Among micro nutrients, DSR had higher Fe and available Zn content, while SRI had higher available Mn content. The nutrient content varied significantly across different soil depths and treatments. The study highlights the importance of considering the nutrient dynamics in different rice establishment methods to optimize crop productivity and soil health.

Key Words: Rice establishment methods, Macro nutrients, Micro nutrients, Nitrogen, Phosphorus, Potassium, Iron, Manganese, Copper, Zinc, Soil depth

Introduction

Rice is a staple food for more than half of the world's population, and its production is crucial for ensuring global food security. With the increasing demand for rice, different establishment methods have been adopted to improve crop productivity and reduce production costs. These methods include transplanted rice (TP), direct seeded rice (DSR), and system of rice intensification (SRI). Each of these methods has its own advantages and disadvantages, and their impact on soil nutrient dynamics can vary significantly.

Soil nutrients play a critical role in determining crop productivity, and their availability can be influenced by the type of establishment method used. Macro nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are essential for plant growth and development, while micro nutrients like iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) are also crucial for various physiological processes in plants. The availability of these nutrients can be affected by factors such as soil type, pH, and organic matter content, as well as the type of establishment method used.

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Understanding the impact of different establishment methods on soil nutrient dynamics is essential for optimizing crop productivity and maintaining soil health. This study aims to investigate the effect of different growing environments on macro and micro nutrient content in rice under various establishment methods, including TP, DSR, and SRI. The findings of this study will provide valuable insights into the nutrient dynamics of different rice establishment methods and will be useful for developing sustainable and efficient rice production systems.

Materials and Methods

Experimental Site

A field experiment was conducted at the ICAR-Indian Institute of Rice Research farm during the Kharif season of 2024 on deep black clayey vertisols (Typic Pellustert) at the IIRR Rice Research farm, Hyderabad (17°19' N latitude, 78°23' E longitude, 542 m altitude with mean annual precipitation of 750 mm). The plot selected for the purpose was A-3, A-5, and B-7. The plot's detailed characteristics are given in the table. Initial and post-harvest soil samples were collected prior to the beginning of the studies and are depicted in the table. All agronomic parameters under different rice establishment methods were recorded.

Experimental Design

The research was designed in a Randomized Block Design (RBD), arranged in three replications and treatments included the growing environment of rice which is transplanted, puddled rice. And three replications and four treatments (Control, TP, SRI and DSR) for the field A3 (a) & for B7 (a) field.

Soil Sampling and Analysis

Soil samples from 0-20, 20-40, and 40-60 cm depth were collected in triplicate. Available N, P, K, Fe, Mn, Cu and Zn parameters, soil samples that passed through 2-mm sieves were used. available N by alkaline-KMnO₄ oxidizable N method (Subbiah and Asija, 1956), available P by 0.5 M sodium bicarbonate (NaHCO₃) extraction method (Olsen et al., 1954), available K (Hanway and Heidel, 1952) and Available Fe, Mn, Cu and Zn by DTPA method (Lindsay and Norvell, 1978).

Results and Discussion

The study evaluated the effect of different growing environments on available N, P, K, Fe, Mn, Cu, and Zn content in rice under various establishment methods. The results are presented below:

Available Nitrogen

The available N content in soil was significantly affected by the different establishment methods. Transplanted Rice (TP) had the highest available N content in soil at 0-20 cm depths is 269 kg ha⁻¹ (Table 1), while Direct Seeded Rice (DSR) had the lowest available N content at 0-20 cm depth (157 kg ha⁻¹). The available N content decreased with increasing soil depth in TP, while it remained relatively stable in DSR and System of Rice Intensification (SRI). This suggests that TP may have a higher available N rate, leading to a decrease in available N content with depth. Previous studies were conducted by Kumar, et al. (2014), Singh, et al. (2014), Amanullah, et al. (2016) and Sharma et al. (2022).

Table 1: Effect of different growing environments on N, P and K (kg ha⁻¹) in different rice establishment methods

Treatments	N (kg ha ⁻¹)			P (kg ha ⁻¹)			K (kg ha ⁻¹)		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
Control	188	145	130	15.4	13.9	11.5	253	225	204
Transplanted Rice (TP)	269	168	106	23.5	19.4	18.3	264	184	168
Direct seeded Rice (DSR)	157	136	132	11.6	10.9	10.2	168	146	156
System of rice Intensification	162	145	130	15.5	14.1	11.7	166	142	112
Sem (±)	5.06	3.80	3.67	1.07	0.78	0.63	5.86	2.27	5.62
CD (0.05)	12.39	9.30	8.99	2.61	1.91	1.55	14.34	12.89	13.75

Available Phosphorus

The available P content in soil was also significantly affected by the different establishment methods. TP had the highest available P content in soil at 0-20 cm depth (23.5 kg ha⁻¹), while DSR had the lowest available P content in soil at 0-20 cm depth (11.6 kg ha⁻¹). The available P content decreased with increasing soil depth in all treatments. This may be due to the fact that P is a relatively immobile nutrient in soil, and its availability decreases with depth. Previous studies were conducted by Anila, et al, (2018) Sharma, et al. (2020), Sharma. et al. (2022) and Indoria, et al. (2024).

Available Potassium

The available K content in soil was highest in the control treatment at 0-20 cm depth (253 kg ha⁻¹), while SRI had the lowest available K content in soil at 40-60 cm depth (112 kg ha⁻¹). The available K content decreased with increasing soil depth in TP and SRI, while it remained relatively stable in DSR. This suggests that available K may be more readily available in the control treatment, while SRI may have a higher available K rate. Previous studies were conducted by Pushpalatha et al. (2015) and Sharma. et al. (2022).

Available Iron

The available Fe content in soil was significantly higher in TP and DSR compared to the control and SRI at 0-20 cm depth (Table 2). The available Fe content in soil decreased with increasing soil depth across all treatments. The available Fe content in soil at the different treatments was as

follows: TP: 5.98 mg kg⁻¹ (0-20 cm), 3.60 mg kg⁻¹ (20-40 cm), 1.10 mg kg⁻¹ (40-60 cm). DSR: 5.98 mg kg⁻¹ (0-20 cm), 3.50 mg kg⁻¹ (20-40 cm), 0.90 mg kg⁻¹ (40-60 cm), SRI: 3.08 mg kg⁻¹ (0-20 cm), 1.10 mg kg⁻¹ (20-40 cm), 0.60 mg kg⁻¹ (40-60 cm), Control: 2.32 mg kg⁻¹ (0-20 cm), 1.66 mg kg⁻¹ (20-40 cm), 1.52 mg kg⁻¹ (40-60 cm). Previous studies were conducted by Srilathaa et al. (2019) and Sharma. et al. (2022)

Available Manganese

The available Mn content in soil was significantly affected by the different establishment methods. SRI had the highest available Mn content in soil at 0-20 cm and 40-60 cm depths, while TP had the lowest Mn content in soil at 20-40 cm and 40-60 cm depths. The available Mn content in soil varied significantly across different soil depths and treatments. The available Mn content in soil at the different treatments was as follows: SRI: 7.76 mg kg⁻¹ (0-20 cm), 3.60 mg kg⁻¹ (20-40 cm), 2.80 mg kg⁻¹ (40-60 cm), TP: 6.1 mg kg⁻¹ (0-20 cm), 0.80 mg kg⁻¹ (20-40 cm), 0.20 mg kg⁻¹ (40-60 cm), DSR: 4.66 mg kg⁻¹ (0-20 cm), 1.80 mg kg⁻¹ (20-40 cm), 1.10 mg kg⁻¹ (40-60 cm). Control: 2.92 mg kg⁻¹ (0-20 cm), 1.05 mg kg⁻¹ (20-40 cm), 0.99 mg kg⁻¹ (40-60 cm). Previous studies were conducted by Pushpalatha et al. (2015) and Sharma. et al. (2022).

Available Copper

The available Cu content in soil was significantly higher in DSR compared to other treatments at 0-20 cm and 20-40 cm depths. The available Cu content in soil decreased with increasing

Table 2: Effect of different growing environments on Fe, Mn, Cu and Zn (mg kg⁻¹) in different rice establishment methods

Treatments	Fe (mg kg ⁻¹)			Mn (mg kg ⁻¹)			Cu (mg kg ⁻¹)			Zn (mg kg ⁻¹)		
	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60	0-20	20-40	40-60
Control	2.32	1.66	1.52	2.92	1.05	0.99	1.64	0.80	0.30	3.76	1.10	0.90
Transplanted Rice (TP)	5.98	3.60	1.10	6.1	0.80	0.20	4.76	1.10	0.90	7.48	2.30	1.90
Direct seeded Rice (DSR)	5.98	3.50	0.90	4.66	1.80	1.10	5.80	3.60	1.20	7.82	3.69	2.80
System of rice Intensification	3.08	1.10	0.60	7.76	3.60	2.80	1.46	0.80	0.40	3.48	1.88	1.10
Sem (±)	0.18	0.12	0.05	0.25	0.08	0.05	0.16	0.07	0.04	0.26	0.11	0.08
CD (0.05)	0.39	0.23	0.10	0.51	0.17	0.11	0.32	0.16	0.07	0.53	0.22	0.16

soil depth in all treatments. The available Cu content in soil at the different treatments was as follows: DSR: 5.80 mg kg⁻¹ (0-20 cm), 3.60 mg kg⁻¹ (20-40 cm), 1.20 mg kg⁻¹ (40-60 cm). TP: 4.76 mg kg⁻¹ (0-20 cm), 1.10 mg kg⁻¹ (20-40 cm), 0.90 mg kg⁻¹ (40-60 cm). Control: 1.64 mg kg⁻¹ (0-20 cm), 0.80 mg kg⁻¹ (20-40 cm), 0.30 mg kg⁻¹ (40-60 cm)- SRI: 1.46 mg kg⁻¹ (0-20 cm), 0.80 mg kg⁻¹ (20-40 cm), 0.40 mg kg⁻¹ (40-60 cm). Previous studies were conducted by Pushpalatha et al. (2015), Sharma. et al. (2022)

Available Zinc

The available Zn content in soil was significantly higher in DSR compared to other treatments at 0-20 cm and 20-40 cm depths. The available Zn content in soil decreased with increasing soil depth in all treatments. The available Zn content in soil at the different treatments was as follows: DSR: 7.82 mg kg⁻¹ (0-20 cm), 3.69 mg kg⁻¹ (20-40 cm), 2.80 mg kg⁻¹ (40-60 cm), TP: 7.48 mg kg⁻¹ (0-20 cm), 2.30 mg kg⁻¹ (20-40 cm), 1.90 mg kg⁻¹ (40-60 cm), SRI: 3.48 mg kg⁻¹ (0-20 cm), 1.88 mg kg⁻¹ (20-40 cm), 1.10 mg kg⁻¹ (40-60 cm), Control: 3.76 mg kg⁻¹ (0-20 cm), 1.10 mg kg⁻¹ (20-40 cm), 0.90 mg kg⁻¹ (40-60 cm). Previous studies were conducted by Srilatha et al. (2019), Lal, et al. (2020) and Sharma. et al. (2022).

Conclusion

The study evaluated the effect of different growing environments on available macro and micro nutrient content in soil at different soil depths under various rice establishment methods. The available nutrient content in soil varied significantly across different soil depths and treatments. These findings have important implications for optimizing crop productivity and maintaining soil health in rice-based systems.

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Effect of Phosphorus and Bio-Organics on Yield and Nutrient Uptake by Mung bean [*Vigna radiata* (L.) Wilczek] in an Inceptisol of Varanasi

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Abstract

A pot experiment was conducted to study the effect of phosphorus and bio-organics on yield, and nutrient uptake by mung bean in an Inceptisol. The results showed that application of phosphorus at 40 kg P₂O₅ ha⁻¹ significantly increased seed yield by 44.7% and stover yield by 35.9% over control. Similarly, application of poultry manure at 2.5 t ha⁻¹ + Rhizobium + PSB increased seed yield by 26.8% and stover yield by 24.5% over control. Phosphorus application also improved nutrient uptake, with maximum nitrogen uptake by seed (69.3%) and stover (86.2%) recorded at 40 kg P₂O₅ ha⁻¹. Bio-organics application also showed significant improvement in nutrient uptake, with poultry manure at 2.5 t ha⁻¹ + Rhizobium + PSB recording 39.5% and 49.8% increase in nitrogen uptake by seed and stover, respectively. The study suggests that integrated use of phosphorus and bio-organics can improve mung bean productivity and nutrient use efficiency.

Keywords: Mungbean, Phosphorus, Bio-organics, Yield, Nutrient uptake, Inceptisol

Introduction

Mung bean (*Vigna radiata* L.) is a vital pulse crop in India, serving as a primary source of protein and nutrients for millions. Beyond its nutritional value, mung bean is valued for its ability to fix atmospheric nitrogen, enhance soil fertility, and provide a valuable income source for farmers. Despite its importance, mung bean productivity in India remains low, largely due to inadequate nutrient management practices. Phosphorus is a crucial nutrient for grain legumes, playing a pivotal role in nodulation, growth, yield, and soil fertility. It is essential for healthy root growth, grain development, and ripening, and participates in

various biochemical processes, including energy transfer and oxidation-reduction reactions. Phosphorus application has been shown to promote cell division, leading to increased growth and productivity in legumes. Bio-organics like vermicompost and poultry manure offer a sustainable alternative to chemical fertilizers, enhancing soil fertility, promoting plant growth, and improving crop yields. These organic amendments can help mitigate the environmental impact of chemical fertilizers, making them an attractive option for sustainable agriculture. This study aims to

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investigate the impact of phosphorus and bio-organics on mung bean growth attributes, with the goal of identifying an effective nutrient management strategy for improving productivity and sustainability in mung bean production systems.

Materials and Methods

A pot experiment was conducted during the kharif season of 2017 in a greenhouse at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The experimental site was located at 25.2677° N latitude, 82.9913° E longitude, and an altitude of approximately 86 meters above mean sea level, falling within the sub-tropical zone. The experiment was conducted on a sandy loam soil with alkaline reaction, low available nitrogen, and medium available phosphorus and potassium. The experiment followed a factorial completely randomized design (CRD) with three replications. The treatments consisted of three levels of phosphorus (0, 20, and 40 kg P₂O₅ ha⁻¹) and five levels of bio-organics: - (Control, Vermicompost (VM) at 2.5 t ha⁻¹, VM at 2.5 t ha⁻¹ + Rhizobium + PSB, Poultry manure (PM) at 2.5 t ha⁻¹ and PM at 2.5 t ha⁻¹ + Rhizobium + PSB). Mung bean was grown in an Inceptisol, and growth attributes were recorded. The crop was sown on

July 15, 2017, and irrigated as needed. Weeds were removed regularly, and the crop was harvested at maturity. Seed and stover samples were analyzed for nitrogen content using the Kjeldahl method (Jackson, 1973). Grain and straw samples were digested in di-acid (HNO₃, HClO₄) and analyzed for phosphorus, potassium, and other nutrients using standard methods. The nutrient uptake was calculated using the yield data and respective nutrient contents.

Results and Discussion

Seed yield

Maximum grain yield was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (1174.49 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (1036.54 kg ha⁻¹) as compared to control (811.50 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase grain yield by 44.73% and 27.73% higher over control, respectively (Table 1). Maximum grain yield was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (1102.99 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (1083.82 kg ha⁻¹) as compared to control (870.02 kg ha⁻¹). Application of poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 26.78% and 24.57%

Table 1: Effect of phosphorus and bio-organism levels on seed and stover yield, nitrogen uptake by seed and stover of mung bean

Treatments	Seed yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)	N uptake by seed (kg ha ⁻¹)	N uptake by stover (kg ha ⁻¹)
P ₀	811.50	1410.35	24.79	17.49
P ₁	1036.54	1679.38	34.96	24.26
P ₂	1174.49	1916.91	41.96	32.57
CD (P=0.05)	19.26	47.73	0.89	1.79
Bio-Organics levels				
BO ₀	870.02	1467.41	27.66	19.64
BO ₁	982.24	1612.81	32.47	22.87
BO ₂	1083.82	1791.86	37.56	27.85
BO ₃	998.49	1646.16	33.24	24.10
BO ₄	1102.99	1826.17	38.59	29.41
CD (P=0.05)	24.86	61.62	1.16	2.51

higher over control, respectively. These findings are consistent with Meena et al (2013), Shukla et al (2016), Meena (2017), and Sharma et al., (2022).

Stover yield

Maximum stover yield was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (1916.91 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (1679.38 kg ha⁻¹) as compared to control (1410.35 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase stover yield by 35.92% and 19.08% higher over control, respectively. Maximum stover yield was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (1826.17 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (1791.86 kg ha⁻¹) as compared to control (1467.41 kg ha⁻¹). Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 24.45% and 22.11% higher over control, respectively. These findings are consistent with Singh et al., (2010), Meena et al., (2011), Meena et al (2013), and Sharma et al., (2022).

Nitrogen uptake by seed

Maximum nitrogen uptake by seed was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (41.96 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (34.96 kg ha⁻¹) as compared to control (24.79 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase nitrogen uptake by seed by 69.26% and 41.02% higher over control, respectively (Table 1).

Maximum nitrogen uptake by seed was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (38.59 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (37.56 kg ha⁻¹) as compared to control (27.66 kg ha⁻¹). Applications of poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 39.52% and 35.79% higher over control, respectively. These findings are consistent with Meena et al., (2012), Singh et al., (2017), Meena et al., (2017), Yadav et al., (2019) and Sharma et al. (2022).

Nitrogen uptake by stover

Maximum nitrogen uptake by stover was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (32.57

kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (24.26 kg ha⁻¹) as compared to control (17.49 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase nitrogen uptake by stover by 86.22% and 38.71% higher over control, respectively.

Maximum nitrogen uptake by stover was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (29.41 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (27.85 kg ha⁻¹) as compared to control (19.64 kg ha⁻¹). Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 49.75% and 41.80% higher over control, respectively. These findings are consistent with Meena et al., (2013), Shukla et al., (2016), Singh et al., (2017), and Yadav et al., (2019),

Phosphorus uptake by seed

Maximum phosphorus uptake by seed was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (5.14 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (3.95 kg ha⁻¹) as compared to control (2.67 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase phosphorus uptake by seed by 92.51% and 47.94% higher over control, respectively (Table 2). Maximum phosphorus uptake by seed was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (4.70 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (4.51 kg ha⁻¹) as compared to control (3.00 kg ha⁻¹). Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 56.67% and 50.33% higher over control, respectively. These results are consistent with the findings of Meena et al., (2013), Shukla et al., (2016), Singh et al., (2017), and Yadav et al., (2019),

Phosphorus uptake by stover

Maximum phosphorus uptake by stover was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (4.95 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (3.56 kg ha⁻¹) as compared to control (2.24 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase phosphorus uptake by stover by 120.98% and 58.93% higher over control, respectively. Maximum phosphorus uptake by stover

Table 2: Effect of phosphorus and bio-organism levels on phosphorus and potassium uptake by seed and stover of mung bean

Treatments	P uptake by seed (kg ha ⁻¹)	P uptake by stover (kg ha ⁻¹)	K uptake by seed (kg ha ⁻¹)	K uptake by stover (kg ha ⁻¹)
Phosphorus levels				
P ₀	2.67	2.24	5.07	20.27
P ₁	3.95	3.56	7.50	26.78
P ₂	5.14	4.95	10.11	33.45
CD (P=0.05)	0.19	0.30	0.52	1.86
Bio-Organics levels				
BO ₀	3.00	2.60	5.28	21.47
BO ₁	3.60	3.24	7.15	25.16
BO ₂	4.51	4.22	8.82	30.32
BO ₃	3.79	3.42	7.34	25.94
BO ₄	4.70	4.45	9.22	31.28
CD (P=0.05)	0.25	0.59	0.67	0.83

was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (4.45 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (4.22 kg ha⁻¹) as compared to control (2.60 kg ha⁻¹). Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 71.15% and 62.31% higher over control, respectively. These results are consistent with the findings of Shukla et al., (2016), Singh et al., (2010), Singh et al., (2017), and Yadav et al., (2019),

Potassium uptake by seed

Maximum potassium uptake by seed was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (10.11 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (7.50 kg ha⁻¹) as compared to control (5.07 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase potassium uptake by grain by 99.41% and 47.93% higher over control, respectively (Table 2). Maximum potassium uptake by seed was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (9.22 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (8.82 kg ha⁻¹) as compared to control (5.28 kg ha⁻¹). Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost. These results are consistent with the findings of Singh et al., (2010), Meena et al., (2013), Shukla et al., (2016), and Meena

(2017),

Potassium uptake by stover

Maximum potassium uptake by stover was recorded in treatment P₂ (40 kg P₂O₅ ha⁻¹) (33.45 kg ha⁻¹) followed by P₁ (20 kg P₂O₅ ha⁻¹) (26.78 kg ha⁻¹) as compared to control (20.27 kg ha⁻¹). Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ were observed to significantly increase potassium uptake by stover by 65.02% and 32.12% higher over control, respectively. Maximum potassium uptake by stover was observed in treatment BO₄ (PM 2.5 t ha⁻¹ + Rhizobium + PSB) (31.28 kg ha⁻¹) followed by BO₂ (VM 2.5 t ha⁻¹ + Rhizobium + PSB) (30.32 kg ha⁻¹) as compared to control (21.47 kg ha⁻¹). Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB represented an increase of 45.69% and 41.22% higher over control, respectively. These results are consistent with the findings of Meena et al., (2012), Meena et al., (2013), Singh et al., (2017), and Yadav et al., (2019),

Conclusion

The study concludes that phosphorus application at 40 kg P₂O₅ ha⁻¹ and bio-organics (poultry manure or vermicompost) with Rhizobium and PSB can significantly improve mung bean yield and nutrient uptake. The integrated use of phosphorus and bio-organics can be recommended

as a sustainable and efficient approach for mung bean production. Further research is needed to optimize the rates and combinations of phosphorus and bio-organics for different soil types and agro-climatic conditions.

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Enhancing Mung bean [*Vigna radiata* (L.) Wilczek] Growth with Phosphorus and Bio-Organics in an Inceptisol

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Abstract

A pot experiment was conducted to evaluate the effect of phosphorus and bio-organics on the growth attributes of mungbean (*Vigna radiata* L.) in an Inceptisol. The study revealed that the combined application of phosphorus and bio-organics significantly improved growth parameters. The treatment comprising 40 kg P₂O₅ ha⁻¹ + poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB resulted in maximum plant height (54.65 cm), branches per plant (6.57), pods per plant (17.67), grains per pod (8.63), and test weight (37.38 g). These findings suggest that integrated nutrient management using phosphorus and bio-organics can be an effective strategy for enhancing mungbean productivity.

Keywords: Mungbean, Phosphorus, Bio-organics, Rhizobium, PSB, Yield Enhancement

Introduction

Mungbean (*Vigna radiata* L.) is one of the most important pulse crops in India, serving as a primary source of protein and nutrients for millions of people. In addition to its nutritional value, mungbean is also valued for its ability to fix atmospheric nitrogen, improve soil fertility, and provide a valuable source of income for farmers. Despite its importance, mungbean productivity in India remains low, largely due to inadequate nutrient management practices. Phosphorus is a critical nutrient for mungbean production, playing a key role in plant growth, nodulation, and yield formation. However, phosphorus deficiency is a widespread problem in many Indian soils, particularly in regions where mungbean is commonly grown. Bio-organics like vermicompost and poultry manure have been

shown to enhance soil fertility, promote plant growth, and improve crop yields. These organic amendments can also help to reduce the environmental impact of chemical fertilizers, making them an attractive option for sustainable agriculture. This study aims to investigate the impact of phosphorus and bio-organics on mungbean growth attributes, with the goal of identifying an effective nutrient management strategy for improving productivity and sustainability in mungbean production systems.

Materials and Methods

A pot experiment was conducted during the kharif season of 2017 in the greenhouse of the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar

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Pradesh. The experimental soil was sandy loam in texture, alkaline in reaction, low in available nitrogen, and medium in available phosphorus and potassium. The experiment was laid out in a factorial completely randomized design (CRD) with three replications. The experiment consisted of three levels of phosphorus (0, 20, and 40 kg P₂O₅ ha⁻¹) and five levels of bio-organics (Control, VM t 2.5 ha⁻¹, VM t 2.5 + Rhizobium + PSB t ha⁻¹, PM t 2.5 t ha⁻¹ and PM t 2.5 + Rhizobium + PSB t ha⁻¹). Mungbean was grown in an Inceptisol, and growth attributes were recorded.

Results and Discussion

Plant Height

The results indicated that maximum plant height was observed under treatment P₃ (40 kg P₂O₅ ha⁻¹), followed by P₂ (20 kg P₂O₅ ha⁻¹), compared to the control (P₁ : 0 kg P₂O₅ ha⁻¹) at 15 DAS (Table 1). The increase in plant height was statistically non-significant at 15 DAS but became significant at 30 and 45 DAS. Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ resulted in increases of 20.6 and 10.8% at 30 DAS, and 14.9 and 8.16% at 45 DAS, respectively, over the control. Among bio-organic treatments, maximum plant height was

Table 1: Effect of phosphorus and bio-organism levels on plant height at different growth stages of mung bean

Treatments	Plant height (cm)		
	15DAS	30DAS	45DAS
Phosphorus levels			
P ₀	24.02	28.91	46.17
P ₁	25.38	32.05	49.94
P ₂	26.01	34.87	53.05
CD (P=0.05)	NS	0.34	0.45
Bio-Organics levels			
BO ₀	24.27	29.39	46.50
BO ₁	25.09	31.48	49.08
BO ₂	25.39	33.33	51.43
BO ₃	25.27	31.90	49.74
BO ₄	25.67	33.62	51.85
CD(P=0.05)	NS	0.44	0.58

recorded in BO₄ (Poultry manure 2.5 t ha⁻¹ + *Rhizobium* + PSB), followed by BO₃ (Vermicompost 2.5 t ha⁻¹ + *Rhizobium* + PSB) at 15 DAS, while the minimum was observed in BO (Control). The increase in plant height was non-significant at 15 DAS but significant at 30 and 45 DAS. Application of poultry manure 2.5 t ha⁻¹ + *Rhizobium* + PSB and vermicompost 2.5 t ha⁻¹ + *Rhizobium* + PSB resulted in increases of 14.8 and 13.4% at 30 DAS, and 11.5 and 10.6% at 45 DAS, respectively, compared to the control. These findings are consistent with Balu et al., (2015), Maurya, et al., (2015) and Meena (2017).

Number of branches per plant

The maximum number of branches per plant was observed in treatment P3 (40 kg P₂O₅ ha⁻¹), followed by P2 (20 kg P₂O₅ ha⁻¹), compared to the control (P1 0 kg P₂O₅ ha⁻¹) at 15 DAS (Table 2). Similar trends were observed at 30 DAS and 45 DAS. The increase in the number of branches per plant was non-significant at 15 DAS and 30 DAS, but significant at 45 DAS. Application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ resulted in increases of 28.1 and 11.1% over the control at 45 DAS, respectively. The maximum number of branches per plant was

Table 2: Effect of phosphorus and bio-organism levels on number of branches per plant at different stages of mungbean

Treatments	No. of branches plant ⁻¹		
	15DAS	30DAS	45DAS
Phosphorus levels			
P ₀	1.18	4.08	4.52
P ₁	1.27	4.23	5.02
P ₂	1.41	4.52	5.79
CD (P=0.05)	NS	0.28	0.18
Bio-Organics levels			
BO ₀	1.14	4.06	4.60
BO ₁	1.23	4.24	4.89
BO ₂	1.37	4.33	5.46
BO ₃	1.26	4.32	4.99
BO ₄	1.43	4.43	5.61
CD (P=0.05)	NS	NS	0.25

observed in treatment BO₄ (Poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB), followed by BO₃ (Vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB) at 15 DAS. The minimum number of branches per plant was observed in treatment BO₀ (Control). The increase in the number of branches per plant was non-significant at 15 DAS and 30 DAS, but significant at 45 DAS. Application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB resulted in increases of 22.0 and 18.7% over the control at 45 DAS, respectively. These findings are consistent with Singh et al., (2010), Meena, and Singh (2011) and Meena, et al., (2012).

Number of grains per pod

The number of grains per pod (Table 3) significantly increased with the application of higher levels of phosphorus in combination with different bio-organics. Maximum number of grains per pod (7.58) was recorded with the application of phosphorus @ 40 kg ha⁻¹, compared to the control (4.87). The application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ significantly increased the number of grains per pod over the control by 55.2 and 25.9%, respectively. The results showed that the maximum number of grains per pod was observed in treatment

Table 3: Effect of phosphorus and bio-organism levels on number of grains per pod, number of pods per plant and test weight of mungbean

Treatments	No. of grains pod ⁻¹	No. of pods plant ⁻¹	Test weight (g)
Phosphorus levels			
P ₀	4.87	11.40	33.37
P ₁	6.13	13.39	34.98
P ₂	7.58	16.04	36.39
CD(P=0.05)	0.22	0.37	0.34
Bio-Organics levels			
BO ₀	4.94	11.39	32.96
BO ₁	5.89	13.24	34.65
BO ₂	6.88	14.56	35.86
BO ₃	6.11	13.51	34.98
BO ₄	7.14	15.33	36.12
CD(P=0.05)	0.29	0.48	0.44

BO₂ (poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB) (6.88), compared to the control (4.94). However, this was found to be at par with treatment BO₃ (vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB). The application of poultry manures 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB significantly increased the number of grains per pod over the control by 44.4 and 34.7%, respectively. These results are consistent with the findings of Meena, et al., (2014), Meena, et al., (2017) and Singh et al., (2017),

Number of pods per plant

A critical examination of the data presented in Table 3 revealed that the maximum number of pods per plant (16.04) was recorded with the application of phosphorus at 40 kg ha⁻¹, compared to the control (11.40). The application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ significantly increased the number of pods per plant over the control by 40.7 and 17.5%, respectively. The results showed that the maximum number of pods per plant was observed in treatment BO₂ (poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB), followed by BO₃ (vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB), as compared to the control. The applications of poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB and vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB significantly increased the number of pods per plant over the control by 34.6 and 27.8%, respectively. These results are in conformity with the findings of Meena, et al., (2013), Singh et al., (2014), Shukla, et al., (2016),

Test weight

The data on test weight of mung bean as influenced by different treatments and their combinations are presented in Table 3. The results showed that the maximum test weight was recorded in treatment P₃ (40 kg P₂O₅ ha⁻¹) (36.39 g), followed by P₂ (20 kg P₂O₅ ha⁻¹) (34.98 g), as compared to the control (33.37 g). The application of 40 kg P₂O₅ ha⁻¹ and 20 kg P₂O₅ ha⁻¹ resulted in significant increases of 9.1 and 4.8% over the control, respectively. The results indicated that the maximum test weight was observed in treatment BO₂ (poultry manure 2.5 t ha⁻¹ + Rhizobium + PSB) (36.12 g), followed by BO₃ (vermicompost 2.5 t ha⁻¹ + Rhizobium + PSB) (35.86 g), as compared to

the control (32.96 g). It was observed that there was no significant difference between treatments BO_2 and BO_3 . The application of poultry manures 2.5 t ha^{-1} + Rhizobium + PSB and vermicompost 2.5 t ha^{-1} + Rhizobium + PSB increased the test weight by 9.6 and 8.8% over the control, respectively. These results are in conformity with the findings of Meena, et al., (2013), Singh et al., (2014), Shukla, et al., (2016),

Conclusion

The study suggests that the combined application of phosphorus and bio-organics can significantly improve the growth attributes of mung bean. The use of $40 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ along with poultry manure 2.5 t ha^{-1} + Rhizobium + PSB can be recommended for maximizing mung bean production.

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Role of different fertilization on growth, yield and quality evaluation in maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) intercropping

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Abstract

A field experiment was conducted during Zaid season 2022-2023. The experiment was conducted in split plot design and replicated thrice. The treatment in main plot consisted of three intercropping and in sub plots five different organic manures and different levels of fertilizers. Soil of the experiment field was clayey in texture had soil slightly alkaline, medium organic carbon (0.71%), low in available nitrogen (246.64 kg ha⁻¹), medium in available phosphorous (21.6 kg ha⁻¹) and high in available potassium (282 kg ha⁻¹). A keen observation of data revealed that application of organic manures and different levels of fertilizers with intercropping both significantly influenced the growth parameters, yield parameters and yield, economic attributes like gross return, net return and B:C ratio was significantly maximum at IC₂ maize + cowpea (2:1) with different organic manures and levels of fertilizers application F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹).

Keywords: (*Zea mays* L.), (*Vigna unguiculata* L.), intercropping, organic manures

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in the worldwide. It belongs to family Gramineae and originated from the Central America and Mexico. It belongs to C₄ plant. Maize is highly valued cereals in the world that is why it is called “Queen of cereals”. Having haploid number of 10 chromosomes (2n=20). In India, the average area is 9.76 million hectare with production of 26.14 million tones and having productivity 2629.28 kg ha⁻¹ (Mishra *et al.* 2019). Maize crop absorbs large quantity of nutrients from soil for complete their life cycle. (Mahmood *et al.* 2017) adopted the different management practices to increase the maize yield

and their production. Use of organic manures to increase the soil structure, soil texture and water holding capacity in the soil is improved. The application of UREA and DAP is help to increase the yield of maize.

Cowpea (*Vigna unguiculata* L.) known as “lobia” is used as a pulse crop, a fodder crop and green manure crop. It is a legume crop. It is also known as black eye pea (Kaviraj *et al.* 2017). It is rich in protein that’s why it is also known as vegetable meat. It is used for both men as well as animal feed. Cowpea is mainly grown in Africa. About 90% of the total world acreage is in Africa.

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In India the area under cowpea is 3.9 million hectares with annual production of 2.21 million tones with a national productivity of 638 kg ha⁻¹.

Intercropping of legumes and cereals is an old practice in tropical agriculture that dates back to ancient civilization. Cereal and Legume intercropping is more productive and profitable cropping system in comparison with solitary cropping (Evans *et al.* 2001). The main objective of intercropping has been to maximize use of resources such as space, light and nutrient (Li *et al.* 2003). The importance of intercropping in farming practices has long been recognized in India (Reddy *et al.* 2004).

Materials and Methods

The present investigation was carried out during *Zaid* season of the year 2022-2023 at Agronomy Research Farm Dhablan (Patiala). The experimental site is situated at about 30°19' North Latitude and 76°24' East Longitude at an altitude of about 250 m above the mean sea level. It is located in south eastern direction in Punjab state and North West India. The experiment site falls in Indo-Gangetic plains. During growing season (February to June), the weekly maximum and minimum temperature ranged from 24.7 °C – 44.4 °C and 10.4 °C – 27.7 °C, respectively. The average relative humidity ranged 90.2% to 43.0%. The total rainfall received during the crop period was 17.3 mm. The soil of experiment site was clayey having 0.71% organic carbon, 246.64 kg ha⁻¹, 21.6 kg ha⁻¹ and 282 kg ha⁻¹ of available N, P₂O₅, K₂O respectively. The experiment was laid out in a SPD (split plot design) and replicated thrice. The main plot having three intercropping and the sub plot having five organic manures and different levels of fertilizers. The intercropping IC₁ (5:1), IC₂ (2:1), IC₃ (3:1). The fertilizer levels F₁: 100% RDF, F₂: 75% RDF + 10 t FYM ha⁻¹, F₃: 50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹, F₄: 50% RDF + 5 t FYM ha⁻¹ + 2 t PM ha⁻¹, F₅: 50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹. The maize and cowpea were sown in lines, row to row spacing is 45 cm and plant to plant spacing is 25 cm. The seed rate of Maize (20 kg ha⁻¹) or Cowpea (18 kg ha⁻¹). Maize variety is (1899) or Cowpea (S 263). The data recorded at 30, 60, 90

DAS and at harvest for all the parameters. Harvesting is done after cobs had turned brownish and grain hardened. The harvesting of cowpea was done manually with the help of sickle when pods were matured (when nearly 75% pods had turned brown). Shelling of cobs was done and grains were kept in bags treatment. Threshing was done by beating the bundle with sticks. Seeds were separated by winnowing and kept treatment wise in bags.

Results and Discussion

Different Growth parameter

The most decisive factors of growth is plant height (cm), number of leaves plant⁻¹, dry weight (g), leaf area index (LAI) have been shown in Table 1 & Fig. 1. The highest value for plant height (172.22 cm), number of leaves plant⁻¹ (15.55), dry weight (63.29 g), leaf area index (6.14) was recorded with intercropping IC₂ maize + cowpea (2:1) respectively. Significantly maximum values for plant height (174.81 cm), number of leaves plant⁻¹ (17.53), dry weight (65.03 g), leaf area index (6.44) was recorded with different organic manures and fertilizer levels F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹). The probable reason for highest values might due to combined application of organic manures and RDF levels of fertilizers. On the other hand, cowpea is a legume crop having nodules which resulted in higher fixation of atmospheric nitrogen. The legume crop increases the root length and root volume of maize, which helps to absorb more water and nutrients. The similar results were also reported by Murlidhar (2011).

The dry weight plant⁻¹ was increased due to manures and intercropping with legume improves the physical, chemical as well as biological properties of the soil, which helps in providing suitable environment for growth of plant. The similar results were founded by Asangla and Gohain (2016).

Intercropping can increase the leaf area index and crop growth rate of both crops. A higher leaf area index means that there are more leaves available for photosynthesis, which can lead to higher yields. These findings are in close vicinity of those of Alhaji (2008) and Choudhary *et al.* (2012).

Table 1: Effect of different fertilization on growth parameters of maize with cowpea intercropping.

Treatments	Growth parameters			
	Plant height (cm)	No. of leaves plant ⁻¹	Dry weight (g)	Leaf Area Index (LAI)
Main plot Intercropping				
IC ₁ : Maize + Cowpea (5:1)	168.72	14.51	61.55	5.96
IC ₂ : Maize + Cowpea (2:1)	172.22	15.55	63.29	6.14
IC ₃ : Maize + Cowpea (3:1)	169.87	14.98	63.23	6.06
SEm(±)	0.21	0.27	0.18	0.01
CD 5%	0.82	1.05	0.71	0.04
Sub plot (Fertilizers)				
F ₁ : 100% RDF	167.79	12.55	60.35	5.67
F ₂ : 75% RDF +10 t FYM ha ⁻¹	168.37	13.88	60.79	5.87
F ₃ : 50% RDF +5 t FYM ha ⁻¹ + 2t VC ha ⁻¹	169.76	15.24	63.17	6.05
F ₄ : 50% RDF +5t FYM ha ⁻¹ +2 t PM ha ⁻¹	170.61	15.86	64.14	6.24
F ₅ : 50% RDF +5 t FYM ha ⁻¹ +2 t VC ha ⁻¹ +2 t PM ha ⁻¹	174.81	17.53	65.03	6.44
SEm(±)	1.04	0.47	0.51	0.01
CD 5%	3.00	1.37	1.47	0.02

Table 2: Effect of different fertilization on yield parameters of maize with cowpea intercropping

Treatments	Yield parameters	
	Seed yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)
Main plot Intercropping		
IC ₁ : Maize + Cowpea (5:1)	42.94	60.39
IC ₂ : Maize + Cowpea (2:1)	45.27	66.63
IC ₃ : Maize + Cowpea (3:1)	45.02	63.39
SEm(±)	0.07	0.10
CD 5%	0.29	0.40
Sub plot (Fertilizers)		
F ₁ : 100% RDF	43.48	61.24
F ₂ : 75% RDF +10 t FYM ha ⁻¹	44.22	62.40
F ₃ : 50% RDF +5 t FYM ha ⁻¹ + 2t VC ha ⁻¹	44.53	62.98
F ₄ : 50% RDF +5t FYM ha ⁻¹ +2 t PM ha ⁻¹	44.74	63.47
F ₅ : 50% RDF +5 t FYM ha ⁻¹ +2 t VC ha ⁻¹ +2 t PM ha ⁻¹	45.09	67.27
SEm(±)	0.11	0.51
CD 5%	0.32	1.48

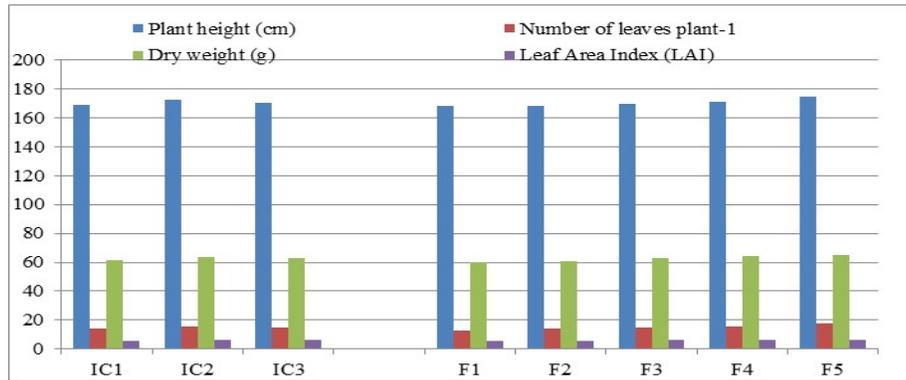


Fig. 1: Effect of different fertilization on growth parameters of maize with cowpea intercropping

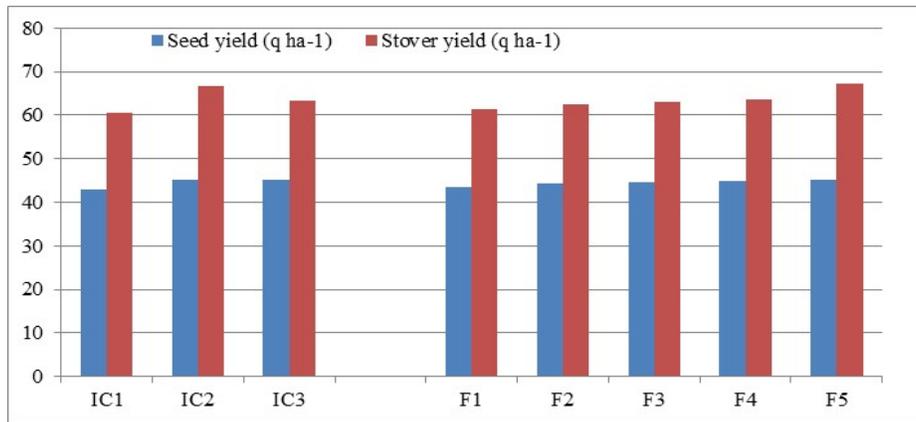


Fig. 2: Effect of different fertilization on yield parameters of maize with cowpea intercropping

The intercropping IC₁ (5:1), IC₂ (2:1), IC₃ (3:1). The fertilizer levels F₁: 100% RDF, F₂: 75% RDF + 10 t FYM ha⁻¹, F₃: 50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹, F₄: 50% RDF + 5 t FYM ha⁻¹ + 2 t PM ha⁻¹, F₅: 50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹.

Yield parameters

The data on seed yield and stover yield was increased with the organic manure and different levels of fertilizers with intercropping (Table 2 & Fig. 2). The maximum seed yield (45.27 q ha⁻¹) and stover yield (66.63 q ha⁻¹) were recorded with IC₂ maize + cowpea (2:1) and also seed yield (45.09 q ha⁻¹) and stover yield (67.27 q ha⁻¹) with F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹). The reason behind this proper vegetative and

reproductive growth is better with combined application of fertilizers and manures with intercropping. These also stimulated the various physiological process and metabolic activities which gave better growth and yield of crop. **Conclusion**

On the basis of obtained results from the field experiment, it can be concluded that maximum growth parameters were achieved when the crops intercrop with IC₂ maize + cowpea (2:1) and also with F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹).

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Survey and mapping of groundwater quality of Karnal block of Karnal district, Haryana, India

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Abstract

A study was conducted at different villages of Karnal block of Karnal, district, Haryana to evaluate the quality of groundwater for irrigation for different crops. In order to ascertain the quality of groundwater, water eighty-five samples were collected and analyzed for various hydro chemical parameters pH, EC, (Ca^{2+} , Mg^{2+} , Na^+ and K^+) and anions (CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-}) by using standard procedures. Irrigation indices such as SAR, RSC, were calculated for these samples. The pH, EC, SAR and RSC in groundwater ranged from 7.26 to 9.20, 0.40-4.80 (dSm^{-1}), 1.23 to 9.87 ($mmol\ l^{-1}$)^{1/2} and 0.00-11.00 ($me\ l^{-1}$), respectively. The trend among the average ionic concentration of cations and anions were $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ and anions were $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-}$. According to AICRP, 1989 In Karnal block of Karnal district 79.67, 3.25, 0.33, 9.27, 6.50 and 0.98 per cent samples were found in good, marginally saline, saline, , marginally alkali, alkali and highly alkali categories, respectively Spatial variability maps of EC, SAR and RSC of ground water used for irrigation in the district were also prepared.

Key words: Groundwater, Saline, Alkali, SAR, RSC, Cations and Anions

Introduction

Over drafting of ground water and its quality deterioration are the major threats to crop production in arid and semiarid regions (Pradhan *et al.*, 2011). Groundwater has emerged as a primary democratic water source and poverty reduction tool. Due to its low capital cost, groundwater is the most preferred source of water for domestic and irrigation purpose in Haryana. Water has played an important role in the development and growth of human civilization. In modern times, water has critical importance in the economic growth of all contemporary societies (Yadagiri *et al.*, 2015). The contamination with various chemical and biological sources and

exploitation of ground water sources created pressure on groundwater resources (Ramprakash *et al.*, 2018 and Singh *et al.*, 2017). However, it is important not only the availability of groundwater, but also its sufficient quality for use in irrigation purposes. The groundwater has played key role in increasing food production and achieving food security in India. In modern world, the preservation of water from contaminated agents is urgently required. If the groundwater and its quality are affected, then it will not be balanced. For critical evaluation of subsurface water quality, it is necessary to feature out the important properties of the ground

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water required for the plant growth and their reasonable concentration. The Mathematical technique provides a framework of analysis of collected data from field studies. The samples of the ground water are collected and studies in terms of total dissolved solids (TDS) measured immediately by using portable meters. Sodium Adsorption Ratio (SAR) and %Na was determined through calculation [Chand *et al.*, 1993].

The chemical properties of water is governed by different factor like geological structure, amount and types of salts, the mineralogy of watersheds and the geological process involved and the reaction that take place (Hamzaoui - Azaza *et al.*, 2011; Etteieb *et al.*, 2017 and Pal *et al.*, 2018). Salts found in groundwater used for irrigation purpose may affect soil structure and crop productivity and the presence of toxic elements may adversely affect vegetation and reduce the suitability of soil for agricultural use (Asawa *et al.*, 2014). In recent decades, many scientists from different countries have focused attention on the negative effects of poor irrigation water quality on soil properties and crop yields (Ghazaryan *et al.*, 2016). In the past, water level was the main quantitative factor that determined the level of groundwater exploitation. Quality aspects decide whether groundwater is suitable for a specific use or not. Underground water is the most important source for irrigation in India, thus deserving significant awareness about its use in agriculture and other sectors. So survey and characterization of groundwater quality for irrigation is an importance tool in arid and semi-arid regions of the world because poor knowledge about quality of water farmers used it and ultimately its lead to the primary salinization and alkalization. The quality of water can be classified according to its physical, chemical and biological properties that are effects on agricultural, industrial and anthropogenic activities. In Haryana state, out of total cultivated area of 3.62 mha, 1.24 mha is canal irrigated 1.65 mha is irrigated by tube wells which often contain water of dubious quality. In the state, 37% of water is of good quality, 8% normal and 55% is of poor quality. The data on quality of water is important for the planner, implementation and government bodies for planning and remediating contamination for the

agriculture and human's purpose. The continuous monitoring of groundwater resources thus, plays a major role in sustainable management of water resources. The irrigation quality of water is expressed by the type and amount of dissolved salt (Etteieb *et al.*, 2017). So for sustainable development of society, groundwater is indispensable, hence the, survey and characterization of groundwater quality in every nook and corner of the country is prerequisite for its better supervision (Rao, 2018). Isolated groundwater mounds and troughs in different parts of the district have been created because of heavy pumping in city area. In general water table has declined all over the district over the past decade. The characterization of irrigation water quality plays a vital role in deciding its management strategies for profitable farming. Ground water aquifer, a main source of water supply in arid and semiarid regions of India is most vulnerable to salinity and sodicity problem resulting in considerable reduction in crop productivity (Kamra *et al.*, 2002). So, keeping in view the present studies on mapping of groundwater quality of Karnal block of Karnal district, were under taken.

Materials and Methods

Study area

A survey experiment was conducted in Karnal block of Karnal district, Haryana to evaluate the quality of groundwater for irrigation for different crops. Karnal districts are located in the north-eastern part of the Haryana state. In Karnal of Haryana state mostly utilize the groundwater through shallow tube wells. Karnal covers about 2520 km² area under tube wells irrigation. Ground Water Resources estimation of the district was done as on 31.03.2011 as per GEC-1997 for each individual block. Stage of ground water development in the district is 148%. The ground water development in all the blocks of the district has exceeded the available recharge and thus all the blocks have been categorized as "over exploited". Net ground water availability of the district is 822.31 million cubic meter (mcm), ground water draft for all users is 1218.91 mcm, whereas net ground water availability for future irrigation development is - 396.60 mcm

In order to assess water quality of the study area a total 615 water samples were collected from

Karnal block of Karnal district from crop growing area from running tube wells and their locations were recorded and the map is presented in (Fig.1).

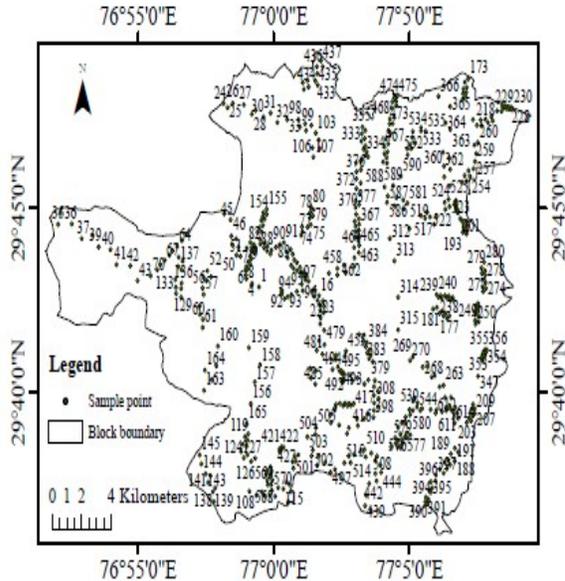


Fig. 1: Location map of sampling points in Karnal

The samples were collected in thoroughly cleaned, properly labeled and carefully corked plastic bottles. Before collection of water in a particular bottle, the bottle is rinsed thoroughly with the respective samples of groundwater and immediately after collection samples were transferred laboratory for chemical analysis. The chemical analysis was accomplished at CCS Haryana Agricultural University, Hisar, India as per the standard methods relevant to analysis of groundwater. Electrical Conductivity (EC) was measured by conductivity meter and pH by digital pH meter. Sodium (Na⁺) and potassium were measured by flame photometer. Calcium and magnesium were determined with standard EDTA solution titrimetrically. Carbonate and bicarbonate were estimated by titration with H₂SO₄, Chloride by titrating against standard silver nitrate (AgNO₃) solution. The colorimetric analysis of sulphate was done by spectrophotometer. Measurements were done in triplicate to ensure reliability and good quality control. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are calculated as:

a) Sodium adsorption ratio (SAR) {Richards 1954}:

$$SAR \text{ (mmol l}^{-1}\text{)}^{1/2} = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$

b) Residual sodium carbonate (RSC) (Eaton 1950):

$$RSC \text{ (me l}^{-1}\text{)} = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Water samples were classified into different categories as per the classification of All India Coordinated Research Project (AICRP, 1989) on Management of Salt Affected Soils and Use of Saline Water in Agriculture Table 1.

Table 1: Criteria for water quality classification (AICRP, 1989)

Quality	EC (dS m ⁻¹)	SAR (mmol L ⁻¹) ^{1/2}	RSC (me L ⁻¹)
Good	<2	<10	<2.5
Marginally saline	2-4	<10	<2.5
Saline	>4	<10	<2.5
High SAR - saline	>4	>10	<2.5
Marginally alkali	<2	<10	2.5-4.0
Alkali	<2	<10	>4.0
Highly alkali	Variable	>10	>4.0

Results and Discussion

In the Karnal block, the electrical conductivity (EC) of the water samples ranged from 0.40 to 4.80 dSm⁻¹ with a mean of 1.40 dS m⁻¹ (Table 2). To study the spatial distribution of EC in the whole block, a spatial variability location map was prepared by using ArcGIS through the interpolation of the available data at 615 sampling points (Fig. 2).

Prakash *et al.* (2020) reported that in Kharkhoda block of Sonapat district electrical conductivity ranged from 0.58 to 13.90 dS m⁻¹ with a mean of 2.57 dSm⁻¹. The pH of the water samples ranged from 7.26 to 9.20 with a mean of 8.30. Rajpaul *et al.*(2025) reported that the pH of the water sample ranged from 7.70 to 8.40 with a mean value of 7.95 in Dadri-I block of Charkhi Dadri district. The sodium adsorption ratio (SAR) of ground water samples ranged from 1.23 to 9.87 (mmol l⁻¹)^{1/2} with a mean value of 3.25 (mmol l⁻¹)^{1/2}. Spatial variable map for SAR of groundwater in Karnal block presented in Fig. 3.

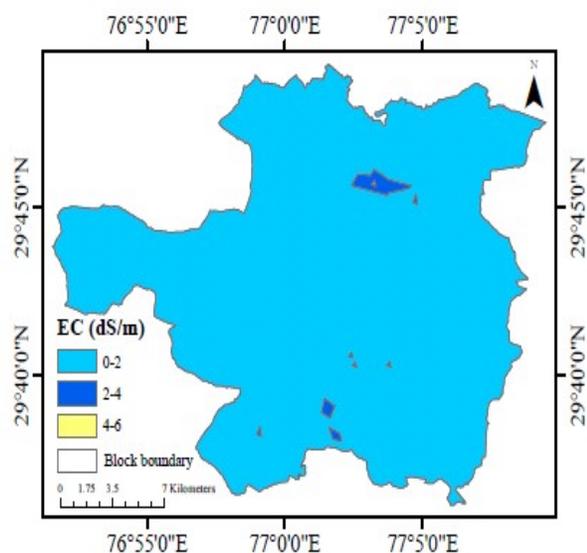


Fig. 2: Spatial variable map for EC of groundwater in Karnal

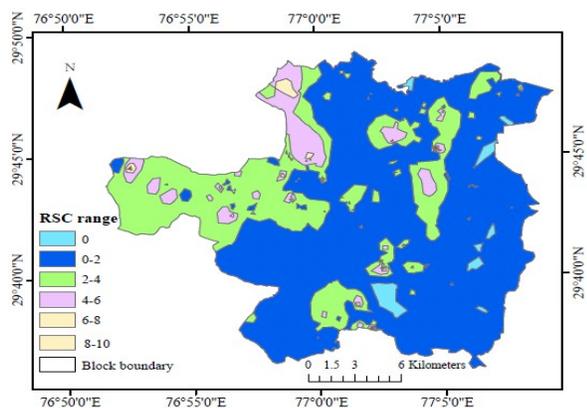


Fig. 3: Spatial variable map of SAR of groundwater in Karnal

The RSC was found 0.00-11.00 me/l with mean value of 1.25 me/l. Spatial variable map for RSC of groundwater in Karnal block presented in Fig. 4.

In case of anions, chloride was the dominant anion with the maximum value of 15.20 me/l and the minimum value of 0.40 me/l was recorded. Bicarbonate ranged from 1.80 to 3.80 me/l with a mean value of 1.16 me/l. The mean values for CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} were found to be 0.05, 1.16, 8.27 and 3.23 me/l, respectively (Table-2). Among cations, Na^+ was highest and also varied widely from 2.20 to 15.60 me/l (Table 2), followed

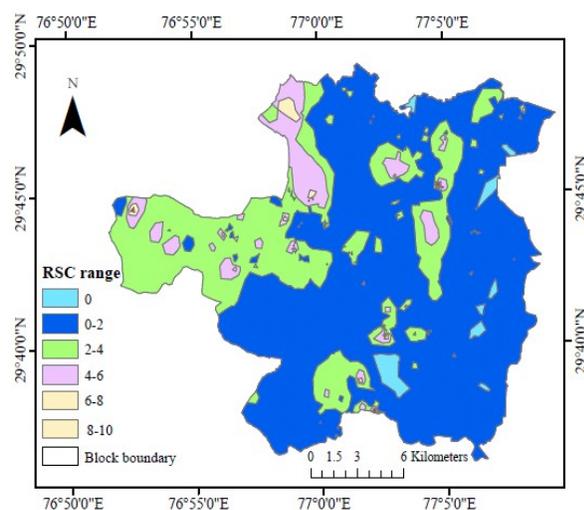


Fig. 4: Spatial variable map of RSC of groundwater in Karnal

Table 2: Range and mean of different water quality parameters in Karnal block

S. No.	Quality Parameter	Range	Mean
1.	pH	7.26-9.20	8.30
2.	EC (dSm^{-1})	0.40-4.80	1.40
3.	RSC (me l^{-1})	0.00-11.00	1.25
4.	SAR (mmol l^{-1}) ^{1/2}	1.23-9.98	3.25
5.	Ca^{2+} (me l^{-1})	0.80-9.97	2.32
6.	Mg^{2+} (me l^{-1})	0.50-5.00	2.41
7.	Na^+ (me l^{-1})	2.20-15.60	4.52
8.	K^+ (me l^{-1})	0.03-2.50	0.45
9.	CO_3^{2-} (me l^{-1})	0.60-1.65	0.05
10.	HCO_3^- (me l^{-1})	1.80-3.80	1.16
11.	Cl^- (me l^{-1})	0.40-15.20	8.27
12.	SO_4^{2-} (me l^{-1})	0.05-7.84	3.23

by magnesium (0.50-5.00 me/l) and calcium (0.80-9.97me/l). Average values for Na^+ , Mg^{2+} , Ca^{2+} and K^+ were 4.52, 2.41, 2.32 and 0.45 me/l, respectively (Table 2). The mean cationic composition was observed in order of $\text{Na}^+ > \text{Mg}^{2+} > \text{Ca}^{2+} > \text{K}^+$ likewise the anionic composition was observed in order of $\text{Cl}^- > \text{SO}_4^{2-} > \text{HCO}_3^- > \text{CO}_3^{2-}$.

The high concentration of sodium may be attributed to a base-exchange reaction and leaching of sodium salt like halite during the movement of

water through sediments (Etteieb *et al.*, 2017). The magnesium is commonly found in ferro-magnesium minerals in igneous rocks and as carbonate in sedimentary rocks (Sridharan and Nathan, 2017).The lower concentration of potassium in groundwater samples may be ascribed to its tendency to be fixed by clay minerals and to participate in the formation of secondary minerals (Jalali,2010). In Karnal block of Karnal district 79.67, 3.25, 0.33, 9.27, 6.50 and 0.98 per cent samples were found in Good, Marginally Saline, High SAR Saline, Marginally Alkali, Alkali and Highly Alkali categories, respectively (Fig.5 and Table 3).

Table 3: Ground water quality classification of Karnal Block of Karnal district

Water quality	Class	Percentage
Good	A	79.67
Marginally saline	B1	3.25
Saline	B ₂	0.00
High SAR saline	B ₃	0.33
Marginally alkali	C1	9.27
Alkali	C2	6.50
Highly alkali	C3	0.98

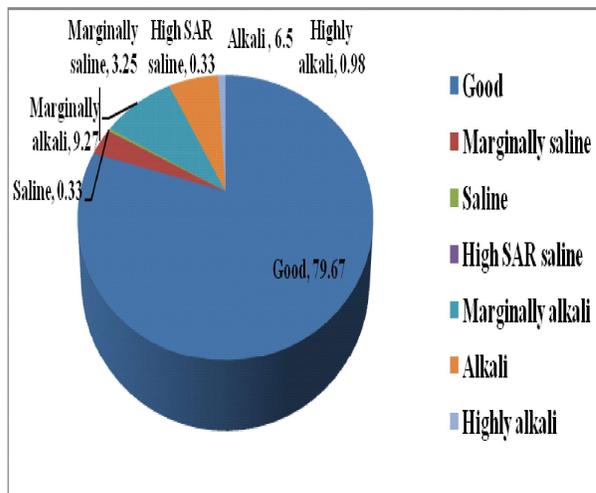


Fig. 5: Percent Groundwater quality in Karnal block of Karnal district

Conclusion

The dominance of major ions were in the order of Na⁺ > Mg²⁺ > Ca²⁺ > K⁺ and anions were Cl⁻ > SO₄²⁻ > HCO₃⁻ > CO₃²⁻ for cations and anions, respectively. Therefore, the chemical composition of the groundwater was characterized by the Na–Cl water type. It was found that 79.67 percent samples were of good quality. Whereas 20.33 percent are poor quality nature. Therefore, the groundwater should be blended with canal water before irrigation which implies that regular monitoring of groundwater is imperative to avoid major environmental threat. The spatial distribution maps generated for various physico-chemical parameters using GIS techniques could be valuable for policy makers for initiating groundwater quality monitoring in the area.

Acknowledgements

The authors are thankful to Indian Council of Agricultural Research (ICAR), New Delhi under Grant of AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture, at ICAR-Central Soil Salinity Research Institute, Karnal.

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Soil test crop response-based fertilizer recommendations in Meghalaya

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Abstract

Three STCR experiments were conducted on maize, rice and soybean. sub- treatments were imposed under four fertility gradient strips developed for each crop in the experimental block of Soil Science Division of ICAR Research Complex for NEH Region, Umiam. Main crops i.e. maize, soybean and rice were grown in the respective experimental plot of STCR. Fertilizer doses were applied in each sub- treatment of four fertility gradient strips on basis of treatment combination. The estimates of nutrient requirement (kg q^{-1}) value of nitrogen, phosphorus and potassium based on yield maximum method were 4.06, 1.60 and 2.15 respectively. The percent nutrient contributions from soil and fertilizer nutrients in Ultic Hapludalf were found to be 18.43, 6.82 and 8.98; 14.3, 85.07 and 12.7 for nitrogen, phosphorus and potassium, respectively under yield maximum method. Using fertilizer adjustment equations derived under yield maximum method, ready reckoner showing optimum N, P and K fertilizer doses at varying soil test values for attaining yield targets of 30 and 40 q ha^{-1} of rice yield was prepared. The results clearly indicated that the fertilizer dose required for attaining a specific yield target of rice yield decreases with increasing soil test values.

Key words: STCR, nutrient, yield, fertilizer, soybean, rice

Introduction

Meghalaya is one of the seven states of North-Eastern Region of India. Meghalaya is located between latitudes of 25°02' and 26°06' and longitudes of 89°48' and 92°50'E with an altitude ranging from 50-1961 above main sea level (msl). The total area of the state is 22,429 sq km with a population of 23,06,069 (Census of India 2001) and 103 persons/ km^2 . The State is bounded by Assam in the North, East and West and Bangladesh in the South and southwest. The state is dominated by tribal population (90.46%). Jaintia and Khasi Hills administratively possess Jaintia Hills, East Khasi Hills, West Khasi Hills, Ri-Bhoi districts and Garo hills constitutes of

East Garo Hills, West Garo Hills and South Garo Hills. The orography of the southern part of Meghalaya helps the occurrence of heavy monsoon rain where Mawsynram and Cherrapunji receives the highest rainfall in the world. The State is directly influenced by the South West monsoon and North Eastern winter winds. The region experiences tropical monsoon climate that varies from Western to Eastern part of the plateau. Garo Hills district has tropical climate characterized by high rainfall and humidity generally warm summer and moderately cold winter. Khasi and Jaintia Hills have high rainfall, moderately warm summer and severe winter with periodic depression below freezing point

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marked by appearance of ground frost at night and morning over higher elevated areas. The lower elevated areas experience fairly high temperature for most part of the year having a mean maximum of 23 to 26°C and a mean minimum of 12 to 17°C. The mean summer temperature is 26°C and the mean winter temperature is 9°C. As a whole state gets on an average 2000 to more than 10,000 mm annual rainfall concentrated from May to September. The humidity always remains more than 80% during the month's pre and monsoon period.

Rice and Maize are the important crops of Meghalaya and the area and production of these crops are 105.8 and 17.2 thousand ha and 120.3 and 24.9 thousand tones, respectively (Verma & Bhatt, 2001). The low productivity of these crops is mainly due to very low and unbalanced use of fertilizers which can be well bridged if the fertilizer application technology is based on STCR approach. This will also, economize the use of fertilizers. By STCR correlation charts, balanced dose of fertilizers can be prescribed on the basis of soil test values for a reasonably desired target yield of these crops. From the nutrient management point of view soil-plant systems is also unique because it will provide a scientific basis for balanced fertilization not only among fertilizer nutrients themselves but also the soil available nutrients. In the present programme, the work was initiated with rice, maize and soybean for the soils of Meghalaya which are the most important cereal and oilseed crops for the state.

Materials and Methods

STCR Experiments in Meghalaya

Three STCR experiments were conducted on maize, rice and soybean. sub-treatments were imposed under four fertility gradient strips developed for each crop in the experimental block of Soil Science Division of ICAR Research Complex for NEH Region, Umiam. Main crops i.e. maize, soybean and rice were grown in the respective experimental plot of STCR. Fertilizer doses were applied in each sub-treatment of four fertility gradient strips on basis of treatment combination. On harvest, dry weight of grain and straw were recorded. The grain and straw samples have been collected at the time of harvest and samples were processed for estimation

of N, P and K concentrations in grain and straw. The total uptake (kg/ha) of the respective crops have been calculated for further use in the adjustment equation of soil test crop response, the details are given in the text below. A field experiment based on STCR methodology on rice with the variety 'RCPL 1-87-4' was conducted at ICAR Research Complex for NEH Region, Umiam in Riboi district from 2004-05 to 2005-06. The soil at Umiam farm was Ultic Hapludalf with pH 4.75, organic carbon 18.3 g kg⁻¹, exchangeable Ca+Mg 1.76 cmol(p⁺) kg⁻¹, available N (alkaline KMnO₄ oxidizable), P (Bray-2) and K (1N NH₄OAc extractable) 477, 11.5 and 167 kg ha⁻¹, respectively. The field layout for crop essentially comprised of four equal strips in which a gradient in soil fertility was artificially created by applying graded doses of N, P and K fertilizer so as get a wide range in soil fertility (N₀P₀K₀, N_{1/2}P_{1/2}K_{1/2}, N₁P₁K₁ and N₂P₂K₂; N₁P₁K₁: 80, 60, 40kg/ha). An exhaustive crop was later on raised on these four strips to stabilize the soil system. For the test crop of rice, the rice itself was the exhaustive crop. After the harvest of exhaustive crop, the experiment with rice as test crop was conducted in the subsequent season by dividing each of the four fertility strips into 30 plots which received 27 selected treatments out of the combination of three levels of N, three levels of P₂O₅ and three levels of K₂O. The remaining three sub-plots in each fertility strip were kept untreated as control and experiment was conducted in a RBD design (Ramamoorthy & Velayutham 1971). The plant samples viz. grain and straw samples collected at harvest were analysed for N, P and K and the plant uptake of nutrients was calibrated by using grain and straw yield data. Using the grain yield and nutrient uptake data, soil test values and applied fertilizer doses of treated and control plots, the basic data viz. nutrient requirement (kg q⁻¹), soil and fertilizer efficiencies (%) for making fertilizer recommendation were estimated by conventional procedure as discussed by Ramamoorthy *et al.* (1967).

STCR on Maize

Maize variety RCM-1-1 was grown in sub-plots of each strips i.e. N₀P₀K₀, N_{1/2}P_{1/2}K_{1/2}, N₁P₁K₁ and N₂P₂K₂. Fertilizer doses were applied in each

plot on basis of treatment combination. Full dose of P and K, and half dose of N were applied at the time of sowing and, the remaining half of N was top dressed in two split doses at 30 and 60 days after sowing. On harvest, dry weight of grain and straw were recorded.

Treatment details:

Nitrogen: 40, 80 and 120 kg N/ha

Phosphorus: 30, 60 and 90 kg P₂O₅/ha

Potassium: 0, 30 and 60 K₂O kg/ha

Total treatment combinations: 27

Control plots: 3

The fertilizer materials used were Urea, SSP and MOP. Full dose of P and K, and half dose of N were applied at the time of sowing. The remaining half of N was top dressed in two split doses at 30 and 60 DAS. The representative soil samples (0 – 0.15m) were taken from each of 120 plots before the application of fertilizers and sowing of the crop. The yield data for grain and straw for all the plots were recorded at the harvest of the crop. Grain and straw samples were analysed for N, P and K. Similarly, available N (Alkaline KMnO₄), available P (Bray-1) and available K (Neutral normal ammonium acetate) were determined in all the soil samples. With the help of nutrient uptake data and soil test values, the basic data (nutrient requirement in kg per quintal of grain, per cent contribution of a particular nutrient from soil, and per cent contribution of a particular nutrient from fertilizer) required for making fertilizer recommendations for different crop production levels were calculated according to procedure of Ramamoorthy et al. (1967).

The grain and straw sample have been collected at the time of harvest and samples were processed for estimation of N, P and K concentrations. The total uptake (kg/ha) of the crop has been calculated for further use in the fertilizer adjustment equation of Soil Test Crop Response of Maize. The soil efficiency was estimated from only unfertilized plots, while the fertilizer efficiency was estimated from fertilized plots. The nutrient requirement was estimated from both the fertilized and unfertilized plots. The computational procedure of basic data is well discussed in Ramamoorthy et al. (1967) and Reddy et al. (1994). The estimates of basic data were used for developing fertilizer

adjustment equations for deriving optimum fertilizer test- based fertilizer recommendations had been prescribed in the form of a ready reckoner for different yield targets.

STCR on Soybean

Soybean variety JS - 335 was grown in sub-plots of each fertility gradient strips i.e. N₀P₀K₀, N_{1/2}P_{1/2}K_{1/2}, N₁P₁K₁ and N₂P₂K₂. Fertilizer doses were applied in each plot on the basis of treatment combination. Full dose of N, P and K were applied at the time of sowing. On harvest, dry weight of grain and straw was recorded.

Treatment details:

Nitrogen: 25 N kg/ha

Phosphorus: 30, 60, 90 and 120 P₂O₅ kg/ha

Potassium: 25, 50, 75 and 100 K₂O kg/ha

Total treatment combinations: 16

Control plots: 3. The grain and straw samples have been collected at the time of harvest and samples were processed for estimation of N, P and K concentrations. The total uptake (kg/ha) of the crop has been calculated for further use in the Fertilizer Adjustment Equation of soybean of Soil Test Crop Response. Nutrient requirement, Soil efficiency percent (FE%), and Fertilizer efficiency percent (SF%) were also calculated.

Results and Discussion

Fertilizer prescription equation for Rice

The basic data viz., the nutrient requirement (kg q⁻¹) for producing one quintal of rice yield, soil and fertilizer efficiencies or the percent contribution from soil and fertilizer nitrogen, phosphorus and potassium were calculated from each plot based on the data and have been presented in table 1. The estimates of nutrient requirement (kg q⁻¹) value of nitrogen, phosphorus and potassium based on yield maximum method were 4.06, 1.60 and 2.15, respectively. The percent nutrient contributions from soil and fertilizer nutrients in Ultic Hapludalf were found to be 18.43, 6.82 and 8.98; 14.3, 85.07 and 12.7 for nitrogen, phosphorus and potassium, respectively under yield maximum method. Using fertilizer adjustment equations derived under yield maximum method, ready reckoner showing optimum N, P and K fertilizer doses at varying soil test values for attaining yield targets of 30 and 40 q ha⁻¹ of rice

Table 1: Basic data for targeted yield equation for Rice

Particular	Nitrogen (N)	Phosphorus (P ₂ O ₅)	Potassium (K ₂ O)
Nutrient required kg/q of grain (NR kgq ⁻¹)	4.06	1.60	2.15
Factor for efficiency soil nutrient (SE%)	18.43	6.82	8.98
Factor for efficiency fertilizer nutrient (FE%)	14.3	85.07	12.

yield was prepared. The results clearly indicated that the fertilizer dose required for attaining a specific yield target of rice yield decreases with increasing soil test values. Earlier reported studies (Mahadeva Swamy et al. 2020), (Ravindra et al. 2021).

Table 2: Fertilizer adjustment equations for rice

Crop	Fertilizer equation
Rice	FN = 2.82 x T - 0.13 x SN FP ₂ O ₅ = 1.88 x T - 0.08 x SP FK ₂ O = 1.69 x T - 0.07 x SK

Note: FN, FP₂O₅ and FK₂O are fertilizer N, fertilizer P₂O₅ and fertilizer K₂O, respectively, and SN, SP and SK are the soil test values for N, P and K in their elemental form and T is the predetermined crop yield target (qha⁻¹).

Fertilizer prescription equation for Maize

The basic data viz., the nutrient requirement (kg q⁻¹) for producing one quintal of maize yield, soil and fertilizer efficiencies or the percent contribution from soil and fertilizer nitrogen, phosphorus and potassium have been calculated from each plot based on the data and have been presented in table 3. The estimates of nutrient requirement (kg q⁻¹) value of nitrogen, phosphorus and potassium based on yield maximum method were 6.97, 1.42 and 1.04, respectively. Earlier reported studies Anila et al

Table 3: Basic data for targeted yield equation for Maize

Crop	Particular	Nitrogen (N)	Phosphorus (P ₂ O ₅)	Potassium (K ₂ O)
Maize	Crop nutrient requirement (kg q ⁻¹ grain)	6.97	1.42	1.04
	Nutrient contribution from soil (%)	22.63	11.3	4.87
	Nutrient contribution from fertilizer (%)	38.50	26.24	23.00

(2018) and Sharma et al (2022). The percent nutrient contributions from soil and fertilizer nutrients in Ultic Hapludalf were found to be 22.63, 11.30 and 4.87; 38.50, 26.24 and 23.00 for nitrogen, phosphorus and potassium, respectively under yield maximum method. The result clearly indicated that the fertilizer dose required for attaining a specific yield target of maize yield is decreasing with increasing soil test values.

Table 4: Fertilizer adjustment equations for maize

Crop	Fertilizer equation
Maize	FN = 1.99 x T - 0.11 x SN FP ₂ O ₅ = 1.49 x T - 0.11 x SP FK ₂ O = 0.83 x T - 0.06 x SK

Note: FN, FP₂O₅ and FK₂O are fertilizer N, fertilizer P₂O₅ and fertilizer K₂O, respectively, and SN, SP and SK are the soil test values for N, P and K in their elemental form and T is the predetermined crop yield target (qha⁻¹).

Fertilizer prescription equation for Soybean

The basic data viz., the nutrient requirement (kg q⁻¹) for producing one quintal of soybean yield, soil and fertilizer efficiencies or the percent contribution from soil and fertilizer nitrogen, phosphorus and potassium have been calculated from each plot based on the data and have been presented (Table 5).

Table 5: Basic data for targeted yield equation for Soybean

Crop	Particular	Nitrogen (N)	Phosphorus (P ₂ O ₅)	Potassium (K ₂ O)
Soybean	Crop nutrient requirement (kg q ⁻¹ grain)	6.97	1.42	1.04
	Nutrient contribution from soil (%)	22.63	11.3	4.87
	Nutrient contribution from fertilizer (%)	38.50	26.24	23.00

Table 6: Fertilizer adjustment equations for soybean

Crop	Fertilizer equation
Soybean	FN= 1.81 x T- 0.06 x SN
	FP ₂ O ₅ = 5.42 x T- 4.33 x SP
	FK ₂ O = 4.51 x T- 0.21x SK

with the farmers' practice (FP). The yield target of 30 q ha⁻¹ could be achieved in both locations tested, but 40 q ha⁻¹ yield target could not be achieved.

Field verification trials on Maize

Field verification trials were conducted in two villages of Riboi district for attaining a yield target of 40 and 50 q ha⁻¹ during kharif 2006 (Table 8). The doses tested were based on the fertilizer adjustment equations calibrated for maize crop, along with the farmers' practice (FP). The yield target of 40 q ha⁻¹ could be achieved in both locations tested, but 50 q ha⁻¹ yield target could not be achieved. Earlier reported studies (Amanullah et al. 2016) and (Padbhushan et al. 2021, 2022).

Field verification trials on Rice

Field verification trials were conducted in two villages of Riboi district for attaining a yield target of 30 and 40 q ha⁻¹ during kharif 2006 (Table 7). The doses tested were based on the fertilizer adjustment equations calibrated for rice crop, along

Table 7: Field verification trials of fertilizer adjustment equations of rice in Ultic Hapludalf of Riboi district of Meghalaya

Farmer/Village	Soil test values(kg ha ⁻¹)			Treatment	Fertilizer doses(kg ha ⁻¹)			Yield (q ha ⁻¹)
	N	P	K		N	P ₂ O ₅	K ₂ O	
O. Khapran/Phyllum block IV	464.13	12.31	284.93	FP	Nil	Nil	Nil	20.12
				40q ha ⁻¹	28.55	58.25	16.10	47.28
				50q ha ⁻¹	48.45	73.15	24.40	48.75
O. Khapran/Phyllum block II	423.03	16.75	201.16	FP	Nil	Nil	Nil	19.89
				40q ha ⁻¹	33.07	57.76	21.13	45.62
				50q ha ⁻¹	52.97	72.66	29.43	47.55

*FP = Farmer's practice

Table 8: Field verification trials of fertilizer adjustment equations of maize in Ultic Hapludalf of Riboi district of Meghalaya

Farmer/Village	Soil test values(kg ha ⁻¹)			Treatment	Fertilizer doses(kg ha ⁻¹)			Yield (q ha ⁻¹)
	N	P	K		N	P ₂ O ₅	K ₂ O	
O. Khapran/Phyllum block IV	464.13	12.31	284.93	FP	Nil	Nil	Nil	20.12
				40q ha ⁻¹	28.55	58.25	16.10	47.28
				50q ha ⁻¹	48.45	73.15	24.40	48.75
O. Khapran/Phyllum block II	423.03	16.75	201.16	FP	Nil	Nil	Nil	19.89

Table 9: Field verification trials of fertilizer adjustment equations of soybean in Ultic Hapludalf of Riboi district of Meghalaya

Farmer/Village	Soil test values(kg ha ⁻¹)			Treatment	Fertilizer doses(kg ha ⁻¹)			Yield (q ha ⁻¹)
	N	P	K		N	P ₂ O ₅	K ₂ O	
O. Khapran/Phyllum block IV	464.13	12.31	284.93	FP	Nil	Nil	Nil	20.12
				40q ha ⁻¹	28.55	58.25	16.10	47.28
				50q ha ⁻¹	48.45	73.15	24.40	48.75
O. Khapran/Phyllum block II	423.03	16.75	201.16	FP	Nil	Nil	Nil	19.89
				40q ha ⁻¹	33.07	57.76	21.13	45.62
				50q ha ⁻¹	52.97	72.66	29.43	47.55

*FP = Farmer's practice

Field verification trials on Soybean

Field verifications trials were calculated in similarly for soybean and the details are given in table 9.

Epilogue

Soil test calibration that was intended to establish a relationship between the levels of soil nutrients determined in the laboratory and crop response to fertilizers in the field permitted balanced fertilization through right kind and amount of fertilizers. Nutrient supplying power of soils, crop responses to added nutrients and amendment needs can safely be assessed through sound soil testing programme. A well established STCR calibration will help to apply fertilizers in precise and judicious amounts, obtain high use of applied fertilizer nutrients and maximum possible yields of the crops. **Earlier reported studies (Nirmala et al. 2021), (Srilatha et al. 2021) and (Verma et al 2019).** Adoption of the best time, method and dose of fertilizer application by the farmers is essential to achieve higher use efficiency. Soil testing to determine the fertilizer need, suitable fertilizer drills for placement of fertilizers, promotion of slow release materials, IPNS and other improved agronomic practices will certainly help in increasing efficiency of applied fertilizers. Use of coated urea, USG, precision farming using GIS for decision support system in efficient use of fertilizer will become necessary to enhance the fertilizer Use Efficiency.

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Effect of different fertilizers with intercropping on quality and yield on maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.)

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Abstract

A field experiment was conducted at Campus for Research and Advanced Studies, Dhablan, P.G. Department of Agriculture, G.S.S.D.G.S Khalsa College, Patiala during Zaid season 2022-2023. The experiment was conducted in Split Plot Design (SPD) and total 15 treatments which were replicated three times. The treatment in main plot consisted of three intercropping with cowpea crop IC_1 (5:1), IC_2 (2:1) and IC_3 (3:1) and in sub plots five different organic manures and different levels of fertilizers. F_1 100% RDF, F_2 75% RDF + 10 t FYM ha^{-1} , F_3 50% RDF + 5 t FYM ha^{-1} + 2 t VC ha^{-1} , F_4 50% RDF + 5 t FYM ha^{-1} + 2 t PM ha^{-1} , F_5 50% RDF + 5 t FYM ha^{-1} + 2 t VC ha^{-1} + 2 t PM ha^{-1} . Soil of the experiment field was clayey in texture had soil pH 7.45 (slightly alkaline), medium organic carbon, low in available nitrogen, medium in available phosphorous and high in available potassium. A data revealed that three intercropping with organic manures and levels of RDF both significantly influenced the growth parameters, yield parameters, quality parameters and economic parameters like gross return and net return was significantly highest at IC_2 maize + cowpea (2:1) with organic manures and different levels of RDF F_5 (50% RDF + 5 t FYM ha^{-1} + 2 t VC ha^{-1} + 2 t PM ha^{-1}) at all stages.

Key words: RDF Recommended dose of fertilizers, FYM farm yard manure, VC Vermicompost, PM poultry manure, IC intercropping

Introduction

Maize (*Zea mays* L.) is the world's most important cereal, providing as both human food and cattle feed. It is thought to have originated in Central America. It is a miracle crop. It is highly valued cereals in the world that is why it is known as "Queen of cereals". It is an important source of carbohydrates (70.4%), protein (10%), oil (4%), crude fiber (2.3%), albuminoids (10.4%). The maize crop is consumed by human and animals. Green cobs

are roasted and consumed by people. India has 6th rank in global maize production. In India, maize is the third important crop after rice or wheat, 70% of the feed industries depend on the maize crop. In India, the average area is 9.76 million hectares with production of 26.14 million tons and having productivity 2629.28 kg ha^{-1} (Mishra *et al.* 2019). Cowpea (*Vigna unguiculata* L.) commonly known as "Lobia" is used as pulse crop, a fodder and green

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manure crop. It is also known as black eye pea (Kaviraj *et al.* 2017). It is rich in protein that's why it is called vegetable meat. It is rich source of calcium and iron. In India the area under cowpea is 3.9 million hectares with annual production of 2.21 million tones with a national productivity of 638 kg ha⁻¹. Total seed protein content ranges from 23.2% to 32%. They are having high carbohydrates (60.3%) and fiber content (1.08%). The main objective of intercropping has been to maximize use of resources such as space, light and nutrients (Li *et al.* 2003) as well as to improve crop quality and quantity. Cereal and legume intercropping is more productive and profitable cropping system in comparison with solitary cropping (Evans *et al.* 2001).

Materials and Methods

The present experiment was carried out during *Zaid* season of the year 2022-2023 at Agronomy Research Farm Dhablan, Patiala. The experimental site is situated at about 30°19' North Latitude and 76°24' East Longitude at an altitude of about 250 m above the mean sea level. It is located in south eastern direction in Punjab state and North West India. The experiment site falls in Indo-Gangetic plains. During growing season (February to June), the weekly maximum and minimum temperature ranged from 24.7 °C – 44.4 °C and 10.4 °C – 27.7 °C, respectively. The average relative humidity ranged 90.2% to 43.0%. The total rainfall received during the crop period was 17.3 mm. The soil of experiment site was clayey having 0.71% organic carbon, 246.64 kg ha⁻¹, 21.6 kg ha⁻¹ and 282 kg ha⁻¹ of available N, P₂O₅, K₂O respectively. The experiment was laid out in a SPD (split plot design) and replicated thrice. The main plot having three intercropping and the sub plot having five organic manures and different levels of fertilizers. The intercropping IC₁ (5:1), IC₂ (2:1), IC₃ (3:1). The fertilizer levels F₁: 100% RDF, F₂: 75% RDF +10 t FYM ha⁻¹, F₃: 50% RDF +5 t FYM ha⁻¹ + 2 t VC ha⁻¹, F₄: 50% RDF +5 t FYM ha⁻¹ + 2 t PM ha⁻¹, F₅: 50% RDF +5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹. The maize and cowpea were sown in lines, row to row spacing is 45 cm and plant to plant spacing is 25 cm. The seed rate of Maize (20 kg ha⁻¹) or

Cowpea (18 kg ha⁻¹). Maize variety is (1899) or Cowpea (S 263). The data recorded for all the parameters. Harvesting is done after cobs had turned brownish and grain hardened. The harvesting of cowpea was done manually with the help of sickle when pods were matured (when nearly 75% pods had turned brown). Shelling of cobs was done and grains were kept in bags treatment. Threshing was done by beating the bundle with sticks. Seeds were separated by winnowing and kept treatment wise in bags.

Results and Discussion

Quality parameters

Protein content (%)

Protein content (%) of maize seeds did not differ significantly by different treatments (Table 1). It is crystal clear from the data that, different treatments failed to show significant effect on the protein content of maize seeds as it ranged (10.07% to 11.37%). However, the maximum protein content were observed (11.37%) with IC₂ maize + cowpea (2:1). Different levels of fertilizers or organic manures the highest protein content (11.36%) with F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t

Table 1: Effect of different fertilization on protein content of maize (%) with cowpea intercropping

Treatment	Protein content (%)
Main plot Intercropping	
IC ₁ : Maize + Cowpea (5:1)	10.15
IC ₂ : Maize + Cowpea (2:1)	11.37
IC ₃ : Maize + Cowpea (3:1)	10.81
SEm(±)	0.10
CD 5%	0.38
Sub plot (Fertilizers)	
F ₁ : 100% RDF	10.07
F ₂ : 75% RDF +10 t FYM ha ⁻¹	10.42
F ₃ : 50% RDF +5 t FYM ha ⁻¹ + 2t VC ha ⁻¹	10.87
F ₄ : 50% RDF +5t FYM ha ⁻¹ +2 t PM ha ⁻¹	11.15
F ₅ : 50% RDF +5 t FYM ha ⁻¹ + 2 t VC ha ⁻¹ +2 t PM ha ⁻¹	11.36
SEm(±)	0.27
CD 5%	0.78

Table 2: Effect of different fertilization on yield parameters of maize with cowpea intercropping

Treatments	Yield parameters	
	Seed yield (q ha ⁻¹)	Stover yield (q ha ⁻¹)
Main plot Intercropping		
IC ₁ : Maize + Cowpea (5:1)	42.94	60.39
IC ₂ : Maize + Cowpea (2:1)	45.27	66.63
IC ₃ : Maize + Cowpea (3:1)	45.02	63.39
SEm(±)	0.07	0.10
CD 5%	0.29	0.40
Sub plot (Fertilizers)		
F ₁ : 100% RDF	43.48	61.24
F ₂ : 75% RDF +10 t FYM ha ⁻¹	44.22	62.40
F ₃ : 50% RDF +5 t FYM ha ⁻¹ + 2t VC ha ⁻¹	44.53	62.98
F ₄ : 50% RDF +5t FYM ha ⁻¹ +2 t PM ha ⁻¹	44.74	63.47
F ₅ : 50% RDF +5 t FYM ha ⁻¹ +2 t VC ha ⁻¹ +2 t PM ha ⁻¹	45.09	67.27
SEm(±)	0.11	0.51
CD 5%	0.32	1.48

PM ha⁻¹). At par values were (11.15 %) and (10.87 %) with F₄ (50% RDF + 5 t FYM ha⁻¹ + 2 t PM ha⁻¹) and F₃ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹). This is due to the combined application of organic manures, levels of RDF with intercropping of legume crop which led to more accumulation nitrogen in seeds due to increased activity of nitrate enzyme. Nitrogen is the main constituent of amino acids which are the building blocks of proteins. Therefore, it led to increase in protein content of maize seeds. The similar results were observed by Singh *et al.* (2005) and Verma *et al.* (2005).

Yield parameters

The data on seed yield and stover yield was increased with the organic manure and different levels of fertilizers with intercropping (Table 2). The maximum seed yield (45.27 q ha⁻¹) and stover yield (66.63 q ha⁻¹) were recorded with IC₂ maize + cowpea (2:1) and also seed yield (45.09 q ha⁻¹) and stover yield (67.27 q ha⁻¹) with F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹). The reason behind this proper vegetative and reproductive growth is better with combined application of fertilizers and manures with intercropping. These

also stimulated the various physiological process and metabolic activities which gave better growth and yield of crop.

Conclusion

On the basis of obtained results from the field experiment, it can be concluded that maximum quality parameters and yield parameters was achieved when the crops intercrop with IC₂ maize + cowpea (2:1) also with F₅ (50% RDF + 5 t FYM ha⁻¹ + 2 t VC ha⁻¹ + 2 t PM ha⁻¹). Further, the maximum gross return, net return and B:C ratio was obtained application of different organic manures and fertilizers levels with intercropping. Above conclusion are however, based on a single season research and it needs further confirmations by repetition of research trail draw valid and definite conclusion.

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Breeding approach to develop climate resilient crops: current status and future prospects: A review

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Introduction

Climate-resilient breeding develops crops that can withstand climate change impacts like drought, heat, floods, and pests, ensuring food security by using advanced techniques (genomics, gene editing) alongside traditional methods (hybridization, selection) to identify and incorporate stress-tolerance genes, creating varieties with stable yields under harsh, erratic conditions, benefiting farmers and global food systems.

Key goals and characteristics

Stress Tolerance: Develops plants resistant to drought, heatwaves, waterlogging (floods), high salinity, and new pests/diseases.

Stable Yields: Maintains productivity even with unpredictable weather and extreme events.

Adaptability: Enables crops to thrive in diverse soils and challenging environments.

Examples & Impact:

Drought-Tolerant Maize: Widely adopted in Africa, improving yields in dry conditions.

Flood-Tolerant Rice: Showing promise in Southeast Asia, reducing crop loss.

Climate-Resilient Wheat: Focuses on early maturity and plant architecture for heat/drought areas.

Importance

Food Security: Secures food supply for growing populations facing climate threats.

Farmer Livelihoods: Protects farm income by preventing crop failure.

Sustainability: Reduces reliance on water and inputs, promoting sustainable agriculture. Climate-resilient

wheat varieties are bred for heat/drought tolerance, better yields under stress, and disease resistance, with key Indian examples including DBW187, DBW222 (Karan Narendra), DBW303, HD 3385, and WH1270, developed by ICAR-IIWBR for timely/late sowing, helping farmers adapt to rising temperatures and ensure food security. These varieties, along with others like PBW826 and HI 1633, focus on traits like better grain filling under heat, lodging resistance, and water efficiency, supported by government and research efforts for widespread adoption.

Key Heat-Tolerant Varieties (India)

DBW187 & DBW222 (Karan Narendra): Highly heat-tolerant, showing significant yield gains in warmer conditions, superior to older heat-tolerant types like HD-3086.

HD 3385: Specifically designed for terminal heat (late March spikes), suitable for both timely and late sowing.

DBW303, DBW327, WH1270, PBW872: Also developed for heat stress, often grown with adjusted planting times (mid-November) to avoid peak heat.

Other Resilient & High-Yielding Varieties

Narendra 09: Farmer-developed, high-yielding, water-efficient, thrives in diverse conditions.

HI 1633 (Pusa Wheat 1633): Recommended for better disease/yield.

PBW 826: A top high-yielding choice.

Muktinath 3170 & GW 451: Hard-grain varieties good for milling and processing.

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Features of resilient wheat

Heat Tolerance: Ability to maintain yield during grain filling when temperatures rise (terminal heat).

Drought Resistance: Better performance in water-scarce regions.

Lodging Resistance: Stronger stems to prevent crop collapse, reducing yield loss.

Disease Tolerance: Resistance to common diseases like rust.

Strategies for resilience

Breeding: ICAR-IIWBR and international partners (CIMMYT) are developing new gene pools for diverse traits.

Sowing Times: Adjusting planting (e.g., mid-November) to align grain filling with cooler temperatures.

Resource Conservation: Using techniques like Zero Tillage (ZT) and Happy Seeder (HS) for better profitability and efficiency.

What is climate-resilient crop varieties?

Climate-resilient crop varieties are plants that are adapted to tolerate extreme weather conditions such as: Drought and Heat and Salinity and Flooding.

Pests and Diseases

These varieties are designed to grow and yield optimally despite environmental challenges, using advanced breeding techniques and biotechnology.

The Need for Climate-Resilient Crops

Erratic Weather Patterns: Unpredictable rainfall and temperature fluctuations threaten crop yields.

Increasing Soil Salinity: Rising sea levels and irrigation practices lead to saline soils, making it hard for conventional crops to grow.

Water Scarcity: Droughts are becoming more frequent, reducing water availability for crops.

Pest and Disease Outbreaks: Warmer temperatures can lead to new and more aggressive pests and diseases.

Examples of Climate-Resilient Crops

Drought-Tolerant Maize: Developed using selective breeding and genetic engineering, varieties like *Drought TEGO* in Africa provide stable yields under water-limited conditions.

Salt-Tolerant Rice: In coastal regions, rice varieties like *Swarna Sub1* can survive submergence and high salinity.

Heat-Tolerant Wheat: Researchers have developed wheat strains with a higher temperature threshold for germination and flowering.

Flood-Resistant Sorghum: Sorghum varieties bred to withstand waterlogged soils help mitigate yield losses in flood-prone regions.

Legume Varieties with Pest Resistance: Cowpeas and chickpeas are being developed with natural pest resistance to reduce chemical pesticide dependency.

Breeding Techniques Used

Conventional Breeding: Cross-breeding plants with desired traits over generations to develop climate-resilient varieties.

Marker-Assisted Selection (MAS): Using molecular markers to identify and select plants with stress-tolerant traits more efficiently.

Genetic Modification (GM): Introducing foreign genes into plants to provide resilience against drought, salinity, or pests.

CRISPR Gene Editing: Precise editing of plant DNA to improve resilience traits without introducing foreign genes.

Speed Breeding: Using controlled environments to accelerate the breeding process.

Benefits of Climate-Resilient Crops

Food Security: Ensures stable food production even under extreme conditions.

Reduced Dependency on Pesticides and Water: Enhanced resistance to pests and diseases reduces the need for chemical treatments, and drought tolerance reduces irrigation requirements.

Economic Stability for Farmers: Resilient varieties minimize crop losses and provide consistent incomes.

Biodiversity Preservation: Diverse crop varieties reduce the risk of monoculture-related vulnerabilities.

Challenges in Developing and Adopting Climate-Resilient Crops

Research and Development Costs: Developing new varieties takes time, money, and extensive research.

Regulatory and Ethical Concerns: Some stakeholders have concerns over the safety and environmental impact of genetically modified crops.

Farmer Awareness and Training: Adoption is slow due to limited knowledge or trust in new crop varieties.

Market Access: Small-scale farmers often lack access to improved seeds or financing options.

Future Outlook and Innovations: The future of climate-resilient agriculture lies in embracing technological innovations such as:

AI and Big Data: Using predictive analytics to identify traits that enhance climate resilience.

Blockchain Technology: Ensuring traceability and transparency in the seed supply chain.

Agroecological Practices: Integrating resilient crops with sustainable farming methods for holistic climate adaptation. The future of climate-resilient breeding is shifting from traditional selection to a highly integrated “smart breeding” framework. This approach combines genomic tools, artificial intelligence, and rapid generation advancement to develop crops that can withstand multiple simultaneous stresses like extreme heat, drought, and flooding.

Key Technological Innovations: The integration of these technologies aims to reduce breeding cycles from decades to just a few years:

Precision Gene Editing (CRISPR/Cas): Beyond simple gene knockouts, future applications focus on multiplex editing to target multiple genes at once for complex traits. It is also being used for de novo domestication, where wild relatives with natural resilience are rapidly “domesticated” by editing key yield-related genes while keeping their native stress tolerance.

Next-Gen Artificial Intelligence (AI): AI and machine learning are becoming central to analysing massive “multi-omics” datasets (genomics, phenomics, enviromics) to predict how specific genotypes will perform in future climate scenarios.

Speed Breeding: By manipulating light and temperature in controlled environments, breeders can now produce up to 6 generations per year for crops like wheat and barley, drastically accelerating the deployment of new varieties.

High-Throughput Phenomics: Using drones, sensors, and hyperspectral imaging, researchers can non-destructively monitor plant health and root architecture in real-time, allowing for the selection

of superior traits that were previously invisible.

Emerging Strategic Priorities Future breeding efforts are expanding beyond single-crop yield to broader ecological resilience:

Exploiting Crop Wild Relatives (CWRs): Gene banks are being “mined” for lost genetic diversity. CWRs and underutilized “orphan crops” (e.g., millets, quinoa) are being prioritized for their inherent survival traits in harsh environments.

Breeding for “Combined Stresses”: Future varieties must handle dual threats, such as drought followed by heatwaves, which require a deeper understanding of complex molecular signaling pathways like ROS and calcium waves.

The Holobiont Approach: Breeding is moving toward a “holistic” view that includes the plant microbiome. Future strategies may involve selecting for plants that better recruit beneficial soil microbes to enhance nutrient uptake and stress tolerance.

Climate Modeling Integration: Incorporating predictive climate models directly into breeding programs helps identify the specific environmental stressors a region will face 20–30 years in the future.

Current Challenges & Bottlenecks: Despite technological promise, several hurdles remain for widespread adoption:

Regulatory & Social Barriers: Gene-edited crops face complex regulatory frameworks and varying levels of public acceptance across different countries.

G x E Interactions: The “Genotype x Environment” interaction remains a major challenge, as a variety that is resilient in one region may fail in another due to local soil or weather nuances.

Data Standardization: The explosion of “big data” from sensors and sequencing requires new standards to ensure information can be shared and used effectively by breeders worldwide.

Government and Policy Support: Governments and international organizations play a vital role in funding research, streamlining regulatory approvals, and creating incentives for farmers to adopt climate-resilient varieties. Initiatives like the Global Commission on Adaptation and CGIAR’s Climate Change Program are already driving innovation in this field.

Conclusion

Climate-resilient crop varieties offer a promising path toward a sustainable and food-secure future. By investing in research, raising awareness, and promoting equitable access to resilient seeds, we can empower farmers to adapt to changing climates and ensure agricultural stability for generations to come.

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