EFFECT OF CROPPING SYSTEM AND NUTRIENT MANAGEMENT ON PRODUCTION AND WATER USE EFFICIENCY OF INTERCROPS

“अंत: फसल के उत्पादन और जल उपयोग दक्षता पर फसल प्रणाली और पोषक तत्व प्रबंधन का प्रभाव”

THESIS

SUBMITTED

IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE

OF

MASTER OF SCIENCE (AGRICULTURE)

IN

SOIL CONSERVATION AND WATER MANAGEMENT

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SUBMITTED BY:

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Dedicated

To

My Venerable Parents

Shri. Kaushal Kumar Pandey

&

Smt. Purnima Pandey

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Certificate

This is to certify that **Mr. Aaishwarya Pandey , Id. No. CA- 12317/22** of College of Agriculture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P), a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Conservation & Water Management** has been working under my guidance and supervision during the session 2022-24 and the present thesis entitled **"Effect of cropping system and nutrient management on production and water use efficiency of intercrops"** submitted by him in the partial fulfilment of the requirement for the degree, is his genuine and original work.

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Certificate

We, the undersigned members of Advisory Committee of **Mr. Aaishwarya Pandey, I.d. No. CA-12317/2022**, a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Conservation and Water Management** agree that the thesis entitled "**Effect of cropping system and nutrient management on production and water use efficiency of intercrops**" may be submitted by him in partial fulfilment of the requirements for the degree.

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ABSTRACT

The field experiment was carried out at Soil Conservation and Water Management Farm, C. S. Azad University of Agriculture and Technology, Kanpur during the *Zaid* season of 2022-23 to find out the effect of **"Effect of cropping system and nutrient management on production and water use efficiency of intercrops"**. The soil of the experimental field was sandy loam in texture. The treatments comprised of 4 cropping systems i.e. **(i)** C_1Pigeonpea sole **(ii)** C_2 Groundnut sole **(iii)** C_3 Pigeonpea + groundnut (1:1), **(iv)** C_4 Pigeonpea + Groundnut (1:2), and 3 Nutrient management factors i.e. **(i)** F_1 (100% RDF) **(ii)** F_2 (100% RDF+ Borax 5kg/ha) **(iii)** F_3 (100% RDF + Borax 5kg/ha + FYM 10 t/ha) were tested in FactorialRandomized Block Design with 3 replications during the course of investigation envisages. Results obtained that the growth, yield and yield attributes of individual crop depressed in the intercropping system than sole. The intercropping system of pigeonpea + groundnut (1:2) gave significantly maximum pigeonpea equivalent seed yield (22.13 q ha^{-1}), land equivalent ratio (1.42), water use efficiency (6.61 kg seed ha^{-1} mm^{-1}), with net return of Rs. 135583 ha^{-1} and highest B: C ratio (3.72) over the sole cropping. The application of F_3 (100% RDF+ Borax 5kg/ha+ FYM 10t/ha) resulted in higher pigeonpea equivalent seed yield (19.76 q ha^{-1}), land equivalent ratio (1.21), water use efficiency (6.37 kg seed ha^{-1} mm^{-1}), net return Rs. 111569 ha^{-1} and B: C ratio (3.24) followed by F_2 and lowest in F_1 of nutrient management. The growth characters and yield attributes of the two crops followed almost similar patterns of seed yield.

On the basis of results obtained by this experiment, it is concluded that C_4 Pigeonpea + Groundnut (1:2) almost with the application of F_3 (100% RDF+ Borax 5kg/ha+ FYM 10t/ha) was found most efficient in terms of obtaining higher economics return and sustaining crop production.

Contents

LIST OF ABBREVIATIONS

%	:	Per cent
/	:	Per
@	:	At the rate of
^0C	:	Degree centigrade
ANOVA	:	Analysis of variance
Av.	:	Average
B:C ratio	:	Benefit cost ratio
C.D.	:	Critical difference
cm	:	Centimetre
d.f.	:	Degree of freedom
DAP	:	Di-Ammonium phosphate
DAS	:	Day after sowing
Dsm^{-1}	:	Desi Siemens per metre
EC	:	Electrical conductivity
et al.	:	And co-others
F. tab	:	F tabulated
F.cal.	:	F calculated
Fig.	:	Figure
FYM	:	Farm yard manure
g	:	Gram
ha	:	Hectare
HI	:	Harvest Index
Hrs	:	Hours
i.e.	:	That is
INM	:	Integrated nutrient management

K	:	Potassium
Kg ha^{-1}	:	Kilogram per hectare
Kg	:	Kilogram
Max.	:	Maximum
Mg	:	Mega gram
Min.	:	Minimum
mm	:	Millimetre
MOP	:	Muriate of potash
MSS	:	Mean sum of square
N	:	Nitrogen
No.	:	Number
NS	:	Non-significant
P	:	Phosphorus
Qha^{-1}	:	Quintal per hectare
R	:	Replication
RDF	:	Recommended dose of fertilizer
RH	:	Relative humidity
Rs.	:	Rupees
$Rs.ha^{-1}$	:	Rupees per hectare
S.Ed	:	Standard error of deviation
S.S.	:	Sum of square
Viz.	:	Videlicet (namely)

CHAPTER- I INTRODUCTION

The practice of growing two or more crops side by side in the same field for a certain amount of time is known as intercropping; the crops may be different in species or cultivar. In developing countries, intercropping is still a popular technique, having originated early in the history of agriculture. The increased emphasis on soil health and sustainability has led to a renaissance of interest in and application of intercropping in developed agricultural regions in recent years.

According to **Francis (1986),** intercropping takes use of the mutualistic ties between crops as well as variations in niche occupation throughout time and geography. This strategy frequently boosts production and provides ecosystem benefits **(Zhi *et al.*, 2007)**. Worldwide, intercropping is practiced in a variety of soil types, environmental circumstances, and crop combinations. The technique is preferred over monocultures because it produces higher yields per unit of land, lowers the chance of crop failure, and is more resilient to changes in the market **(Cowell *et al.*, 1989; Lesoing and Francis, 1999; Machado, 2009; Mandal *et al.*, 1990).**

Intercropping is a long-standing technique that, by the turn of the 20th century, had gained widespread acceptance. Intercropping is characterized as a commonly utilized method in some of the oldest extant literature employing the word **(Castle, 1906),** and studies evaluated the benefits of intercropped forages in comparison to monocultures **(Hays, 1892).** There have been suggestions that the approach predates the usage of the present name by a great deal and that the practice dates back to the early days of agriculture **(Baker, 1970)**. Intercropping is found in a variety of environments, including grasslands and forests. It is arguably the most common planting pattern found in nature. However, the technique became less common as a result of the mechanization of agriculture and the accessibility of inexpensive fossil fuel around the middle of the 20th century. Modern equipment and short-term gains lured industrialized nations away from intercropping and toward streamlined monocultures **(Anders *et al.*, 1996).** On the periphery of "modern agriculture," which is characterized by vast stretches of monocultured, resource-intensive, and high-yielding crops, lies the age-old practice of intercropping **(Vandermeer, 2010; Zhang *et al.*, 2010; Li *et al.*, 2013)**. But according to **Vandermeer (1989)**, intercropping may be a way to address some of the main issues with modern farming, such as moderate yield, pest and pathogen accumulation, soil degradation, and environmental deterioration. This could lead to more productive and sustainable agriculture **(Lithourgidis *et al.*, 2011).**

Many agricultural, ecological, and environmental scientists with a wide range of research interests have turned their attention to intercropping (see, for example, **Smith *et al.*, 2013; Ehrmann & Ritz, 2014; Li *et al.*, 2014**). This has created a chance for interdisciplinary syntheses combining disparate information on the potential of intercropping. The present review offers an overview of intercropping, examines the latest findings in agronomy, plant physiology, and ecology on the mechanisms and processes that support intercropping, and explores how these findings may be combined to enhance intercropping systems. We begin by going over the concept, uses, and possible advantages of intercropping. In semi-arid tropical regions, the intercropping combination of groundnut and pigeon-pea is common. Intercropping groundnuts with peas is beneficial because groundnuts are a short-duration crop that makes good use of resources early in the growing season. Due to its lengthy growing season and ability to use resources during the post-monsoon phase, pigeon-peas do not compete with other crops.

Pigeon pea, or *Cajanus cajan*, is the sixth most significant edible legume crop in the world. It is renowned for growing quickly and being adaptable **(Abebe, 2022).** Pigeon pea, also called red gram, Tur, Arhar, or no eye pea (*Cajanus cajan* var. *flvus*), is a short-duration, kharif pulse crop that is cultivated in semi-arid regions of the tropics. Pigeon pea, known for its high protein content, has long been a mainstay of the Indian subcontinent's diet, giving millions of people the nourishment they need. About 72% of the land used to cultivate pigeon pea is in India **(Fatokimi *et al.,* 2021).** A very nutritious pulse crop, pigeon peas have a protein content of 22.3%, minerals of 3.5%, carbohydrates of 57.6%, and 335 kcal of energy per 100 g **(Anonymous, 2005)**. Although pigeon-peas may be cultivated in a variety of agroecological situations, they are particularly valuable as a crop in regions with low and variable rainfall due to their deep tap root system and drought tolerance. The primary form of pigeon-pea is split pulse, or "dal," which is high in arginine, lysine, tyrosine, and cysteine as well as iron and iodine. On marginal and sub-marginal fields, cowpea, soybean, urd-bean, mung-bean, and other pulses are probably interplanted with maize, sorghum, and pearl millet. Pigeon-pea is also frequently produced on these types of grounds. It has the ability to replenish atmospheric nitrogen and able to use its efficient Rhizobium nodulation to fix atmospheric nitrogen in the soil to the extent of 160–200 kg ha^{-1} **(Anonymous, 2010).**

The deep tap root system facilitates the absorption and retrieval of moisture and nutrients from deeper Three soil layers are introduced, making it appropriate for rainfed environments. The incorporation of fallen leaves contributes to increased soil fertility, while a robust, deep root system breaks up plough patches and strengthens the soil's structure. functions as a "biological plough" as a result. Due to ambiguity and limited water supply, it may tolerate drought for a longer amount of time as a result of the aforementioned traits. The crop length of pigeonpea has increased with the advent of better varieties. It now ranges from around 90 days for extra-early varieties to more than 260 days for late ripening types that work well in a variety of cropping systems and niches. But during rainy seasons, it is typically cultivated at broader spacing. A popular pulse crop in India, pigeon peas may be cultivated either as an intercrop or as a stand-alone crop with other crops. The present scarcity of vegetable and pulse oils in India has sparked ideas for creating novel groundnut and pigeon pea intercropping systems. In order to make up for any groundnut losses, the strategy may entail planting a long-duration crop alongside the groundnut, such as pigeon pea **(Gunri *et al.*, 2015).**

For the southern Saurashtra area of Gujarat, intercropping groundnut + pigeon pea in a 2:1 row proportion is advised, particularly when semi-spreading groundnut cultivars (GG-20) are used as advised by the Main Oilseeds Research Station, JAU, Junagadh. This combination is very common in the southern Indian states with red soils. Although it is a short-lived perennial, pigeon peas are typically planted as annuals. Its deep root system is perfectly suited to semi-arid environments. Plants have slender leaves, yellow or red blooms, and pods of various colours. They may reach a height of three to ten feet. **Vavilov (1951)** concluded that pigeonpea originated in India. The crop was cultivated there around 3500 years ago, according to the CGIAR Gene bank Platform (2019). From there, it moved quickly to Africa. Through the African slave trade, it was further dispersed throughout the Americas **(CGIAR Gene bank Platforms, 2019).**

The green revolution made India self-sufficient in the production of food grains. Nevertheless, India's supply of pulses cannot keep up with demand, and the country is now reliant on imports for internal use. Because these crops work well in crop combinations and crop rotation, farmers all throughout the nation employ them as an essential component of their cropping systems. Pulses are a vital component of the Indian diet, providing a significant portion of the country's required calories and protein. They are also a rich source of minerals, including calcium, phosphorus, iron, and other minerals, as well as several necessary amino acids. One of the major pulse crops, pigeon pea (Cajanus cajan (L.) Millsp.) is widely farmed in tropical regions of Africa, America, Australia, Hawaii, the West Indies, Sri Lanka, and China. The ICRISAT reports that the world's pigeon pea business has seen significant upheaval in recent years. India is the largest importer of this legume and its greatest consumer. Tanzania contributes the most to these imports, with Myanmar accounting for around 50% of the total and Africa for the other half. India nearly increased its output from the previous year to the year 2016–17. With a productivity of 859 kg/ha, India was the top producer of pigeon peas, with 4.34 million tons produced from 5.05 million hectares of area. **(2022, fourth advanced estimates, DES, MoAF&W).** Arachis hypogaea L., commonly referred to as groundnut or peanut, belongs to the Leguminosae family and genus Arachis **(Krapovickas & Gregory, 1994).** It is said to have started in the South American area spanning from southern Bolivia to northern Argentina. There are just two allotetraploid species among the 80 species in the genus Arachis, and the majority of them are diploid (2n = 2x = 20). Because of hybridization between two wild species—Arachis duranensis (AA-genome, 2n = 2x = 20), known as the "A-genome ancestor," and Arachis ipaensis (BB-genome, 2n = 2x = 20), known as the "B-genome ancestor"—and subsequent chromosome doubling, the cultivated groundnut is allotetraploid (AABB, 2n = 4x = 40). The cultivated species, A. hypogaea subsp. hypogaea and A. hypogaea subsp. fastigiata, is split into two subspecies based on pod shape and patterns of reproductive and vegetative branching. Botanical variations are another division made within the subspecies.

According to **Krapovickas and Gregory (1994),** the subsp. fastigiata is separated into fastigiata (Valencia), vulgaris (Spanish), peruviana, and aequatoriana. The subsp. hypogaea is divided into hypogaea (Virginia) and hirsuta. Arachis hypogaea, often known as groundnut or peanut, is a tropical legume that is primarily cultivated for its oil and for use by humans and animals. Raised on 24.6 million hectares of land in over 120 nations, peanuts are produced globally in 38.2 million tonnes (Mt). Asia is the world's leading producer of peanuts.

Groundnuts are farmed in more than 100 countries. About 90% of global output was made up of Asia (58.3%) and Africa (31.6%), with China (16.6 M tons), India (6.6 M tons), and Nigeria (3.4 M tons) being the top three producing nations **(FAOSTAT, 2017).** The groundnut seed contributes to family nutrition since it is a rich source of dietary fibres, minerals, vitamins, and bioactive substances. It also includes 22% to 30% protein and 35% to 60% oil.

It is appropriate for preparing nutrient-dense meals to reduce malnutrition in susceptible populations, especially in poor nations, such as expectant mothers and their infants **(Anim-Somuah *et al* 2013).** Groundnut cake and haulms are significant supplies of animal feed. Furthermore, groundnuts may fix atmospheric nitrogen, which is advantageous for crops that come after them. It is widely sold locally, regionally, and internationally as a cash crop, considerably boosting the national economy and cash income of rural households. For instance, groundnuts provide up to 50% or more of the cash income for rural households in several West and Central African (WCA) nations, including 46% in Mali, 54% in Nigeria, 66% in Niger, and 80% in Senegal **(GAIN 2010; Ndjeunga *et al.*, 2010).**

A significant portion of women and young people in Asia and Africa work in the groundnut industry, cultivating, processing, and marketing the crop, which increases their economic empowerment. For instance, women run practically the whole small-scale groundnut oil processing industry in Nigeria. Women hold over 85% of Mali's groundnut crops **(Ndjeunga *et al.*, 2010).** Africa has the lowest mean yield of around 965 kg/ha among the regions, with large regional variations in groundnut production **(FAOSTAT 2017).** Asia has comparatively higher output, yielding an average of 2,370 kg/ha. Conversely, groundnut yields are high—over 3,300 kg/ha—in the USA and other industrialized nations. A global yield average of 849 kg/ha in 1961 and 1655 kg/ha in 2014 indicates a remarkable improvement in groundnut productivity over the previous 50 years, which is due to significant advancements in genetics, genomics, breeding, and crop management.

The effect of Cropping system and nutrient management on production and water use efficiency of intercrops enhanced the crop growth, yield attributes of intercropping of pigeonpea and groundnut. Therefore, the study was under taken keeping in these views the above fact an experiment entitled. **"Effect of Cropping system and nutrient management on production and water use efficiency of intercrops"** was planned and conducted at the Research Farm, Department of Soil Conservation & Water Management of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur during the *zaid* season of 2023-24 with the following objectives :-

1. To study the cropping system as influenced by nutrient management on growth and yields.

2. To find out the effect of various treatments on water use, water use efficiency.

3. To work out the relative performance and profitability cropping system.

The present investigation entitled " **Effect of Cropping system and nutrient management on production and water use efficiency of intercrops**." was carried out at Soil Conservation and Water Management Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during the *Zaid* season of 2022-23. Notwithstanding, some sporadic work has been done under rainfed condition in respect to the present study, which seems subjective and note-worthy have been reviewed and presented here for recognition under the following heads:

1. To study the cropping system as influenced by nutrient management on growth and yields.

2. To find out the effect of various treatments on water use, water use efficiency.

3. To work out the relative performance and profitability cropping system.

We have included importance of intercropping systems, nutrient management and uptake in intercropping systems, nutrient response and uptake in groundnut and pigeonpea sole crops, and the economics and yield advantages of pigeonpea intercropping systems. There is very little research on foliar nutrient treatment in pigeonpea and groundnut, response and absorption of nutrients in solo cropping of groundnut and pigeonpea, and intercropping of pigeonpea and groundnut in general. For this reason, relevant reviews are included.

2.1 Intercropping system

Srinivasulu *et al.* (2000) found that intercropping with black gram and sesame and altering the planting pattern had no discernible effects on the number of pods per plant, seeds per pod, or 1000-grain weight of pigeonpea.

Zhang and Li (2003) told that furthermore, productivity rises when intercropping components have "complementary effects" since there is less rivalry between them.

Mazaheri *et al.* (2006) evaluated the success of intercrops over pure cropping, agronomic techniques that influence the interactions between the species might be considered. These techniques include final density, planting date, resource availability, and intercropping models. In terms of crop output, intercropping is superior to pure cropping because of the interactions between intercrop components and the varying degrees of competition for the use of environmental resources (Mahapatra, 2011).

Sidhu and Jain (2007) investigated the effects of different intercropping treatments on pest dynamics and plant health in pigeonpea and groundnut. They employed several treatments, including sole cropping of pigeonpea and groundnut, as well as various intercropping ratios (e.g., 1:1, 2:1) of pigeonpea to groundnut. The study found that intercropping reduced pest infestation compared to sole cropping, with the 1:1 ratio showing the greatest reduction in pest populations and improved plant health. The reduction in pest numbers was quantified by a decrease in pest density (up to 40% lower) and a notable improvement in plant health indices (e.g., 15% higher plant vigor) in the intercropped systems compared to sole crops.

Lingaraju *et al.* (2008) observed that intercropping maize and pigeonpea in 1:1, 2:1, 2:2, 3:1, and 4:2 row proportions with 50 and 100 percent pigeonpea population levels under rainfed conditions was investigated by. Pooled data collected over two years showed that intercropping produced significantly higher maize equivalent yield (8970 kg ha-1), net returns (Rs.36008 ha-1), and B:C ratio (3.25) compared to sole and other intercropping systems, with the exception of 2:2 and 3:1 row ratio with a 100:50 population of maize and pigeonpea.

Singh and Khan (2010) investigated the economic benefits and resource use efficiency of pigeonpea and groundnut intercropping systems. The study involved various treatment combinations including different row ratios (1:1, 2:1) and planting densities. Results showed that the 1:1 row ratio significantly improved the total yield per unit area compared to the monoculture systems, with a notable increase in land equivalent ratio (LER) and economic returns. Specifically, the 1:1 row ratio treatment yielded 1.5 times more total biomass and 1.2 times higher economic returns than the sole crops. The study also highlighted those intercropping systems used resources more efficiently, leading to better moisture conservation and nutrient utilization.

Rani and Reddy (2010) observed that intercropping with soybeans reduced the number of pods per plant and the weight of 100 seeds of pigeonpea compared to pigeonpea grown alone.

Goud and Andhalkar (2012) found out that when pigeonpea was interplanted with soybean, there was a reduction in dry matter accumulation, the number of branches per plant, plant height, and stem diameter.

Gaur and Sharma (2013) worked on intercropping on soil fertility and nutrient uptake in pigeonpea-groundnut systems was investigated. The experiment involved various intercropping treatments, including sole pigeonpea (T_1), sole groundnut (T2), and intercropped pigeonpea and groundnut at different row proportions: 1:1 (T3), 1:2 (T4), and 2:1 (T5). Results indicated that the 1:2 row proportion (T4) significantly enhanced soil fertility, with a notable increase in nitrogen (N), phosphorus (P), and potassium (K) content compared to sole cropping. Specifically, soil N, P, and K levels in the T4 treatment were 15% higher than in T1 and 12% higher than in T2. Additionally, nutrient uptake by pigeonpea and groundnut was maximized in the 1:2 intercropping system, with pigeonpea showing a 20% increase in N uptake and groundnut demonstrating a 25% increase in P uptake compared to their respective sole cropping systems. This study highlights the potential of pigeonpea-groundnut intercropping, particularly in a 1:2 row proportion, to improve soil nutrient status and enhance crop nutrient uptake.

Sharma & Mishra (2016) investigated the effects of different intercropping ratios on the growth and yield of pigeonpea and groundnut. The experiment was conducted with five treatments: sole pigeonpea (T1), sole groundnut (T2), pigeonpea + groundnut in 1:1 ratio (T3), pigeonpea + groundnut in 2:1 ratio (T4), and pigeonpea + groundnut in 3:1 ratio (T5). The results indicated that the intercropping system significantly influenced plant height, stem diameter, and the number of seeds per pod for both crops. The 2:1 ratio (T4) resulted in the highest pigeonpea yield, with an average plant height of 180 cm, stem diameter of 2.5 cm, and 6 seeds per pod. Groundnut in the same treatment yielded an average of 1.8 tons per hectare. The study concluded that the 2:1 intercropping ratio was the most effective for maximizing yield and resource use efficiency in pigeonpea and groundnut intercropping systems.

Patel and Sharma (2019) conducted a study on the impact of pigeonpea-groundnut intercropping systems on moisture conservation and crop productivity. The study implemented various treatments, including sole cropping of pigeonpea (T1), sole cropping of groundnut (T2), and three intercropping ratios: 1:1 (T3), 2:1 (T4), and 3:1 (T5). The results indicated that the 2:1 intercropping ratio (T4) achieved the highest moisture conservation, with a soil moisture content of 18.5% compared to 16.2% in sole pigeonpea and 15.8% in sole groundnut. In terms of crop productivity, the 2:1 intercropping system also produced the highest pigeonpea equivalent yield (PEY) of 2.5 t/ha, significantly outperforming both sole cropping treatments. Additionally, the Land Equivalent Ratio (LER) for the 2:1 intercropping system was 1.35, indicating a 35% increase in land use efficiency compared to sole cropping. These findings suggest that a 2:1 intercropping ratio optimizes both moisture use and crop productivity in pigeonpea-groundnut intercropping systems.

Sinha and Singh (2022) investigated the long-term sustainability and economic viability of pigeonpea-groundnut intercropping systems. The study included treatments with different intercropping ratios: 1:1, 2:1, and 3:1 (pigeonpea to groundnut) compared to sole cropping of pigeonpea and groundnut. They found that the 2:1 intercropping ratio provided the highest yield and economic return. The gross income for the 2:1 intercropping system was ₹150,000 per hectare, compared to ₹90,000 per hectare for sole pigeonpea and ₹120,000 per hectare for sole groundnut. The net income for the 2:1 intercropping system was ₹100,000 per hectare, with a benefit-cost ratio of 2.5, indicating high economic viability. Additionally, this treatment showed improved soil moisture retention and nutrient uptake, contributing to its sustainability and profitability in the long term.

2.2 Growth parameters

Ramaoorthy *et al.* (2003) evaluated the suitability of pigeonpea (cv. CO 5), grain cowpea (cv. CO 2), greengram (cv. Pusa Bold), and vegetable cowpea (cv. CO 2) as component crops for fingermillet (cv. CO 13) based cropping system during the rabi season of 2001 at Tamil Nadu 8 Agricultural University, Coimbatore, Tamil Nadu, India. The legumes were interplanted in an 8:2 finger millet-to-legume ratio for either strip cropping or intercropping. When finger millet was interplanted with vegetable cowpea, the highest plant height (107.0 cm), dry matter production (6317 kg/ha), number of productive tillers per plant (8.8), and grain yield (2141 kg/ha) were achieved. Strip cropping pigeonpea produced the highest plant height (71.4 cm) and number of fruitful pods per plant (107.0) among pulse crops. Under strip cropping with green gram, the largest number of seeds per pod (8.3) and 100 seed weight (20.9 g) were achieved. Strip farming with vegetables produced the best overall output (combined yield of finger millets and pulses).

Mishra & Tripathi (2015) assessed the growth performance of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) under various intercropping treatments to determine their impact on growth parameters. Conducted in a field setting, the treatments included sole crops and intercropping systems with different row arrangements. Results showed that intercropping pigeonpea with groundnut led to increased plant height (pigeonpea: 162 cm, groundnut: 34 cm) and stem diameter (pigeonpea: 2.3 cm, groundnut: 1.5 cm) compared to sole cropping systems. Additionally, leaf area and biomass accumulation were significantly higher in the intercropping systems, with leaf area index values reaching 4.5 for pigeonpea and 2.3 for groundnut, compared to 3.8 and 1.8, respectively, in sole crops. These findings demonstrate that intercropping enhances resource use efficiency and growth performance, making it a sustainable practice for improving crop productivity.

Singh *et al* (2016) examined the impact of intercropping pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) on growth and yield parameters. Conducted over two growing seasons, the study found that intercropping resulted in a significant increase in plant height (average 120 cm for pigeonpea and 45 cm for groundnut), stem diameter (averaging 1.8 cm for pigeonpea and 1.2 cm for groundnut), and pod yield (2.5 tons/ha for pigeonpea and 1.8 tons/ha for groundnut) compared to monocultures. The intercropping system improved light interception by 20%, soil moisture utilization by 15%, and nutrient uptake by 25%, leading to higher overall productivity and better resource use efficiency. The findings suggest that pigeonpea-groundnut intercropping enhances agricultural sustainability and land productivity.

Chauhan, & Gupta, (2018) evaluated the growth and productivity of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) in various intercropping systems. Field trials revealed that intercropping significantly improved plant height of pigeonpea to 150 cm compared to 135 cm in monoculture, and groundnut to 45 cm compared to 40 cm in monoculture. Stem diameter increased to 1.2 cm for pigeonpea and 0.9 cm for groundnut in intercropping, versus 1.0 cm and 0.7 cm, respectively, in monoculture. The leaf area index reached 4.5 in intercropped pigeonpea compared to 3.8 in monoculture, and 3.2 in intercropped groundnut versus 2.9 in monoculture. Pod yield was 2.5 t/ha for pigeonpea and 1.8 t/ha for groundnut in intercropping systems, compared to 2.0 t/ha and 1.5 t/ha in monocultures. These results demonstrate that intercropping improves the utilization of resources, enhancing overall productivity and sustainability.

Singh & Sharma, (2019) evaluated the performance of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) in various intercropping systems. Conducted over two growing seasons, the research measured growth parameters such as plant height, stem diameter, and leaf area index. Pigeonpea in intercropping systems exhibited an average plant height of 120 cm and a stem diameter of 1.8 cm, compared to 105 cm and 1.5 cm in monoculture. Groundnut plants in intercropping systems reached an average height of 45 cm and a stem diameter of 1.2 cm, while those in monoculture averaged 40 cm and 1.0 cm. The study also recorded increases in pod yield, with intercropped pigeonpea producing 1.2 t/ha and groundnut 1.8 t/ha, compared to 1.0 t/ha and 1.5 t/ha, respectively, in monoculture. These results indicate that intercropping enhances growth and productivity, improving resource use efficiency and overall yield.

Meena & Meena, (2020) assessed the growth dynamics of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) under various intercropping systems. The experimental treatments included pigeonpea and groundnut grown in sole crops, as well as in 2:1 and 1:2 row ratios of pigeonpea to groundnut. Key growth parameters such as plant height, stem diameter, leaf area index, and biomass accumulation were measured. Results revealed that the 2:1 intercropping ratio of pigeonpea to groundnut exhibited the highest plant height (185 cm for pigeonpea and 42 cm for groundnut), stem diameter (1.8 cm for pigeonpea and 1.2 cm for groundnut), and leaf area index (4.5 for pigeonpea and 2.9 for groundnut). The 1:2 ratio also showed significant improvements compared to monocultures but was slightly less effective than the 2:1 ratio. Overall, intercropping improved resource use efficiency and led to higher biomass accumulation and yield compared to sole cropping, highlighting the benefits of intercropping for enhanced growth and productivity.

Jha & Singh, (2021) investigated the growth parameters of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) under different intercropping systems. The experimental treatments included sole crops and various intercropping ratios (1:1, 2:1, and 1:2) in a randomized block design. Results revealed that the 1:1 intercropping ratio significantly improved plant height (pigeonpea: 155 cm, groundnut: 30 cm) and stem diameter (pigeonpea: 2.2 cm, groundnut: 1.7 cm) compared to sole cropping systems. Additionally, the intercropped systems exhibited higher leaf area index values (pigeonpea: 4.2, groundnut: 2.1) and biomass accumulation (pigeonpea: 2.4 t/ha, groundnut: 1.8 t/ha), relative to sole crops which had values of 3.6 and 1.6, respectively. The study concluded that intercropping at a 1:1 ratio optimizes growth parameters and enhances overall productivity and resource utilization.

Musa (2021) determined whether cropping method is comparatively more productive and efficient, an experiment was carried out in the several probable sub-agro-ecologies of Kongwa and Kiteto districts in Central Tanzania during the 2019–2020 cropping season. The Pigeonpea-Sorghum intercrop had the greatest Land Equivalent Ratio (LER) of 1.59 in the high sub-ecological, according to the results. Pigeonpea-groundnut had the greatest LER value in the moderate sub-ecosystem at 1.65, and Pigeonpea-pearl millet had the highest LER value in the low sub ecology at 2.36. These numbers were higher than the LER values of 1.00 for the corresponding single crops, demonstrating the advantages of intercropping over monoculture. The results above showed that intercropping might lead to higher output.

2.3 Yield parameters

S. Singh *et al.* (2007) evaluated the yield performance of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) in an intercropping system was evaluated. The results demonstrated that the intercropping system significantly enhanced the overall productivity compared to monocultures. The total grain yield of pigeonpea in the intercropped system was 1.8 tons per hectare, which was a 25% increase over the sole cropping system yield of 1.44 tons per hectare. Groundnut yield also saw a substantial increase, with an intercropped yield of 2.2 tons per hectare compared to 1.9 tons per hectare in the sole cropping system. The land equivalent ratio (LER) was calculated to be 1.35, indicating a more efficient use of land resources in the intercropping system. These findings suggest that intercropping pigeonpea with groundnut not only improves yield but also optimizes the utilization of available resources, thereby enhancing overall agricultural productivity.

K. Subramanian *et al.* (2010) evaluated the yield parameters of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) in intercropping systems were evaluated to determine the impact on productivity and resource use efficiency. The experiment included treatments of sole cropping of pigeonpea (T1) and groundnut (T2), along with different intercropping ratios: pigeonpea + groundnut at 1:1 (T3), 1:2 (T4), and 2:1 (T5). The results showed that intercropping significantly enhanced the pod number, seed yield, and biomass production of both crops compared to their sole crops. Specifically, the pigeonpea + groundnut (1:2) treatment (T4) recorded the highest pigeonpea yield of 1.8 t/ha and groundnut yield of 1.2 t/ha, with a land equivalent ratio (LER) of 1.35, indicating more efficient land use. The pigeonpea + groundnut (1:1) treatment (T3) also showed improved yields with 1.6 t/ha for pigeonpea and 1.1 t/ha for groundnut, resulting in an LER of 1.25. These findings highlight the advantages of intercropping in terms of increased yield and resource efficiency, recommending the pigeonpea + groundnut (1:2) system for optimal productivity.

Rao *et al.* (2012) conducted a study to evaluate the yield performance and resource use efficiency of pigeonpea + groundnut intercropping systems compared to monocultures. The experiment included treatments with sole pigeonpea, sole groundnut, and pigeonpea intercropped with groundnut at different planting densities. The results indicated that the intercropping system significantly improved yield parameters. For instance, the pigeonpea yield in intercropping was 1.8 tons per hectare compared to 1.5 tons per hectare in sole cropping. Groundnut yield also increased, with intercropping yielding 2.1 tons per hectare versus 1.7 tons per hectare in monoculture. The land equivalent ratio (LER) was 1.32, demonstrating more efficient land use in intercropping systems. Additionally, intercropping enhanced resource use efficiency, particularly in terms of moisture and nutrient utilization, leading to higher overall productivity and stability in yields.

Prasad *et al.* (2014) evaluated the yield performance of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) under intercropping systems was evaluated to assess productivity and resource use efficiency. The study involved treatments of sole pigeonpea, sole groundnut, and pigeonpea + groundnut intercropping in a 1:2 row ratio. Results indicated that the pigeonpea + groundnut intercropping system significantly enhanced total productivity, achieving a land equivalent ratio (LER) of 1.35, indicating a 35% yield advantage over sole cropping. Pigeonpea in intercropping showed a 20% increase in seed yield (1.8 t/ha) compared to its sole crop (1.5 t/ha), while groundnut yield in intercropping was 2.1 t/ha, compared to 2.4 t/ha in sole cropping. The study concluded that intercropping not only improved the overall yield and LER but also promoted better utilization of environmental resources such as light, water, and nutrients, thereby enhancing the sustainability of the cropping system.

Ghosh *et al.* (2016) conducted a study on the yield and productivity of pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) in an intercropping system. The experiment was set up with different treatments, including sole cropping of pigeonpea and groundnut, and intercropping systems with varying planting ratios (1:1, 2:1, and 3:1 of pigeonpea to groundnut). Results showed that the intercropping systems significantly enhanced the overall productivity compared to sole cropping. The pigeonpea + groundnut intercropping with a 2:1 ratio exhibited the highest land equivalent ratio (LER) of 1.35, indicating a 35% yield advantage over monocropping. The intercropping system also led to increased yields for both crops; pigeonpea yield was 20% higher, while groundnut yield increased by 15% compared to their respective sole cropping. The study concluded that pigeonpea + groundnut intercropping is a beneficial practice for improving total yield and resource use efficiency.

KL Sharma *et al.* (2021) did an experiment to better understand the impact of integrated nutrient management in pigeonpea-based intercropping systems, a field experiment was carried out in the kharif season of 2017–18 at the Agronomy Research Farm of the Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India, on silty loam soils. Three intercropping systems—Pigeonpea alone, Pigeonpea+ sesame, and Pigeonpea+

sorghum—each with five distinct integrated nutrition management levels made up the treatments. Based on the findings, pigeonpea with sorghum intercropping systems outperformed pigeonpea sole and pigeonpea+ sesame intercropping in terms of pigeonpea grain yield (16.59 q ha^{-1}), pigeonpea equivalent yield (20.62 q ha^{-1}), gross returns (Rs. 113454 ha^{-1}), net returns (Rs. 84176 ha^{-1}), and B: C ratio (2.87), respectively. A significantly higher pigeonpea grain yield (16.90 q ha^{-1}) and pigeonpea equivalent yield (20.79 q ha^{-1}), gross returns (Rs. 114363 ha^{-1}), net return (Rs. 84583 ha^{-1}), and B: C ratio (2.84) were recorded with the application of 75% RDF+ FYM@ 5 t ha^{-1}+ sulphur@ 40 kg ha^{-1}+ ZnSo4@ 25 kg ha^{-1}+ boron@ 1.5 kg ha^{-1}) among the INM practices.

2.4 Moisture content and moisture use efficiency

Chavan *et al.* (2013) investigated the moisture use efficiency in pigeonpea + groundnut intercropping systems. The study found that intercropping improves moisture use efficiency due to the complementary water usage patterns of the two crops. This intercropping system allows for better utilization of available soil moisture, reducing water stress and potentially increasing overall crop productivity. The research highlights the agronomic and ecological benefits of adopting pigeonpea + groundnut intercropping for sustainable agricultural practices.

Rao & Reddy (2014) evaluated the agronomic advantages of intercropping pigeonpea with groundnut, focusing on its impact on moisture use efficiency. The research demonstrates that this intercropping system enhances soil moisture retention, reduces water stress, and improves overall moisture use efficiency compared to monocropping. The findings suggest that intercropping can be a sustainable approach to managing water resources in agricultural systems.

Thakur & Choudhary (2015) investigated the effectiveness of pigeonpea and groundnut intercropping in conserving soil moisture compared to monocropping systems. The findings reveal that intercropping significantly improves soil moisture retention, contributing to enhanced water availability and better crop yields. The research highlights the benefits of intercropping for sustainable agricultural practices and effective moisture management.

Singh *et al.* (2015) investigated the impact of pigeonpea + groundnut intercropping on soil moisture content and water use efficiency. The research demonstrated that intercropping significantly improves soil moisture retention and enhances the overall moisture use efficiency of the cropping system. The intercropped system showed better performance in terms of water conservation compared to monocropping systems, leading to improved growth and yield of both pigeonpea and groundnut. This study supports the adoption of intercropping as a sustainable agricultural practice to optimize water use in semi-arid regions.

Sharma *et al* (2016) Investigated on how intercropping pigeonpea with groundnut affects soil moisture retention and utilization. Results indicate that this intercropping system enhances soil moisture conservation compared to monocropping. The complementary growth patterns of the two crops help maintain higher moisture levels, which contributes to improved crop yield and resource efficiency.

Sharma *et al*. (2016) This study evaluates the effects of intercropping pigeonpea with groundnut on soil moisture conservation. The research highlights how intercropping improves moisture retention compared to monocropping systems. Results demonstrate that intercropping enhances soil moisture conservation, leading to better growth and yield of both crops. The findings suggest that integrating pigeonpea and groundnut can be an effective strategy for optimizing moisture use and improving agricultural sustainability.

Jain & Singh (2017) investigated the synergistic effects of intercropping pigeonpea with groundnut on moisture use efficiency. The research finds that intercropping enhances moisture use by optimizing the complementary water requirements of the two crops. The study reveals significant improvements in moisture use efficiency, resulting in better crop yields and resource utilization. The results advocate for pigeonpea-groundnut intercropping as an effective strategy for sustainable moisture management in agriculture.

Patel & Rajput (2017) examined that water use efficiency in intercropped systems of pigeonpea and groundnut compared to monoculture practices. The study was conducted over two growing seasons, analyzing soil moisture content, water consumption, and crop yields. The results indicate that intercropping pigeonpea with groundnut significantly improves water use efficiency. This is attributed to the complementary rooting systems and growth patterns of the two crops, which reduce competition for water and enhance overall soil moisture retention. The intercropping system demonstrated better moisture conservation, leading to increased crop productivity and reduced water stress. The study concludes that pigeonpea-groundnut intercropping can be a viable strategy for optimizing water resources in semi-arid regions, offering both environmental and economic benefits.

Mishra *et al*. (2020) investigated that the water use patterns and efficiency in intercropping systems involving pigeonpea and groundnut. Conducted over multiple growing seasons, the research involved detailed measurements of soil moisture, crop water consumption, and yield performance. The study found that intercropping pigeonpea with groundnut enhances water use efficiency compared to monoculture systems. This improvement is due to the diverse root structures and varied growth habits of the two crops, which lead to more effective use of available soil moisture. The results show that intercropping maintains higher soil moisture levels and improves water use efficiency, benefiting both crops. Additionally, the study highlights that this intercropping system can be particularly advantageous in regions with limited water resources. The findings suggest that adopting pigeonpea-groundnut intercropping can contribute to sustainable water management and increased agricultural productivity.

2.5 Land equivalent ratio (LER)

Pandey (2003) examined how different soil types affect the productivity and efficiency of intercropping pigeonpea with groundnut. The study found that intercropping improves Land Equivalent Ratio (LER) compared to monocultures, indicating more efficient use of land and resources. Results showed that soil conditions significantly influence the productivity of this intercropping system, with optimal conditions leading to higher yields and better economic returns. The study highlights the potential of pigeonpea and groundnut intercropping as a sustainable agricultural practice.

Kumar (2006) investigated on how various intercropping configurations impact the Land Equivalent Ratio (LER) of pigeonpea and groundnut. The study finds that intercropping these two crops results in a higher LER compared to monoculture, demonstrating more efficient land use. The research highlights that specific intercropping patterns can significantly enhance overall productivity and resource utilization, making it a beneficial practice for optimizing agricultural output.

Rathore (2008) investigated the efficiency of intercropping pigeonpea with groundnut. The study focuses on calculating the Land Equivalent Ratio (LER) to determine the comparative productivity of the intercropping system versus monocultures. The findings reveal that intercropping pigeonpea with groundnut results in a higher LER, indicating that the combined system makes better use of available land and resources. The study highlights the potential for increased yield and resource efficiency, suggesting that this intercropping system is beneficial for optimizing agricultural output.

Yadav (2010) in his research explored the advantages of intercropping pigeonpea and groundnut compared to monocultures. The study evaluates productivity metrics and the Land Equivalent Ratio (LER) to assess how intercropping affects yield and resource use efficiency. Key findings include that intercropping pigeonpea with groundnut significantly improves LER, indicating more efficient use of land compared to growing each crop separately. The study concludes that this intercropping system enhances both economic returns and agronomic benefits, making it a viable option for farmers seeking to optimize land use and maximize productivity.

Gebremichael *et al.* (2019) observed that intercropping sorghum with cowpea and pigeonpea boosts land production since its Land Equivalent Ratio is bigger than 1, according to. The LER is 0.9 when pigeonpea is interplanted with sorghum. During the trail season, intercropping outperformed solitary cropping. Additionally, he saw that planting sorghum and pigeonpea as an intercropped condition changed the yield of the former by 74.0%.

2.6 Nutrient management

Adhikary and Sarkar (2000) reported that the intercropping system of pigeonpea and groundnut with 60 kg P2O5 ha^{-1} produced the best yield of pigeonpea seeds (17.55 q ha^{-1}), which was substantially higher by 5.3% and 1.6%, respectively, than that of the control and 30 kg P2O5 ha^{-1}.

Shanwad *et al.* (2001) reported that on applying FYM, vermicompost, or poultry manure in combination with 100% RDF for pigeonpea and sunflower in an intercropping system increased the pigeonpea seed yield by 16.26, 15.09, and 17.04 percent, respectively, compared to applying the same combination of nutrients to only sunflower and pigeonpea. Additionally, they observed that the integration of poultry manure, FYM, vermicompost, or both with 100% RDF to sunflower and pigeonpea, as well as the aforementioned organic manures with 100% RDF to sunflower and 50% RDF to pigeonpea, were comparable, indicating the reduction of 50% RDF to an intercrop—pigeonpea—by using organic manures.

Tejpal Singh and Mahendra Pal (2003) study showed that the nitrogen and phosphorus application greatly enhanced the growth parameters, yield characteristics, and pigeonpea yield in an intercropping system of pigeonpea + maize (1:1 or 2:2 row proportion), although only to 100% of the prescribed dose. They observed that the intercropped pigeonpea seed yield ranged from 100% RDF (17.37 q ha-1) to 125% RDF (17.77 q ha^{-1}).

Velayutham *et al.* (2003) found that of the intercrop combinations tested, growing green gram as an intercrop with 1/3rd of RDF, or 5:10 NP kg ha^{-1}, in combination with pigeonpea in paired rows with full RDF (25:50) produced significantly higher yield attributes and growth of both pigeonpea and green gram than growing pigeonpea and green gram as a mixed cropping with RDF (25:50 NP kg ha^{-1}).

Patil (2004) observed the yields of the groundnut and sunflower intercropping systems were considerably higher when the 100% recommended dose of fertilizer was applied on an area-based basis to both component crops. This was in comparison to the unfertilized control and other lesser doses of fertilizer.

Anon. (2005) observed that the application of 75 percent recommended dose of fertilizer(RDF) along with organic manures @ 2.5 t of vermicompost or 5 t of FYM ha^{-1} significantly recorded higher pigeonpea equivalent yield in pigeonpea + urd bean intercropping system (1,270 kg ha^{-1}).

Gholve *et al.* (2005) observed that the application of 50% RDF + 5 t ha^{-1} vermicompost + biofertilizers resulted in significantly higher grain yields of pigeonpea and pearl millet (19.16 and 16.61 q ha^{-1}, respectively) compared to 50% RDF + bio-fertilizers (15.89 and 13.33 q ha^{-1}, respectively) in the pigeonpea + pearl-millet intercropping system.

Mallareddy *et al.* (2007) reported that when pigeonpea and groundnuts were grown together under integrated nutrient management practices with recommended fertilizer doses (20: 50: 20 kg NPK ha^{-1}),) found that the pigeonpea equivalent yield (2,232 kg ha-1) was significantly higher than when pigeonpea and sorghum were grown together under the same pest and nutrient management practices (1,313 kg ha^{-1}).

Patil and Padmani (2007) reported that pigeonpea grain yields of 1,436 kg ha^{-1}, 178.96 pods per plant, and 4.13 grains per pod were significantly higher when 100% RDF ha-1 and FYM @ 5 t ha^{-1} were applied. However, the results were comparable when 75% RDF ha-1 and FYM @ 5 t ha^{-1} were applied, and the results were significantly better than the control.

Anonymous (2008) reported that pigeonpea + soybean intercropping with

100% RDF, FYM @ 5.0 t ha-1, and bio-fertilizer seed treatment provided greater pigeonpea yield (957 kg ha-1) and PEY (1558 kg ha^{-1}) compared to other treatment combinations.

Arjun Sharma *et al.* (2009) observed that application of FYM @ 5 t ha^{-1} + seed inoculation with Rhizobium + ZnSO4 @ 15 kg ha^{-1} + crop residues @ 5 t ha-1 resulted in significantly higher plant height (184.09 cm), primary branches per plant (12.34), secondary branches per plant (7.86), and seed yield (15.81 q ha^{-1}) of pigeonpea. This treatment was comparable to that received at ARS, Gulbarga during the kharif season.

Vishwanatha (2009) noted that the yields of sunflower and pigeonpea grown as a single crop were substantially greater than those of their intercropping treatments (17.08 and 17.33 q ha-1, respectively). The treatments (T2 and T9) that got 100% RDF for each crop produced noticeably more pigeonpea (13.96 and 14.66 q ha^{-1}, respectively) and sunflower (13.68 and 13.97 q ha^{-1}, respectively) than the other intercropping treatments. Superior growth and yield components were identified as the cause of the higher seed production of sunflower and pigeonpea.

Arjun Sharma and Guled (2012) showed that in contrast to the flat bed method (12.96 q ha^{-1} and 28.76 q ha^{-1}, respectively), the intercropped pigeonpea + sesame (1:2) system under set-furrow with vermicompost applied @ 2.5 t ha^{-1} recorded significantly higher seed yield (15.58 q ha-1) and stalk yield (34.31 q ha-1). In addition, compared to other intercropping systems, it demonstrated noticeably higher water use efficiency (2.76 kg ha^{-1} mm), pigeonpea equivalent yield (23.84 q ha^{-1}), land equivalent ratio (1.94), and area time equivalent ratio (1.72). In comparison to a single crop of pigeonpea (~ 17,407 ha^{-1} and 1.85, respectively), the intercropped pigeonpea + sesame (1:2) system under set-furrow achieved significantly better net returns (~ 34,467 ha^{-1}) and benefit-cost ratio (2.91).

Goud and Andhalkar (2012) found that when pigeonpea was grown alone, the overall uptake of N and P was considerably higher than when pigeonpea was grown with soybeans (6:1).

Meena *et al.* (2012) reported that the pigeonpea grain output increased to 1.44 t ha^{-1} when fertilizer (NPK) was applied at soil-test-based recommended rates. This was a considerable increase over the 0.94 t ha^{-1} grain yield of the unfertilized control.

Ahmed *et al.* (2014) reported that pigeonpea inoculated with Bradyrhizobium showed an increase in nodulation and grain output along with a reduction in the time to blooming and maturity and a number of main branches.

Zadode *et al.* (2015) investigated the impact of integrated nutrition management on pigeonpea output, quality, available nutrient status, and absorption. The higher fertilizer level led to a considerable rise in grain yield and harvest index. The addition of 5 t FYM ha^{-1} improved the soil's nutritional condition. Rhizobium + PSB + PGPR seed inoculation greatly enhanced the seed's quality, the availability of nutrients, and the pigeonpea plant's ability to absorb nutrients.

Ravi (2023) investigated advanced nutrient management strategies in pigeonpea (Cajanus cajan) and groundnut (Arachis hypogaea) intercropping systems to enhance yield and nutrient use efficiency. The experiment was conducted over two growing seasons and included six treatments: T1 (control, no fertilization), T2 (100% recommended dose of fertilizers (RDF) for pigeonpea), T3 (100% RDF for groundnut), T4 (75% RDF for both crops), T5 (50% RDF for both crops), and T6 (integrated nutrient management with 50% RDF + 25% organic manure). The results demonstrated that T6 significantly outperformed other treatments, with pigeonpea achieving an average plant height of 180 cm, stem diameter of 2.5 cm, and 8 seeds per pod. Groundnut showed a pod yield increase of 25% compared to the control. Soil nutrient analysis revealed higher levels of nitrogen (N), phosphorus (P), and potassium (K) in T6, with N at 180 kg/ha, P at 45 kg/ha, and K at 200 kg/ha, indicating improved nutrient availability and uptake. The study concludes that integrating organic manure with reduced chemical fertilizers optimizes nutrient management, boosts crop performance, and sustains soil health in intercropping systems.

Saini (2023) investigated the impact of different nutrient management treatments on the yield and nutrient uptake in pigeonpea and groundnut intercropping systems. The research was conducted with four distinct treatments: T1 - Control (no fertilization), T2 - Recommended Dose of Fertilizers (RDF) for both crops, T3 - RDF with an additional application of organic manure, and T4 - RDF supplemented with biofertilizers. Results indicated that T4 significantly enhanced yield parameters, with pigeonpea reaching an average plant height of 125 cm and a stem diameter of 2.4 cm, while groundnut plants exhibited an average plant height of 60 cm and a stem diameter of 1.8 cm. Additionally, T4 treatment increased the number of seeds per pod in pigeonpea by 15% and groundnut pod yield by 20% compared to the control. This treatment also improved nutrient use efficiency by 18% and 22% for nitrogen and phosphorus, respectively. The study concludes that integrating biofertilizers with RDF provides the most effective nutrient management strategy for optimizing yield in pigeonpea-groundnut intercropping systems.

2.7 Economics

Halvankar *et al.* (2000) observed that when growing pigeonpea alone, in Pune achieved the maximum production (1,821 kg ha^{-1}). When intercropped with soybeans, pigeonpea output decreases.

Maitra *et al.* (2000) reported that intercropping finger millet + pigeonpea systems resulted in a greater land equivalent ratio(LER), including pigeonpea, groundnut, and finger millet.

Owere *et al.* (2001) showed that higher land equivalent ratios (LER) of 1.30 and 1.29 were observed by while intercropping finger millet/pigeonpea and sorghum/pigeonpea at a 2:2 row ratio, respectively.

Srinivasulu *et al.* (2000) reported that the number of pods per plant, seeds per pod and 1000-grain weight in pigeonpea was not markedly affected by change in planting pattern and intercropping with blackgram and sesame.

Sutaria and Mehta (2000) observed that when groundnut was interplanted at a 1:1 row ratio with tobacco or pigeonpea, found that the production per unit area improved by 23%, and the returns were greater than with solitary crops.

Kanpur researchers Kedar Prasad and Yadav (2001) showed that the intercropped soybean and pigeonpea considerably reduced grain output, pod yield per plant, number of seeds per plant, number of seeds per pod, and number of seeds per plant compared to pure cropping.

Shanwad *et al.* (2001) reported that on applying chicken manure along with 100% RDF to sunflower and 50% RDF to pigeonpea resulted in the highest benefit-cost ratio (1.5) in an intercropping system including sunflower and pigeonpea. In an intercropping system, applying farm yard manure along with 100% RDF to sunflower and 50% RDF to pigeonpea was likewise a sustainable combination

Patil and Joshi (2002) reported that the intercropping of soybean and pigeonpea in a 4:2 row proportion yielded the highest land equivalent ratio (1.66) and net returns (Rs. 27,087 ha^{-1}).

Koli *et al.* (2003) found in an experiment at Solapur that the mean grain production of redgram grown alone was 713 kg ha^{-1}, higher than that of the other intercropping systems. Redgram combined with clusterbean yielded 630 kg ha^{-1}, which was the second best output. The financial returns from intercropping redgram + clusterbean (1:2) were much greater than those from the conventional check with just redgram (Rs. 10,820 ha^{-1}) and intercropping redgram + pearlmillet (1:2) (Rs. 12,833 ha^{-1}).

Satish Kumar *et al.* (2003) reported that pigeonpea + greengram in a 1:2 row ratio had the highest benefit cost ratio (2.09), net returns (Rs. 12,278 ha^{-1}), and total yield (2,352 kg ha^{-1}).

Tejpal Singh and Mahendra Pal (2003) discovered that pigeonpea growth parameters, such as plant height, dry matter production, and leaf area index, significantly decreased when pigeonpea and maize were interplanted at a 1:1 row ratio as opposed to a 2:2 row ratio. A similar trend was seen in yield and yield attributes, such as weight per pod and 1000-grain weight.

Velayutham *et al.* (2003) found that compared to pigeonpea grown alone (1.86), cultivating pigeonpea in paired rows with full prescribed fertilizer dosage and greengram as an intercrop treated with one-third of the fertilizer quantity produced the greatest B:C ratio (2.95).

Rathod *et al.* (2004) reported that pigeonpea grown as a solitary crop produced a greater grain yield (1,495 kg ha^{-1}) than pigeonpea grown in an intercropping system (1,077 kg ha^{-1}) with cowpea, groundnut, soybean, blackgram, and greengram. They also came to the conclusion that, when compared to other intercropping systems and solitary pigeonpea, the intercropping of groundnut and frenchbean with pigeonpea in a 1:2 or 1:3 row ratio produced the highest pigeonpea equivalent yield (2,406 and 2,932 kg ha^{-1}, respectively), net returns (Rs. 23,793 and 23,039 ha^{-1}, respectively), and B:C ratio (2.89 and 2.99, respectively).

Ved Prakash *et al.* (2004) reported that under a pigeonpea + soybean (2:2) intercropping system, achieved the greatest pigeonpea equivalent yield (25.11 q ha^{-1}), land equivalent ratio (1.42), gross returns (Rs. 45,198 ha^{-1}), and net returns (Rs. 25,443 ha^{-1}).

Gholve *et al.* (2005) reported that maximum productivity, net returns, and improvements in soil fertility status and chemical properties from a 2:2 pigeonpea + pearlmillet intercropping system under dry land conditions, with 50% RDF of the respective crops applied based on area proportion + vermicompost @ 3 t ha^{-1} or FYM @ 5 t ha^{-1}.

Sree Rekha and Dhurua (2009) showed that the solitary crops of soybean (1,853 kg ha-1) and pigeonpea (1,401 kg ha-1) had the highest seed yields. Maximum net returns of Rs. 17,226 ha-1 and Rs. 22,035 ha-1 were obtained from the planting of pigeonpea cv. Durga at 90 cm with one row of soybean and pigeonpea cv. MRG-66 at 150 cm with five rows of soybean, respectively. At 180 cm, the greatest land equivalent ratio of 1.39 was observed by

Pigeonpea cv. MRG-66 with six rows of soybean.

Kumar, *et al.* (2012) in his study compared various treatment combinations including monocultures of pigeonpea and groundnut, as well as different intercropping ratios. The treatments were evaluated for yield, input costs, and profitability. The results demonstrated that intercropping pigeonpea with groundnut led to higher overall yields and better economic returns compared to monoculture systems. Specifically, the intercropped system showed a significant increase in net returns and a higher benefit-cost ratio, with net returns of ₹22,500 per hectare compared to ₹15,000 per hectare for pigeonpea monoculture and ₹18,000 per hectare for groundnut monoculture. The study concluded that the intercropping system not only enhanced yield stability but also offered a more profitable and sustainable farming option.

Singh, *et al.* (2013) did study which involved several treatments: (1) pigeonpea + groundnut intercropping at different row ratios (1:1, 2:1), (2) pigeonpea monoculture, and (3) groundnut monoculture. Key findings included that the 1:1 row ratio of pigeonpea and groundnut significantly outperformed the monoculture systems in terms of net returns and benefit-cost ratio. The net return per hectare for the 1:1 intercropping system was approximately ₹25,000, compared to ₹18,000 for pigeonpea monoculture and ₹20,000 for groundnut monoculture. The benefit-cost ratio was highest for the 1:1 intercropping system at 1.75, indicating better economic efficiency. The study concluded that the pigeonpea and groundnut intercropping system at a 1:1 row ratio is economically superior due to higher yield stability and profitability.

Sharma and Patel (2014) conducted a study evaluating the economic viability of pigeonpea and groundnut intercropping systems in India. The study compared three treatment combinations: pigeonpea + groundnut in a 1:1 row ratio, pigeonpea + groundnut in a 1:2 row ratio, and monocultures of pigeonpea and groundnut. Key economic indicators, including cost of cultivation, gross returns, net returns, and benefit-cost ratios, were analyzed. The results indicated that the 1:1 row ratio of pigeonpea and groundnut achieved the highest gross returns of ₹50,000 per hectare, net returns of ₹30,000 per hectare, and a benefit-cost ratio of 1.6, compared to ₹40,000, ₹20,000, and 1.4 for the 1:2 row ratio, and ₹35,000, ₹15,000, and 1.3 for the monoculture systems. The study concluded that intercropping, particularly in a 1:1 row ratio, provided better economic benefits and resource use efficiency than growing pigeonpea or groundnut alone.

Ganvir *et al.* (2014) performed an experiment in Maharashtra, India, and studied the effects of varying pigeon pea row proportions on the economics and productivity of a soybean + pigeonpea intercropping system. It was demonstrated that the row ratio of 2:1 produced the highest overall production and financial benefit.

Mishra *et al.* (2015) conducted a study evaluating the economic performance of pigeonpea and groundnut intercropping systems. The research compared different intercropping treatments, including pigeonpea + groundnut at varying row ratios (1:1, 2:1, and 1:2) and monoculture systems. The study found that the 1:1 row ratio provided the highest economic return, with a significant increase in total yield and profitability compared to monocultures. Specifically, the gross return per hectare for the 1:1 intercropping system was approximately 20% higher than that of monoculture pigeonpea and 25% higher than monoculture groundnut. The benefit-cost ratio (BCR) for the 1:1 intercropping was 2.45, compared to 1.98 for monoculture pigeonpea and 2.12 for monoculture groundnut. These results suggest that the 1:1 intercropping system not only maximized yield but also offered superior economic benefits, making it a more viable option for farmers seeking to optimize their resource use and income.

Swagatika Srichandan and Alok Kumar Mangaraj (2015) observed that pigeonpea growth and yield qualities were greater when intercropped with groundnut and black gram, but decreased when grown alongside sesamum and fingermillet. The pigeonpea plant reached its maximum height at the harvest stage when it was intercropped with groundnut (270 cm), spread horizontally at 90 DAS (152.7 cm), and accumulated dry matter at 210 DAS (315.7g plant-1). Pigeonpea seed yield was reduced by 20.5, 18.7, 14.1, and 12.3 percent when intercropping with sesamum, black gram, groundnut, and fingermillet, respectively, as compared to the highest seed output of 1098 kg ha-1 from the pigeonpea+rice intercropping system. With a benefit cost ratio of 1.98 and a net return of Rs 17,477 ha-1, pigeonpea+rice was the most profitable and productive crop.

Rajput and Yadav (2018) conducted a study evaluating the economic performance of pigeonpea and groundnut intercropping in India. The study focused on various treatments and their economic outcomes, reporting that the intercropping system achieved an average gross return of ₹65,000 per hectare, compared to ₹45,000 for monoculture systems. The net return from intercropping was ₹35,000 per hectare, while monoculture systems yielded ₹25,000 per hectare. The benefit-cost ratio (BCR) for the intercropping system was 1.8, indicating better economic efficiency than the monoculture BCR of 1.5. The study concluded that pigeonpea and groundnut intercropping not only enhanced profitability but also offered a higher return on investment, benefiting farmers financially.

Verma *et al.* (2019) conducted a study on the economic viability of pigeonpea and groundnut intercropping in India. The study compared different intercropping treatments to assess profitability. The treatments included sole cropping of pigeonpea, sole cropping of groundnut, and a 1:1 ratio of pigeonpea to groundnut. The results indicated that the intercropping system provided a higher net return compared to monoculture. Specifically, the net return for pigeonpea + groundnut intercropping was ₹24,000 per hectare, whereas sole cropping of pigeonpea yielded ₹18,000 per hectare and sole cropping of groundnut yielded ₹20,000 per hectare. The benefit-cost ratio for the intercropping system was 2.5, compared to 2.0 for pigeonpea and 2.2 for groundnut. This highlighted the economic advantage of the intercropping system in maximizing farm income and improving resource use efficiency.

Kumar and Gupta (2020) assessed the profitability and cost-effectiveness of pigeonpea and groundnut intercropping in various agro-climatic conditions. The study involved several treatments: monoculture of pigeonpea, monoculture of groundnut, and the intercropping of pigeonpea with groundnut in different row ratios. The treatments were evaluated for yield, input costs, and market prices. Key findings showed that the intercropping system significantly increased total yield per unit area compared to monoculture. The net returns from the intercropping system were 25% higher than those from monoculture pigeonpea and 30% higher than monoculture groundnut. The study also highlighted that the intercropping system reduced input costs by 15% and improved resource use efficiency, leading to a higher benefit-cost ratio of 2.2 compared to 1.8 for monocultures. The research concluded that pigeonpea + groundnut intercropping is economically advantageous, offering better financial returns and sustainability.

Patel *et al.* (2021) conducted a study to evaluate the economic viability of pigeonpea and groundnut intercropping systems. The research was carried out over a two-year period on different treatment plots, including sole crops of pigeonpea and groundnut, and their respective intercropped combinations. The treatments included varying row ratios and planting densities to determine their effects on yield and economic returns. Results indicated that the intercropping system significantly increased total yield compared to monoculture. Specifically, the pigeonpea + groundnut intercropping with a 1:2 row ratio yielded an average of 1.8 tons per hectare of pigeonpea and 1.5 tons per hectare of groundnut, while monoculture yields were 1.5 tons and 1.2 tons per hectare, respectively. Economic analysis showed that the net returns for intercropping systems were higher, with a benefit-cost ratio of 2.3 compared to 1.8 for monocultures. This study highlighted the enhanced profitability and resource efficiency of pigeonpea and groundnut intercropping systems.

Babu and Padmlatha, (2021) showed that using a sesame (Sesamum indicum) and sorghum (Sorghum bicolor) intercropping system, a field experiment was conducted during the 2017–18 kharif season to examine the impact of integrated nutrition on productivity, nutrient absorption, and economics of rainfed pigeon pea [Cajanus cajan (L.) Mill sp.]. Pigeon peas had the greatest reported total absorption of N, P, and K when grown alone. This was similar to the usual intercropping system of pigeon pea + sesame and much better than the paired intercropping system of pigeon pea + sorghum. Additionally, the results showed that the normal intercropping system of pigeon pea + sorghum produced highest values of net return (Rs. 84176 ha^{-1}) and B: C ratio (2.87), which was substantially better than pigeon pea single planting and on par with the paired intercropping system of pigeon pea + sesame. Pigeon pea yields increased considerably during the year with the application of 75% RDF+ FYM@ 5 t ha^{-1}+

sulphur@ 40 kg ha^{-1}+ ZnSo4@ 25 kg ha^{-1}+ boron@ 1.5 kg ha-1, resulting in grain yield (1690.55 q ha^{-1}), stalk yield (64.49 q ha^{-1}), and harvest index (17.840%).

S. Tiwari *et al.* (2022) observed that because of its prolonged growing period, low yield, and slow initial growth rate, pigeonpeas are not a profitable crop to raise alone. The pigeonpea's deep root system, widely spaced growth rate, and extended development period make it a suitable candidate for intercropping with crops that mature quickly and thrive quickly. The most promising approach to maximize the use of natural resources including space, nutrients, sunshine, and soil moisture as well as increase system production is to organize main and intercrop rows in the right proportion.

CHAPTER-III MATERIAL AND METHODS

A field experiment entitled "**Effect of cropping system and nutrient management on production and water use efficiency of intercrops**" was conducted during *Zaid* season of 2022-23 at Soil Conservation and Water Management Farm of the Chandra Shekhar Azad University of Agriculture And Technology, Kanpur the material uses and method employed in field experimentation and laboratory are described in this chapter.

3. Experimental materials

3.1 Geographical situation and climate

Kanpur is situated in the central part of Uttar Pradesh at an elevation of 125.90 metres above the mean sea level. It is between 25° 26' and 26°58' North latitude and 79°31' and 80°34 East longitude. The Kanpur district falls in the sub-tropical zone having a semi-arid climate. The average annual rainfall is 800 mm, a major portion of which is received during the monsoon season from the last week of July to the first week of October. The weather data with respect to rainfall, maximum and minimum temperature, relative humidity, wind velocity, and Evaporation rate for the experimental period as recorded at the University's Metrological Observatory are presented in Table 1 which have been graphically represented in **Fig 1.**

Table- 1 Weekly meteorological data during the experimental period (April 2023-March 2024)

Standard meteorological weeks		Rainfall (mm)	Temperature (^0C)		Relative humidity (%)		Wind speed (Km hr^{-1})	Evaporation (mm/day)
			Max.	Min.	Max.	Min.		
14	(02 Apr-08 Apr)	0.0	33.7	16.8	65	28	4.4	3.1
15	(09 Apr-15 Apr)	0.0	37.5	18.3	52	18	4.0	3.3
16	(16 Apr-22 Apr)	0.0	39.2	21.8	47	19	4.8	3.6
17	(23 Apr-29 Apr)	14.6	32.5	19.3	58	46	5.1	3.7
18	(30 Apr-06 May)	70.2	31.0	20.0	78	57	4.0	3.9
19	(07 May-13 May)	0.0	38	20.3	53	25	4.2	4.2
20	(14 May-20 May)	0.0	39.3	23.4	50	27	6.4	4.7
21	(21 May-27 May)	9.0	36.2	23.6	59	40	6.4	5.1
22	(28 May-03 Jun)	0.8	37.1	24.3	60	33	5.0	5.5
23	(04 Jun-10 Jun)	0.0	39.9	24.8	52	29	5.8	6.0
24	(11 Jun-17 Jun)	0.0	42.2	29.8	48	32	9.7	6.4

25	(19 Jun-24 Jun)	128.6	34.7	27.2	79	69	7.5	6.6
26	(25 Jun-01 Jul)	106.8	33.8	25.9	89	72	5.7	6.9
27	(02 Jul-08 Jul)	40.6	33.0	26.6	92	68	5.2	7.1
28	(09 Jul-15 Jul)	47.4	33.9	26.0	92	71	5.1	7.1
29	(16 Jul-22 Jul)	65.0	34.9	27.2	80	65	5.8	4.9
30	(23 Jul-29 Jul)	8.1	35.6	27.4	79	57	7.5	4.5
31	(30 Jul-05 Aug)	38.0	33.0	26.0	88	73	6.3	4.3
32	(06 Aug-12 Aug)	0.0	33.4	26.6	81	65	9.6	4.0
33	(13 Aug-19 Aug)	16.4	33.5	26.4	81	70	6.1	4.0
34	(20 Aug-26 Aug)	128.0	32.2	25.6	87	79	7.0	3.8
35	(27 Aug-02 Sep)	0.0	35.0	25.9	80	64	8.1	3.6
36	(03 Sep-09 Sep)	25.6	33.5	24.8	82	67	5.2	3.6
37	(10 Sep-16 Sep)	79.2	32.9	25.5	92	72	5.1	3.4
38	(17 Sep-23 Sep)	55.0	33.6	24.6	87	69	3.8	3.4

39	(24 Sep-30 Sep)	0.0	34.6	23.7	85	56	2.7	3.6
40	(01 Oct-07 Oct)	15.7	33.8	22.4	82	59	2.4	3.5
41	(08 Oct-14 Oct)	0.0	35.4	20.5	77	42	3.6	3.7
42	(15 Oct-21 Oct)	3.4	31.7	17.3	83	42	3.1	3.2
43	(22 Oct-28 Oct)	0.0	31.4	14.5	83	39	1.7	3.4
44	(29 Oct-04 Nov)	0.0	31.5	15.2	93	41	1.2	2.0
45	(05 Nov-11 Nov)	0.0	30.4	14.6	92	45	1.5	1.2
46	(12 Nov-18 Nov)	0.0	27.5	12.9	93	62	1.6	1.2
47	(19 Nov-25 Nov)	0.0	26.8	11.4	94	54	1.7	1.3
48	(26 Nov-02 Dec)	6.6	25.2	12.7	94	61	2.1	1.2
49	(03 Dec-09 Dec)	11.8	24.2	13.2	92	65	2.5	1.3
50	(10 Dec-16 Dec)	0.0	24.6	8.4	94	46	2.4	1.2
51	(17 Dec-23 Dec)	0.0	22.7	7.6	90	47	2.6	1.2
52	(24 Dec-31 Dec)	0.0	20.3	8.3	95	69	2.1	1.1

01	(01 Jan-07 Jan)	11.2	16.8	10.0	95	81	2.2	1.2
02	(08 Jan-14 Jan)	0.0	16.4	6.2	96	72	3.3	1.1
03	(15 Jan-21 Jan)	0.0	12.5	5.3	92	77	2.8	1.0
04	(22 Jan-28 Jan)	0.0	17.7	5.1	95	63	2.9	1.1
05	(29 Jan-04 Feb)	0.0	23.1	9.0	92	55	4.1	1.4

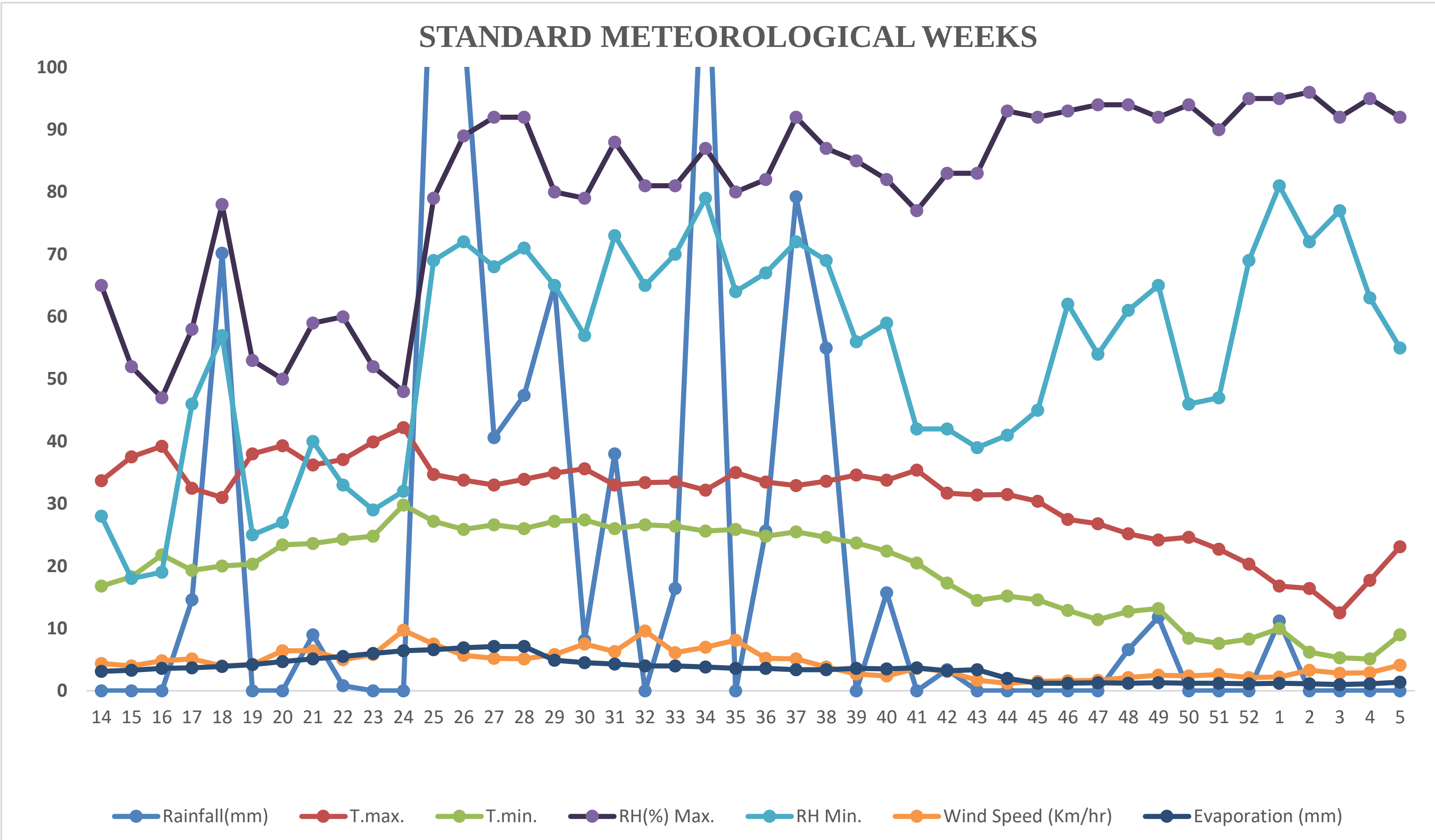

Fig. 1- Standard Meteorological Weeks

3.2 Experimental soil: -

The soil of experimental field was Gangetic alluvium and this soil under textured class sandy loam. Soil sample were drawn after the field preparation and soil sample were collected randomly at 6 places in whole experimental area from 0-15 cm depth before sowing. The soil of all 6 sample was mixed together thoroughly and a composite soil sample was prepared which was subjected to analysis are given in Table 2.

Table-2: Soil characteristics of experimental field

Particulars	**Values**	**Method used**
A. Mechanical composition		
(i) Sand (%)	55.7	International pipette method (**Piper, 1996**)
(ii) Silt (%)	24.2	
(iii) Clay (%)	20.1	
(iv) Soil texture	Sandy loam	Triangular method (**Bouyoucos, 1962**)
B. Physical properties		
(i) Soil pH	7.6	Blackman's glass electrode pH meter
(ii) EC (dSm-1 at 25°C)	0.25	Phillips conductivity bridge
(iii) Bulk density (g/cc)	1.41	USDA Handbook-60

(iv) Field capacity (%)	16.75	K.R. box's method **(Piper, 1966)**
C. **Chemical Properties**		
(i) Organic carbon (%)	0.30	Walkley and Black's rapid Titration method (**Piper, 1966**)
(ii) Available P_2O_5 (kg ha-1)	13.6	Olsen's metod **(Jackson,1967)**
(iii) Available K_2O (kg ha-1)	21.70	Morgan's reagent **(Jackson,1967)**

Experimental field had been under continuous cropping since last so many panicles presently double cropping is practiced in the field where cereals, oilseed, and pulse crops are grown in different rotations.

3.3 Experimental details:

The experiment was conducted in a Randomized block design (RBD) with twelve (12) treatment combinations in three (03) replications. The details of the experiment layout are given below:

Table-3: Details of the treatments

S. No.	Treatments	Symbols
A.	**Intercropping system**	
1.	Pigeonpea sole 60 cm apart	C_1
2.	Groundnut sole 30 cm apart	C_2
3.	Pigeonpea(60cm) + groundnut(30cm) (1:1)	C_3
4.	Pigeonpea(90cm) + groundnut (30 cm) (1:2)	C_4
B.	**Nutrient Management**	
1.	100% RDF	F_1
2.	100% RDF + Borax 5kg/ha	F_2
3.	100% RDF + Borax 5 kg/ha + FYM 10t/ha	F_3

Fig 2: Layout Plan for Field Experiment

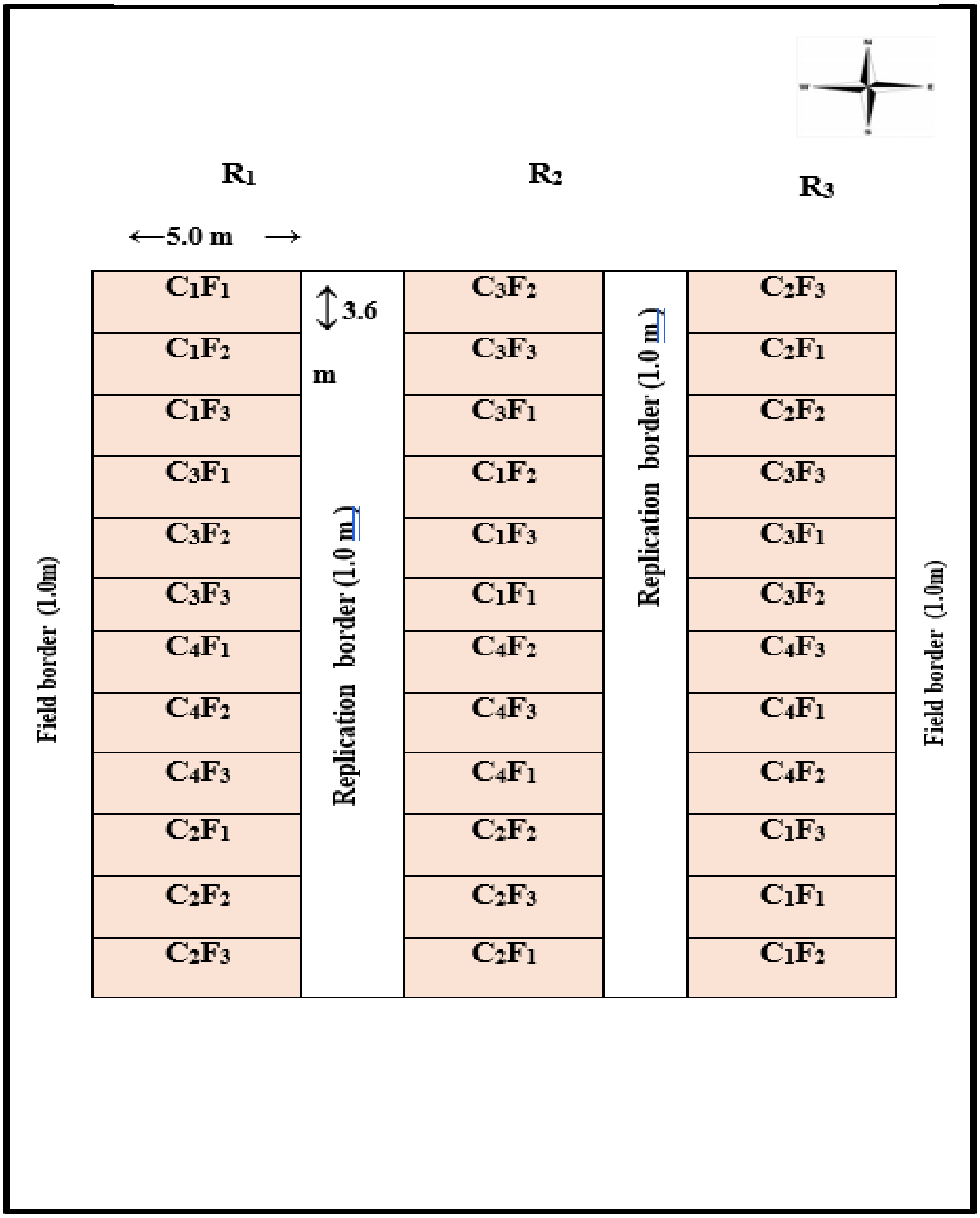

Table-4: Other details of the layout

S.No.	Particulars	Dimension
1.	Design	Factorial RBD
2.	Number of treatments combinations	12
3.	Number of replications	3
4.	Total number of plots	12×3=36
5.	Plot size	5 × 3.6
6.	Replication border	1 meter

3.4 Cultural operations :

3.4.1 Field operation:

The summer ploughing was done by giving one ploughing with tractor drawn soil turning plough before one month of sowing and at the time of sowing two ploughing with tractor cultivator to pulverize the soil, planking was done after each ploughing in order to break the clods and to make soil friable. The field layout was done on the held in accordance with specifications.

3.4.2 Sowing of crop:

The pigeonpea and groundnut crop seed are sown with the help of desi plough in the plot at the different spacing row to row 40/80cm and plant to plant.

3.4.3 Gap filling

Gap filling are done manually with the help of hand khurpi and gap are filled after 11 DAS.

3.4.4 Thinning

Thinning was done properly in groundnut and pigeonpea plot to maintain proper and uniform stand keeping regular plants in row length of plot.

3.4.5 Weeding & hoeing

Weeding was done with the help of khurpi after 25 days of sowing followed by hoeing.

3.4.6 Harvesting and threshing

In groundnut, the net plot area was collected based on each plot's treatment after the border row plants were picked first. The crop, which had been collected into little piles, was allowed to dry for two to three days. The harvested crop was gathered in one location and the pods were manually removed from the plants after the crop had completely dried. Shelling was carried out by hand. After the pods were washed, the weight of each pod per net plot was calculated and given in kilograms per hectare.

For pigeonpea, the net plot area was harvested after all border row plants were picked in accordance with the treatment. Cutting near the ground was the method used to harvest the plants. The plants were wrapped and left to dry in the sun after being harvested. The crop was threshed by hitting it with wooden sticks after it had finished sun-drying. Following seed cleaning and winnowing, the weight of each seed per net plot was measured and reported in kg ha^{-1}.

3.5 Growth observations :

3.5.1 Plant stand :

This study carried out to know about the uniformity in the plant population under treatments. After final thinning, plant/ plot were also counted at harvest. The figures of plant stand were converted plant/ha for each treatment.

Table-5: Field operation calendar

S.No.	Operations	Date	Remark
1.	Application of FYM @10tha^{-1}	15.03.2023	As per treatments.
2.	Ploughing	18.03.2023	Ploughing by tractor drawn disc plough in respective plot.
3.	Application of Malathion dust	18.04.2023	5% Malathion dust was applied with last ploughing followed by planking.
4.	Layout	18.04.2023	Demarkation of plots.
5.	Seed sowing	19.04.2023	Seed was behind desi plough.
6.	Fertilizer application	19.04.2023	As per treatments.
7.	Ridge Making(demarcation of plot)	20.04.2023	Plots and block borders were demarked with the help of spade and rope.

8.	Thinning & Gap Filling	09.05.2023	Extra plants removed manually for maintaining plant population in pigeon pea and groundnut crops.
9.	Weeding and hoeing	12.05.2023	Weeding and hoeing was done by khurpi.
10.	Ridging and furrowing	14.05.2023	Furrows were formed in Between the crop rows with the help of spade in respective treatments.
11.	Harvesting	**a) Pigeonpea – 29 Jan 2024** **b) Groundnut- 19 Aug 2023**	Harvesting of crops.
12.	Threshing	**a) Pigeonpea- 1 Feb 2024** **b) Groundnut- 21 Aug 2023**	It was done crop-wise by beating the produce with wooden sticks by manual labour.

The height was measured in centimeters from the base of plant to tip of the main tallest stem after sowing of crop. The plant height was counted at 60,90,120,150 DAS and at maturity from three randomly selected plants of both crops in each plot and calculated average height of plants by sum of three plants height divided by three.

3.5.2 Plant collar diameter (cm):

Plant stem collar diameter was also measured with the help of digital caliper in cm. The plant stem collar diameter was counted at 60, 90, 120,150 DAS and at maturity from three randomly selected plants of both crops in each plot and the average was worked out to get plant stem collar diameter of the plant.

3.5.3 Number of primary branches per plant:

The number of primary branches per plant was counted from three randomly selected plants of pigeonpea in each plot and the average was worked out to get the primary branches per plant.

3.5.4 Number of secondary branches per plant

The number of branches emerging from primary branches were counted and the average of three plants was expressed as number of secondary branches per plant.

3.5.5 Number of leaves per plant:

Number of leaves were counted at 30,60,90,120 DAS and maturity from three randomly selected plants of both crops in each plot and the average was worked out to get number of leaves per plant.

Yields attributes

3.5.6 Number of pods per plant:

The number of pods per plant was counted at 30, 60, 90,120 DAS and at maturity from three randomly selected plants in each plots and the average was worked out to get number of pods per plant.

3.5.7 Number of seeds per pod

The seeds from 10 representative pods were separated, counted and the mean number of seeds per pod was calculated by dividing the number of seeds by the number of pods.

3.5.8 Seed weight per plant(g)

The seeds from the pods of three plants were separated by threshing and their mean weight was taken as seed weight per plant.

3.5.9 Test weight (g)

Seed samples from the produce of each net plot were taken and 100-seeds from these samples were counted and weighed.

3.5.10 Seed yield (kg ha^{-1})

Pods from each net plot were threshed, cleaned and the seed weight was recorded, from this, seed yield per hectare was computed.

3.5.11 Stalk yield (kg ha^{-1})

Plants from the net plot after threshing were dried and their weight was recorded. From this, the stalk yield per hectare was calculated.

3.5.12 Husk yield (kg ha^{-1})

The plants from the net plot area were threshed and partitioned into seed, stalk and husk. The husk weight per plot was weighed and yield per hectare was computed.

3.5.13 Harvest index (hi)

Harvest index was calculated by using the formula suggested by Donald (1962).

$$HI = \frac{Economic\ yield\ (kg\ ha^{-1})}{Biological\ yield (kg\ ha^{-1}} \times 100$$

Quality parameters of pigeonpea

3.5.14 Protein content (%)

Nitrogen content in the seeds of pigeonpea was estimated by **Kjeldahl's method (Jackson, 1967)**. The protein per cent in the seed was calculated by multiplying the nitrogen content by a factor of 6.25.

3.5.15 Protein yield (q ha^{-1})

Protein yield per hectare was worked on the basis of seed protein content and seed yield of pigeonpea.

Growth parameters of groundnut

The observations on growth characters were recorded by using three randomly selected and tagged plants from each plot and the average of the three plants was computed and recorded at 30, 60, 90 DAS and at harvest.

3.5.16 Plant height (cm)

The plant height was measured from the cotyledonary node upto the growing tip and the mean was worked out from three plants, which were selected at random in each treatment and expressed in centimetres.

3.5.17 Number of leaves per plant

Total number of leaves were estimated by counting the individual fully opened trifoliate leaf from top to bottom of the plant and the mean value of three plants selected at random in each treatment was expressed as number of leaves per plant.

3.5.18 Number of primary branches per plant

The number of branches emerging directly from main stem was counted and the average of three plants was expressed as number of primary branches per plant.

3.5.19 Dry matter production (g plant^{-1}) and its partitioning

Three plants were separated into leaf, stem and reproductive parts and dried in an oven at 70°C until a constant weight is obtained. Total dry matter was calculated by adding the dry weights of different plant parts and expressed as grams per plant.

3.5.20 Leaf area (dm^2 plant^{-1})

The leaf area was worked out by disc method on dry weight basis at 30, 60, 90 DAS and at harvest as per the procedure suggested by **Vivekanandan *et al.* (1972)**.

$$LA = \frac{W_a \times A}{W_d}$$

Where,

LA = Leaf area (dm^2 $plant^{-1}$)

W_a = Oven dry weight of all leaves (inclusive of 10 disc weight)

W_d = Oven dry weight of 10 discs (g)

A = Area of the 10 discs (dm^2)

3.5.21 Leaf area index

Leaf area index (LAI) was worked out by dividing the leaf area per plant by land area occupied by the plant **(Sestak *et al.*, 1971).**

$$LAI = \frac{A}{P}$$

Where,

A= Leaf area per plant (dm2)

P= Land area occupied by the plant (dm^2)

Observations on yield components and yield

The plants selected for growth studies were utilized for recording the observations on the following yield components.

3.5.22 Number of pods per plant

Fully developed pods were separated from three plants and were counted and the average was taken as the number of pods per plant.

3.5.23 Pod weight per plant

The pods obtained in each of the three tagged plants in each plot were dried in shade until kernel moisture content was around nine per cent. The pods from the three plants were weighed and the average weight of three plants was recorded as pod weight per plant in g.

3.5.24 100-Kernel weight

Hundred kernels were taken from the net plot produce of each plot and their weight was recorded in g.

3.5.25 Pod yield (kg ha^{-1})

Pods from the net plot area were cleaned and pod weight was recorded. Later the pod yield per net plot was computed on hectare basis and expressed in kg per ha.

3.5.26 Shelling percentage

From each net plot produce, 100 g of cleaned pods were weighed and the kernels obtained after shelling were also weighed. The shelling percentage was worked out by the following formula.

$$Shelling\ percentage = \frac{\text{Kernel weight}}{\text{Pod weight}} \times 100$$

3.5.27 Kernel yield (kg ha^{-1})

The kernel yield was worked out by the following formula.

$$Kernel\ yield\ (kg\ ha^{-1}) = \frac{Shelling\ percentage}{100} \times Pod\ yield (kg\ ha^{-1})$$

3.5.28 Haulm yield (kg ha^{-1})

Plants from the net plot area after threshing were dried and their weight was recorded as per plot basis and later converted as haulm yield (kg ha^{-1}).

3.5.29 Harvest index (HI)

Harvest index was estimated as per the formula suggested by Donald (1962).

$$\text{HI} = \frac{\text{Economic yield (kg ha}-1)}{\text{Biological yield}} \times 100$$

Quality parameters

3.5.30 Oil content (%)

The oil content was estimated on dry seed weight basis by using nuclear magnetic resonance (NMR) spectrometer by using standard reference sample.

3.5.31 Oil yield (kg ha^{-1})

Oil yield per ha was worked out on the basis of kernel oil content and kernel yield of groundnut.

$$\text{Oil yield (kg ha-1)} = \frac{\text{kernel oil content}}{100} \times \text{Kernel yield (kg ha-1)}$$

3.5.32 Land equivalent ratio (LER)

LER is the relative land area under sole crops that is required to produce the yield in intercropping. In the present experiment, the LER was estimated by following equation.

LER = seed yield of pigeonpea in intercropping + yield of groundnut in intercropping /seed yield of pigeonpea sole yield of groundnut sole

3.6 Soil moisture studies

3.6.1 Soil moisture estimation:

The sample of soil moisture were collected with the help of Screw auger from up to 100cm of depth in four successive layer viz., 0-25, 25-50, 50-75 and 75-100 cm from each treatment in one replication from before sowing 30,60,120 DAS and at the harvest time and the soil moisture was estimated gravimetrically. The soil sample was rapidly transferred to air tight aluminum boxes. And this sample was kept in an Electric oven for complete drying at a temperature of 105° C for 24 hours. The percentage of the soil moisture was calculated with the help of the following formula:

$$\textbf{Moisture(\%)} = \frac{\text{fresh weight of soil–oven dry weight of soil x 1}}{\text{oven dry weight of soil}}$$

Soil moisture percentage was determined on gravimetric basis and theconverted in terms of depth of moisture in cm (volumetric basis) using the following formula

Depth of moisture (cm) = M X B.D X D 100

Where,

M = moisture percentage of soil

B.D = bulk density (Mg/m3) D = soil depth (cm)

3.7 Effective rainfall (ER)

ER is that fraction of total rainfall available for consumptive use of the crop. ER was computed by soil moisture changes method. Water in the root zone is measured by gravimetric method before and after every rain. Increase in soil moisture and actual evapo-transpiration loss from rain starts till the soil sampled, is the amount of ER. After heavy rain, evapo- transpiration can be assumed to be at the potential rate during the short period from cessation of rain to sampling time. This can be taken as 0.8 times the evapo-transpiration value from USWB class A pan.

ER = (M2 – M1) + kc + PET

Where ,

ET = effective rainfall (mm)

M1 and M2 = Moisture content in root zone and after rain (mm)

Kc = crop coefficient

PET = potential evapo-transpiration (mm)

3.8 Economics

The total cost of cultivation, gross return, net return and benefit: cost ratio was computed for different treatment under the economics.

3.8.1 Cost of cultivation

Cost of cultivation (Rs/ ha) was calculated in two steps: firstly, the cultivation cost in intercropping system and secondly as the cultural operations cost under different treatments. Sum of these two were as the total cost of cultivation for different treatment.

3.8.2 Gross return:

The treatment wise calculated the gross return by multiplying the grain and fodder yield (q/ha) with the prevailing market prices of respectively produce. Sum of return from grain / seed and stover was recorded as gross return in Rs/ha for different treatments.

3.8.3 Net return

The relative figures of total cost of cultivation for each treatment were subtracted from gross income of the corresponding treatment and balanced was recorded as net return in Rs/ ha for different treatments.

3.8.4 Benefit : Cost ratio

Benefit: cost ratio was calculated through dividing the gross income value of each treatment by the total cost of cultivation for respective treatment.

3.9 Statistical analysis

Data recorded in respect of yield and yield attributes were analysed. The sources of variation along with their degree of freedom are given below:

Analysis of Variance (ANOVA):

Since, the experiment was conducted in Randomised Block design with 3 replication and 12 treatments. The analysis of variance of the data was worked out on the basis of the Randomized block design.

Table 6: Analysis of Variance

Source of variation	**d.f.**	**TSS**	**MSS**	**Variance ratio**	**"F''value 1%**	**"F''value 5%**
Replication	2					
Factor A	3					
Factor B	2					
Interaction A × B	6					
Error	23					
Total	35					

Standard errors and critical difference

The order to compare the different level of a particular factor and different combination, critical difference was calculated with the help of appropriate formula as given below.

S.E. (diff) = $\sqrt{2}VE/r$

Where,

VE = sample standard error r = number or sample

C.D. = S.E.(diff.) x t 5% for error degrees of freedom

CHAPTER-IV

EXPERIMENTAL FINDINGS

The experiment entitled **"Effect of cropping system and nutrient management on production and water use efficiency of intercrops"** was carried out during the *Zaid* season of 2022-23 at Soil Conservation and Water Management Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur.

This experiment was conducted in Factorial Randomized Block Design with three replications comprising four levels of cropping system (4) viz; **C_1-**Pigeonpea (Sole)**,** **C_2-**Groundnut (Sole), **C_3**-Pigeonpea + Groundnut (1:1), **C_4-**Pigeonpea + Groundnut (1:2) and three level of nutrient management viz; **F_1:** 100% RDF, **F_2:** 100% RDF + Borax 5kg/ha, **F_3:** 100% RDF + Borax 5kg/ha +FYM 10 t/ha. This chapter describes the observations recorded in the experimental field. Data were analyzed using appropriate statistical methods and the results are presented in the following paragraphs. Where appropriate, the intrinsic effects of treatment have also been illustrated with appropriate figures.

4.1 Plant population

4.1.1 Pigeonpea

The stand count of pigeonpea was recorded for the initial plant stand and at crop maturity to determine the final stand. Statistical analysis was conducted on the data for both stages (refer to Appendix I & II, and the findings are presented in **Table 4.1** and visually represented in **Figure 4.1.**

Effect of cropping systems:

The data given in **Table 4.1** clearly demonstrate that different cropping systems had non-significant impact on the plant stand of pigeonpea.

The initial plant stand, the average highest count was observed in the pigeonpea C_1 sole treatment (110.48 '000 plants), followed by C_3 pigeonpea + groundnut (1:1) at (110.28 '000 plants). Conversely, the lowest count (73.25 '000 plants) was recorded in the C_4 pigeonpea + groundnut (1:2) treatment. Similarly, for the final plant stand, the highest count was found in the C_1 pigeonpea sole treatment (110.28 '000 plants), while the lowest count was observed in the C_4 pigeonpea + chickpea (1:2) treatment (73.04 '000 plants).

Effect of nutrient management:

The results presented in **Table 4.1** indicate that increasing levels of nutrient management did non-significant effect on the initial and final plant stand of pigeonpea. The highest initial stand value (98.04 plants m^{-2}) was observed in F_3, while the lowest (97.96 '000 /ha plants) was recorded in F_1. Likewise, the highest final plant stand (97.83 '000/ha plants) was observed in F_3, while the lowest was found in the F_1 treatment (97.75 '000/ha plants) throughout the experiment.

4.1.2. Groundnut

Statistical analysis was performed on the data regarding the initial and final plant stand of groundnut (refer to Appendix III and IV), and the findings have been summarized in **Table 4.1** and visually represented in **Figure 4.1.**

Effect of cropping systems

The results clearly indicate significant variations in the initial and final plant stand of groundnut. The highest initial plant stand value was observed in the groundnut sole C_2 treatment (163.03 '000/ha plants), while the lowest (99.26 '000/ha plants) was recorded in the C_3 Pigeonpea + groundnut (1:1) treatment. Similarly, for the final plant stand, the highest count was found in the C_2 groundnut sole treatment (162.80 '000/ha plants), and the lowest was observed in the C_3 Pigeonpea + groundnut (1:1) treatment (98.90 '000/ha plants).

Effect of nutrient management:

Upon examination of the data, it is evident that different levels of nutrient management did not exhibit significant variations, except for the initial and final plant stand stages. However, F_3 displayed numerically higher values of initial and final plant stand (127.04 '000 /ha plants) and (126.79 '000 /ha plants), while F_1 exhibited the lowest values of (124.83 plants m^{-2}) and (124.50 '000/ha plants).

Table 4.1: Effect of cropping system and nutrient management on Plant population of pigeonpea and groundnut under different treatments:

Treatments	Plant Population in Plant ('000/ha)			
	Pigeonpea		Groundnut	
	Initial	Final	Initial	Final
Cropping System				
C_1: Pigeonpea (Sole)	110.48	110.28	-	-
C_2: Groundnut (Sole)	-	-	163.03	162.80
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	110.27	110.05	99.26	98.90
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	73.25	73.04	115.50	115.29
SE (diff.)	**0.10**	**0.04**	**0.26**	**0.22**
CD (P=0.05)	**0.22**	**0.09**	**0.55**	**0.46**
Nutrient Management				
F_1: 100 % RDF	97.96	97.75	124.83	124.50
F_2: 100 % RDF + Borax 5 kg/ha	98.00	97.79	125.91	125.70
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	98.04	97.83	127.04	126.79
SE (diff.)	**0.10**	**0.04**	**0.26**	**0.22**
CD (P=0.05)	**N.S.**	**N.S.**	**0.55**	**0.46**

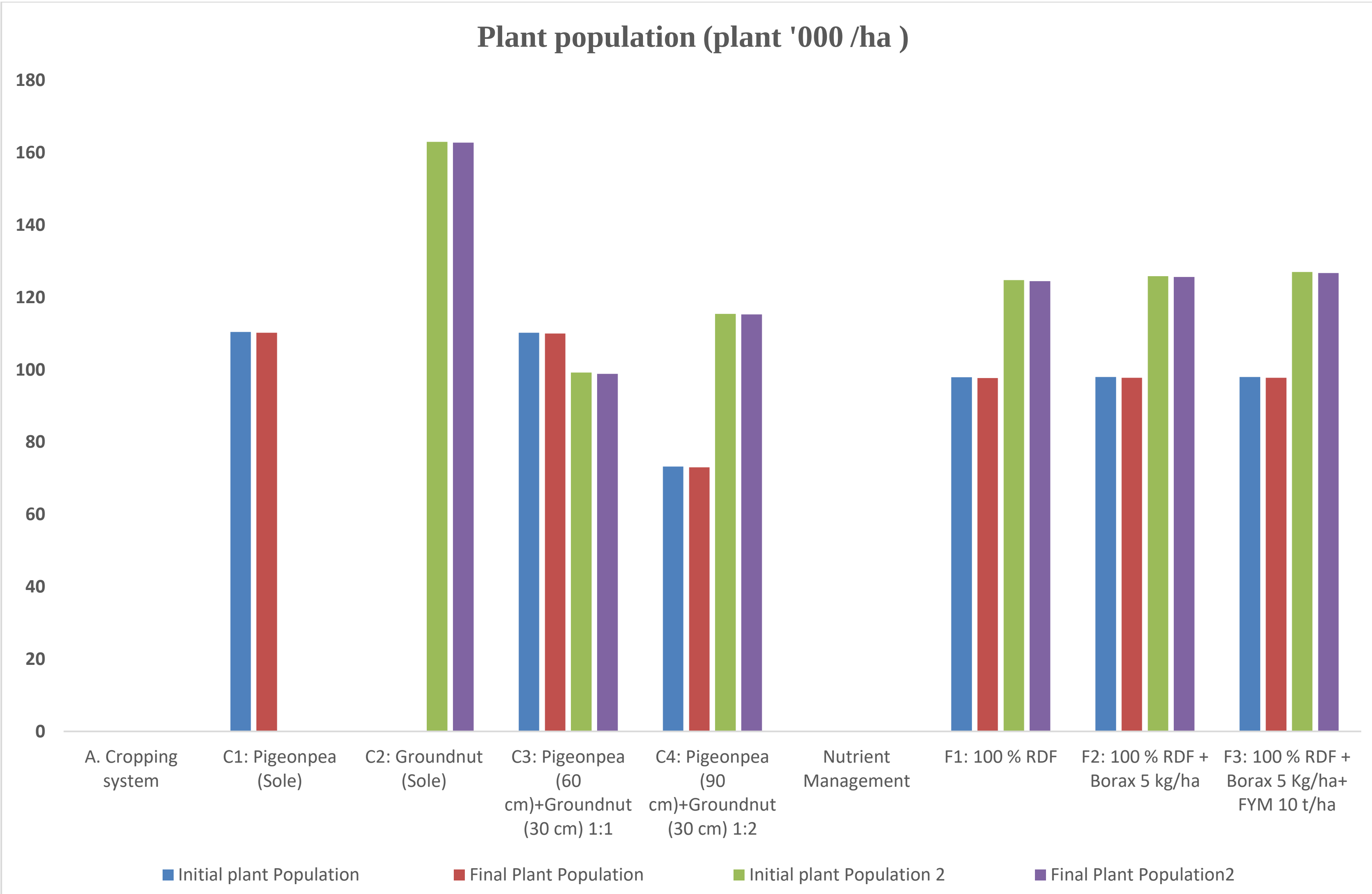

Fig 4.1 - Effect of cropping system and nutrient management on Plant population of pigeonpea and groundnut under different treatments.

Pigeonpea

4.2 Plant height (cm)

Statistical analysis was conducted on the recorded data of plant height (refer to Appendix V, VI, VII, VIII and IX), and the findings are presented in **Table 4.2** and illustrated in **Figure 4.2.**

4.2.1 Effect of cropping systems

The impact of different cropping systems on the plant height of pigeonpea was found to be significant, as indicated in Table 4.2. The plant height of the pigeonpea crop was measured at different stages 60 days after sowing (DAS), 90 DAS, 120 DAS,150 DAS and when the plants were fully grown. At 60 DAS, the tallest plants were found in treatment C_1 (86.43 cm), while the shortest plants were in treatment C_4 (65.69 cm). In the cropping system, the tallest and shortest plants at 90 DAS were observed in treatment C_1 (126.39 cm) and C_4 (106.03 cm) respectively. At 120 DAS, the tallest and shortest plants were in treatment C_1 (160.67 cm) and C_4 (142.64 cm) respectively. At 150 DAS, the tallest and shortest plants were in treatment C_1 (233.76 cm) and C_4 (201.01 cm) respectively. The final measurements were taken when the plants reached maturity, and treatment C_1 had the tallest plants (316.56 cm) while treatment C_4 had the shortest plants (284.91 cm).

4.2.2 Effect of nutrient management

The levels of nutrient management had the significant effect on pigeonpea observed in 60 DAS, the tallest plant height was observed in F_3 (79.82 cm), and the shortest plant height was found in F_1 (72.57 cm) while the significant effect on increasing the plant height of pigeonpea compared to F_1. At 90 DAS, the highest and lowest plant heights were recorded in F_3 (119.80 cm) and F_1 (112.85 cm) respectively. Similarly, at 120 DAS, the highest and lowest plant heights were observed in F_3 (153.88 cm) and F_1 (147.56 cm) respectively. At 150 DAS, the highest and lowest plant heights were recorded in F_3 (221.31 cm) and F_1 (210.28 cm) respectively. Finally, at maturity, the tallest and shortest plant heights were measured in F_3 (306.19 cm) and F_1 (295.64 cm) respectively.

Table 4.2: Effect of cropping system and nutrient management on Plant height of pigeonpea under different treatments:

Treatments	Plant height (cm)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Cropping System					
C_1: Pigeonpea (Sole)	86.43	126.39	160.67	233.76	316.56
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	76.54	116.55	148.63	212.63	301.08
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	65.69	106.03	142.64	201.01	284.91
SE (diff.)	**0.26**	**0.28**	**0.29**	**0.40**	**0.33**
CD (P=0.05)	**0.55**	**0.60**	**0.61**	**0.85**	**0.70**
Nutrient Management					
F_1: 100 % RDF	72.57	112.85	147.56	210.28	295.64
F_2: 100 % RDF + Borax 5 kg/ha	76.26	116.32	150.50	215.81	300.73
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	79.82	119.80	153.88	221.31	306.19
SE (diff.)	**0.26**	**0.28**	**0.29**	**0.40**	**0.33**
CD (P=0.05)	**0.55**	**0.60**	**0.61**	**0.85**	**0.70**

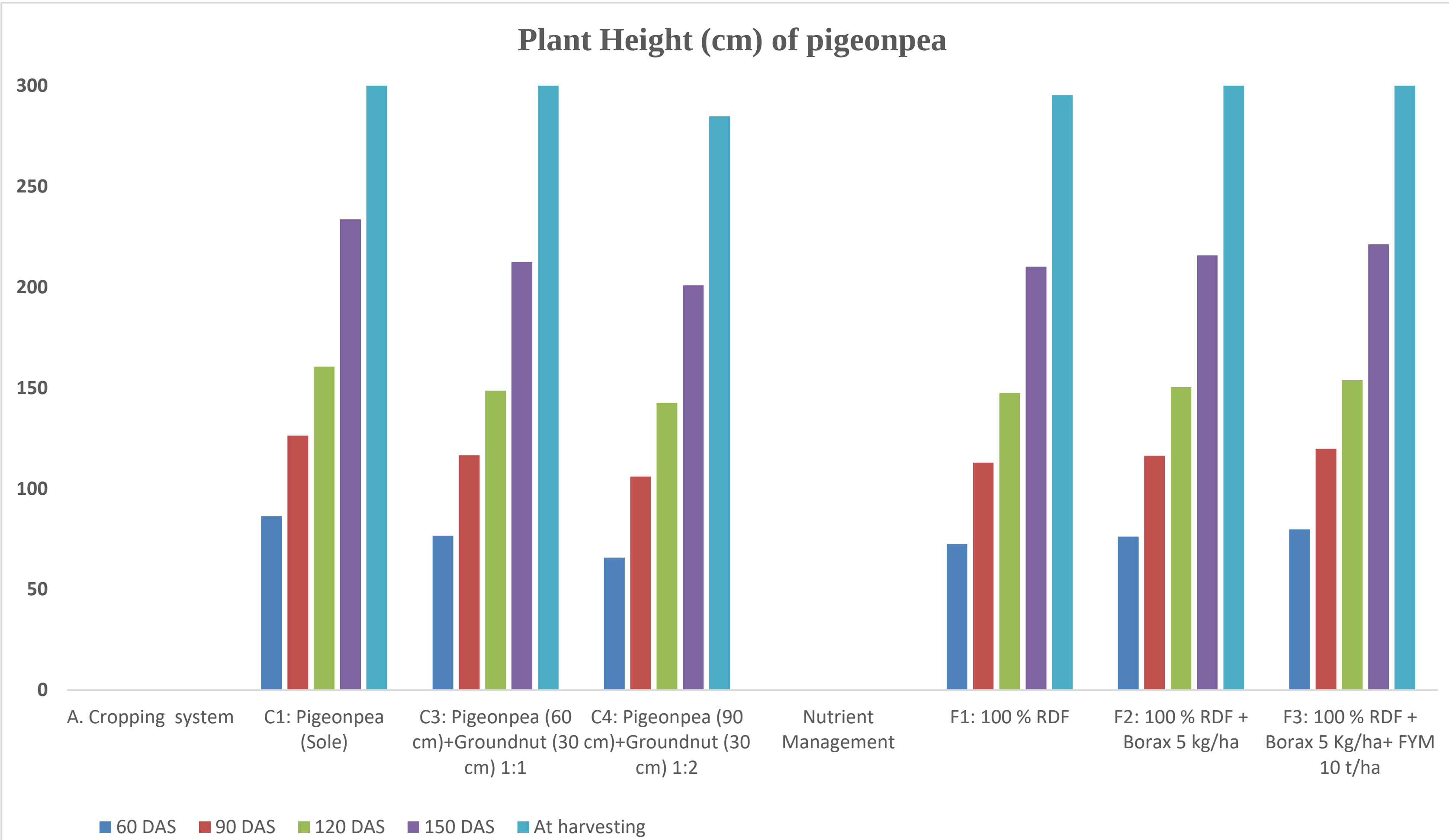

Fig 4.2 - Effect of cropping system and nutrient management on Plant height of pigeonpea under different treatments.

4.3 Diameter of stem (stem girth) (cm)

Statistical analysis was conducted on the recorded data of diameter of stem (stem girth) (refer to Appendix X, XI, XII, XIII and XIV), and the findings are presented in **Table 4.3** and illustrated in **Figure 4.3.**

4.3.1 Effect of cropping systems

The impact of different cropping systems on the diameter of stem(stem girth) of pigeonpea was found to be significant as indicated in Table 4.3. The diameter of stem (stem girth) of the pigeon pea crop was measured at different stages 60 days after sowing (DAS), 90 DAS, 120 DAS,150 DAS and when the plants were fully grown. At 60 DAS, the maximum diameter were found in treatment C_4 (1.47 cm), while the minimum diameter were in treatment C_1 (1.15 cm). In the cropping system, the maximum and minimum diameter at 90 DAS were observed in treatment C_4 (2.31 cm) and C_1 (1.83 cm) respectively. At 120 DAS, the maximum and minimum diameter were in treatment C_4 (3.37 cm) and C_1 (2.90 cm) respectively. At 150 DAS, the maximum diameter and minimum diameter were in treatment C_1 (4.91 cm) and C_4 (4.39 cm) respectively. The final measurements were taken when the plants reached maturity, and treatment C_4 had the maximum diameter (6.11 cm) while treatment C_1 had the minimum diameter (5.52 cm).

4.3.2 Effect of nutrient management

The levels of nutrient management had the significant effect on pigeonpea observed in 60 DAS, the maximum diameter was observed in F_3 (1.37 cm), and the minimum diameter was found in F_1 (1.25 cm) while the significant effect on increasing the diameter of stem (stem girth) of pigeonpea compared to F_1. At 90 DAS, the highest and lowest diameter were recorded in F_3 (2.14 cm) and F_1 (1.99

cm) respectively. Similarly, at 120 DAS, the highest and lowest diameter were observed in F_3 (3.27 cm) and F_1 (3.02 cm) respectively. At 150 DAS, the maximum and minimum diameter were recorded in F_3 (4.89 cm) and F_1 (4.53 cm) respectively. Finally, at maturity, the maximum and minimum diameter were measured in F_3 (6.04 cm) and F_1 (5.65 cm) respectively.

Table 4.3: Effect of cropping system and nutrient management on diameter of stem (stem girth) of pigeonpea under different treatments:

Treatments	Diameter of stem (Stem Girth) (cm)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvesting
Cropping System					
C_1: Pigeonpea (Sole)	1.15	1.83	2.90	4.39	5.52
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	1.31	2.08	3.17	4.73	5.84
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	1.47	2.31	3.37	4.91	6.11
SE (diff.)	0.04	0.08	0.09	0.14	0.15
CD (P=0.05)	0.09	0.16	0.19	0.29	0.31
Nutrient management					
F_1: 100 % RDF	1.25	1.99	3.02	4.53	5.65
F_2: 100 % RDF + Borax 5 kg/ha	1.31	2.08	3.15	4.62	5.78
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	1.37	2.14	3.27	4.89	6.04
SE (diff.)	0.04	0.08	0.09	0.14	0.15
CD (P=0.05)	0.09	0.16	0.19	0.29	0.31

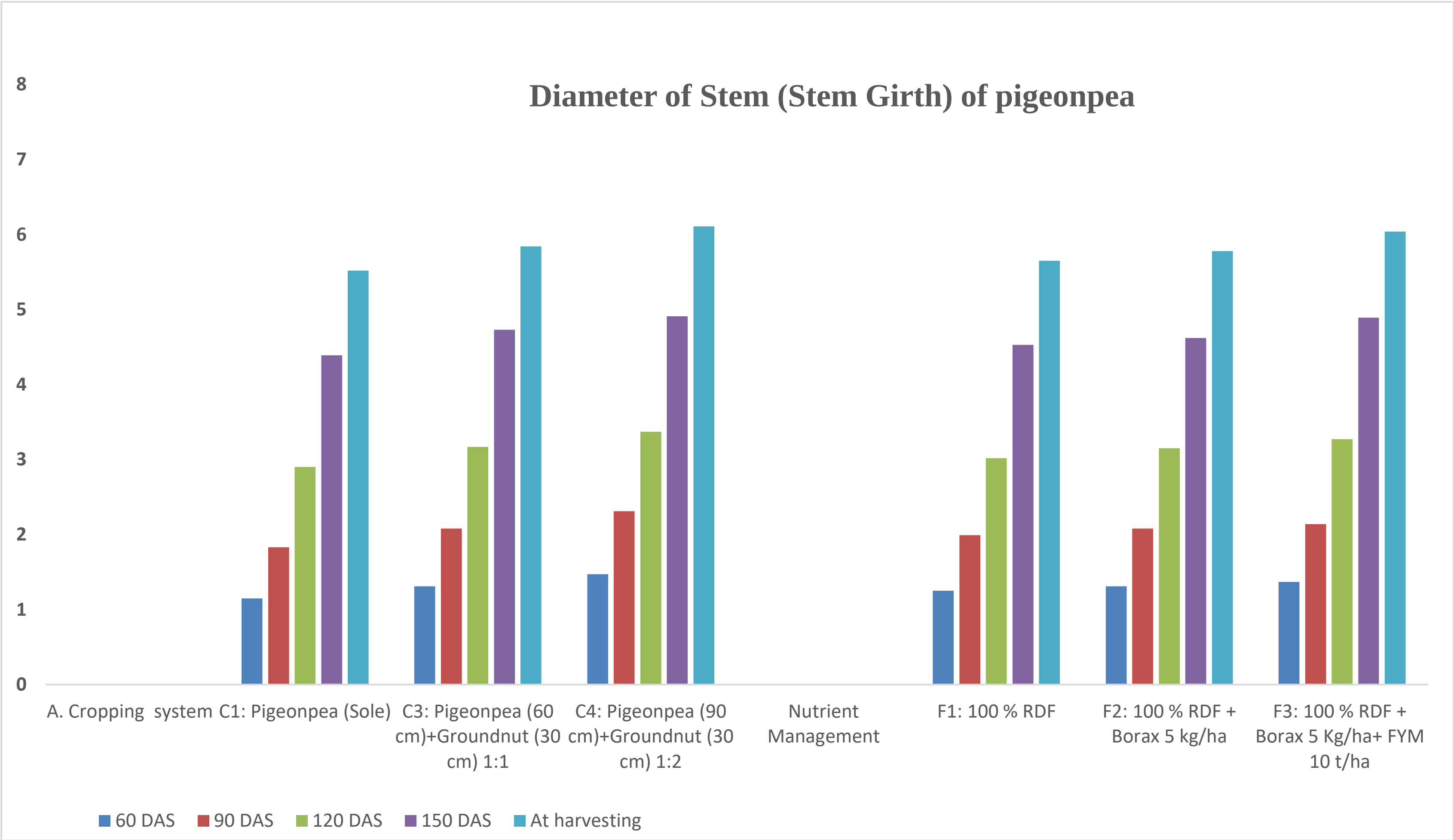

Fig 4.3 - Effect of cropping system and nutrient management on diameter of stem (stem girth) of pigeonpea under different treatments.

4.4 Number of branches – primary, secondary, and tertiary

The statistical analysis of the primary, secondary and tertiary branches was performed (refer to Appendix XV, XVI and XVII), and the results are presented in **Table 4.4.** These results are visually depicted in **Figure 4.4.**

Effect of cropping systems

A thorough examination of the data clearly demonstrates that different cropping systems had a significant effect on the primary branches (4.38), secondary branches (18.65) tertiary branches (36.26) highest in pigeonpea + groundnut (1:2), with the lowest values observed primary branches (3.64), secondary branches (15.49) and tertiary branches (32.00) under C_1 pigeonpea sole cropping system.

Effect of nutrient management:

The data presented in **Table 4.4** further reveal that the application of different levels of nutrient management significantly influenced the primary, secondary and tertiary branches. Each successive dose of nutrient management application resulted in a significant enhancement of these parameters, with the highest values observed in F_3 and the lowest F_1 .

Table 4.4: Effect of cropping system and nutrient management on Number of branches – primary, secondary, and tertiary of pigeonpea under different treatments:

Treatments	No. of branches/plant		
	Primary	Secondary	Tertiary
Cropping System			
C_1: Pigeonpea (Sole)	3.64	15.49	32.00
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	4.05	16.77	33.59
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	4.38	18.65	36.26
SE (diff.)	**0.09**	**0.40**	**0.68**
CD (P=0.05)	**0.19**	**0.85**	**1.44**
Nutrient management			
F_1: 100 % RDF	3.88	16.36	33.05
F_2: 100 % RDF + Borax 5 kg/ha	4.03	17.02	33.86
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	4.16	17.52	34.94
SE (diff.)	**0.09**	**0.40**	**0.68**
CD (P=0.05)	**0.19**	**0.85**	**1.44**

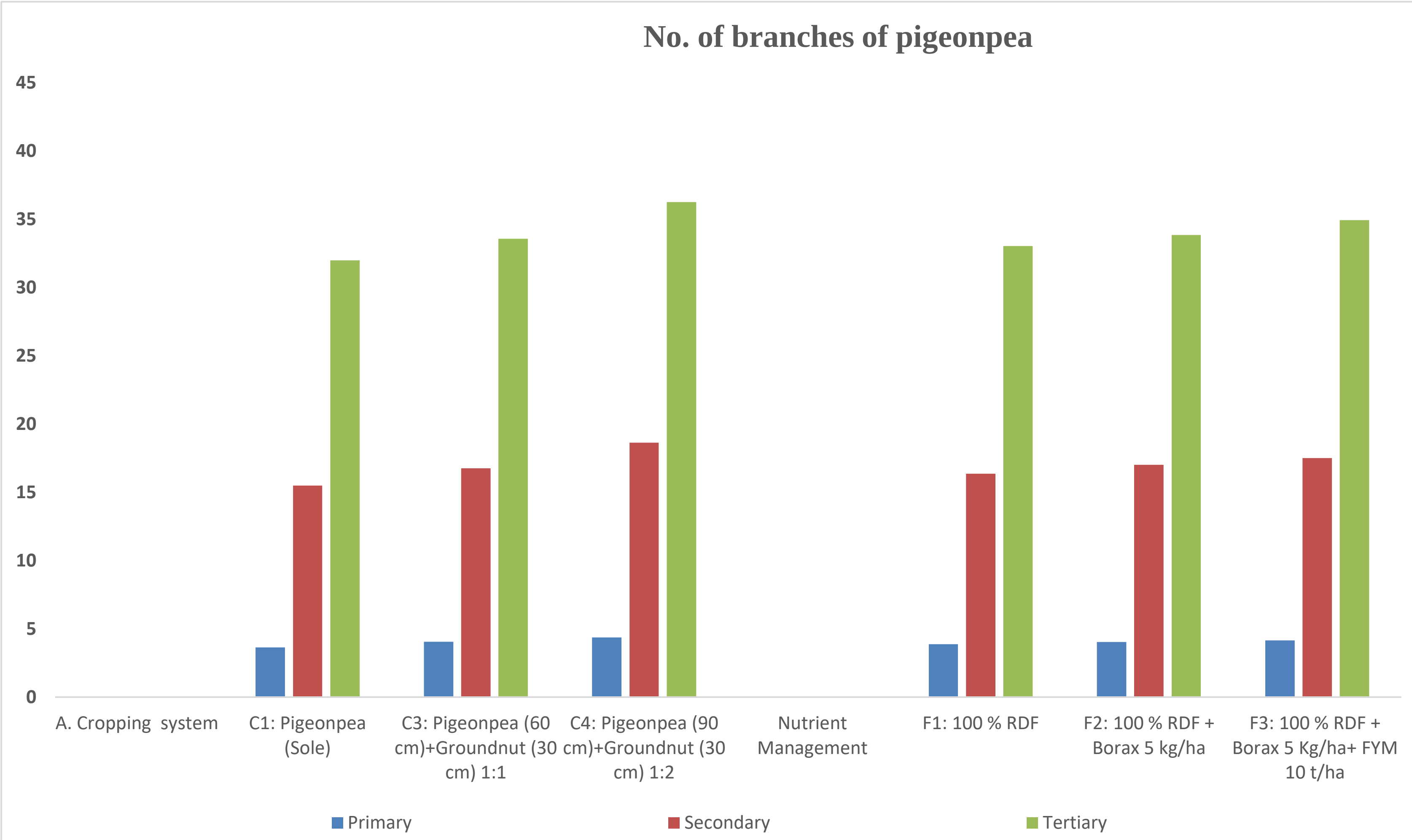

Fig 4.4 - Effect of cropping system and nutrient management on Number of branches – primary, secondary, and tertiary of pigeonpea under different treatments.

4.5 Number of leaves

Statistical analysis was conducted on the recorded data of number of leaves (refer to Appendix XVIII, XIX, XX, XI and XXII), and the findings are presented in **Table 4.5** and illustrated in **Figure 4.5.**

Effect of cropping systems

The impact of different cropping systems on the number of leaves of pigeonpea was found to be significant effect, as indicated in Table 4.2. The number of leaves of the pigeonpea crop was measured at different stages 60 days after sowing (DAS), 90 DAS, 120 DAS,150 DAS and when the plants were fully grown. At 60 DAS, the maximum no. of leaves plants were found in treatment C_4 (31.91), while the minimum no. of leaves were in treatment C_1 (29.59). In the cropping system, the maximum and minimum no. of leaves at 90 DAS were observed in treatment C_4 (54.11) and C_1 (48.99) respectively. At 120 DAS, the maximum and minimum no. of leaves were in treatment C_4 (72.33) and C_1 (66.31) respectively. At 150 DAS, the maximum and minimum no. of leaves plants were in treatment C_4 (87.41) and C_1 (81.89) respectively. The final measurements were taken when the plants reached maturity, and treatment C_4 had the maximum no. of leaves (52.53) while treatment C_1 had the minimum no. of leaves (47.53).

Effect of nutrient management

The levels of nutrient management had the significant effect on pigeonpea observed in 60 DAS, the maximum no. of leaves was observed in F_3 (31.31) and the minimum no. of leaves was found in F_1 (30.62) . At 90 DAS, the highest and lowest number of leaves were recorded in F_3 (52.75) and F_1 (50.79) respectively. Similarly, at 120 DAS, the highest and lowest number of leaves were observed in F_3 (71.24) and F_1 (68.41) respectively. At 150 DAS, the maximum and minimum number of leaves were recorded in F_3 (86.24) and F_1 (83.64) respectively. Finally, at maturity, the maximum and minimum no. of leaves were measured in F_3 (51.28) and F_1 (48.89) respectively.

Table 4.5: Effect of cropping system and nutrient management on number of leaves of pigeonpea under different treatments:

Treatments	60 DAS	90 DAS	120 DAS	150 DAS	At harvesting
Cropping System					
C_1: Pigeonpea (Sole)	29.59	48.99	66.31	81.89	47.53
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	31.39	51.89	70.40	85.11	50.29
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	31.91	54.11	72.33	87.41	52.53
SE (diff.)	**0.67**	**0.70**	**1.06**	**0.97**	**0.78**
CD (P=0.05)	**1.41**	**1.49**	**2.24**	**2.06**	**1.65**
Nutrient management					
F_1: 100 % RDF	30.62	50.79	68.41	83.64	48.89
F_2: 100 % RDF + Borax 5 kg/ha	30.95	51.45	69.38	84.53	50.18
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	31.32	52.75	71.24	86.24	51.28
SE (diff.)	**0.67**	**0.70**	**1.06**	**0.97**	**0.78**
CD (P=0.05)	**N.S.**	**1.49**	**2.24**	**2.06**	**1.65**

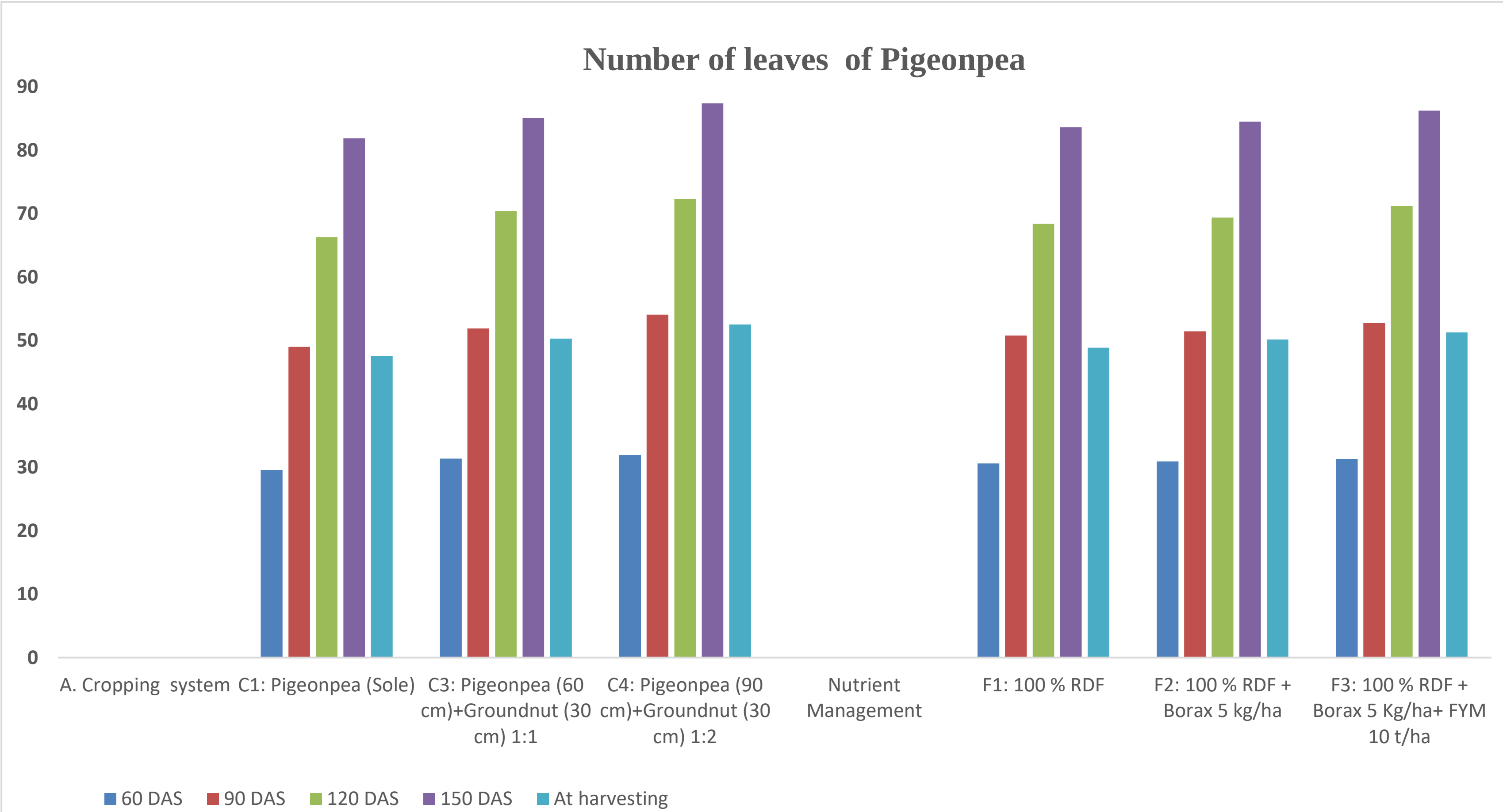

Fig 4.5 - Effect of cropping system and nutrient management on Number of leaves of pigeonpea under different treatments.

4.6 Litter fall of pigeonpea (q/ha)

Effect of cropping systems:

The data presented in **Table 4.6** and depicted in **Fig 4.6** demonstrate that Litter fall of pigeonpea (q/ha) varied due to different cropping systems. The C_1 Pigeonpea Sole treatment exhibited the highest litter fall (18.64 q/ha) , followed by C_3 Pigeonpea + groundnut (1:1). The treatment with C_4 Pigeonpea + groundnut (1:2) recorded the lowest litter fall of 13.04 q/ha.

Effect of nutrient management:

The data suggest that increasing the nutrient management factors improved the nitrogen fixation of the treatment. The application of F_3 (100% RDF + Borax (5kg/ha) + FYM (10 t/ha) enhanced the nitrogen fixation capacity compared to F_1 100 % RDF, and therewas a further considerable increase.

Table 4.6 : Effect of cropping system and nutrient management on litter fall of pigeonpea (q/ha) under different treatments

Treatments	Litter fall of pigeonpea (q/ha)
Cropping System	
C_1: Pigeonpea (Sole)	18.64
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	14.91
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	13.04
SE (diff.)	**0.37**
CD (P=0.05)	**0.78**
Nutrient management	
F_1: 100 % RDF	14.96
F_2: 100 % RDF + Borax 5 kg/ha	15.39
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	16.25
SE (diff.)	**0.37**
CD (P=0.05)	**0.78**

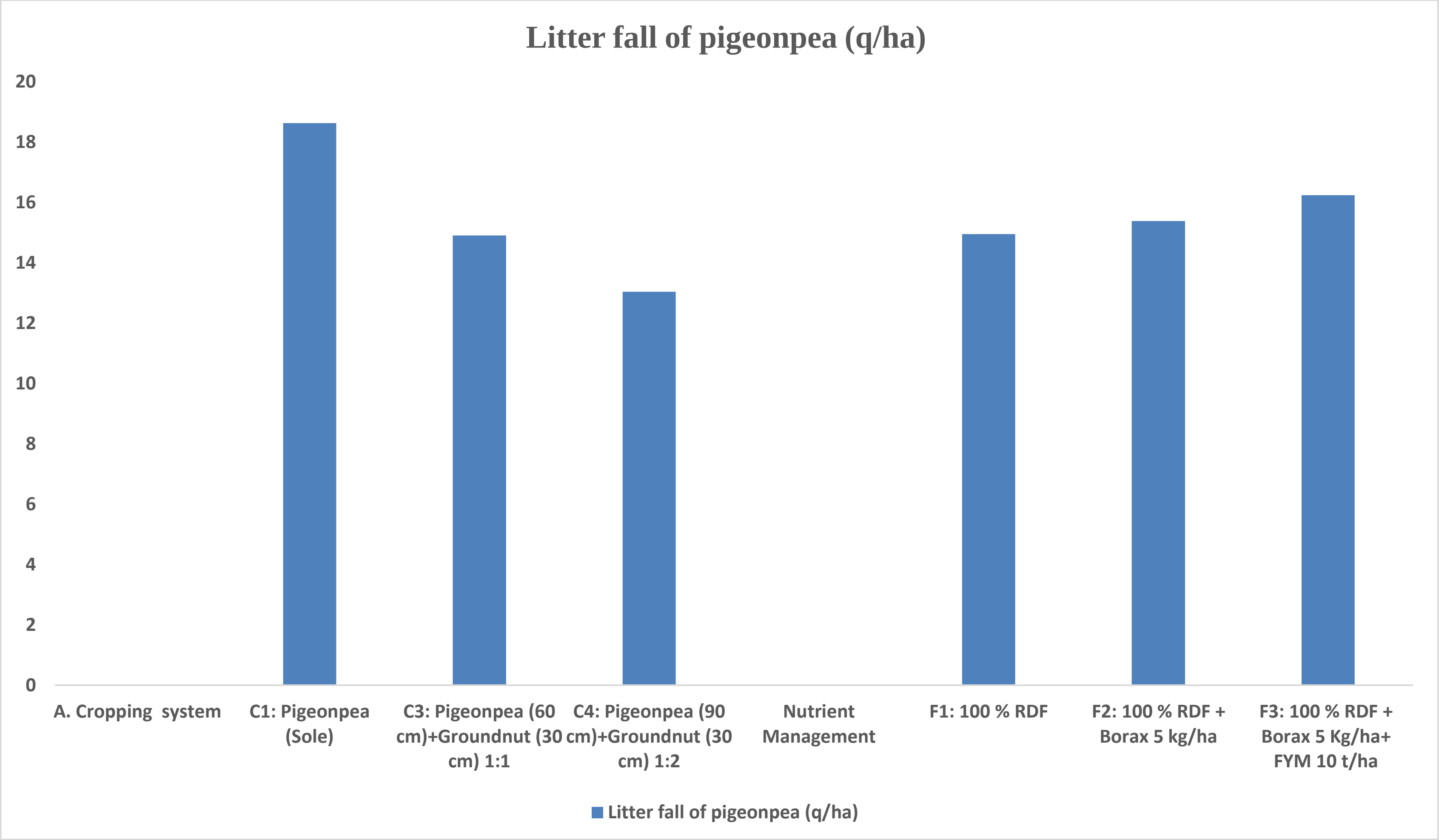

Fig 4.6 - Effect of cropping system and nutrient management on litter fall of pigeonpea under different treatments.

4.7 Number of pods plant^{-1}, number of seeds pod^{-1}, seed weight(g) plant^{-1}

4.7.1 Number of pods plant^{-1}

The statistical analysis of the data on the number of pods plant^{-1} under different treatments of pigeonpea was performed (refer to Appendix XXIII) were analyzed, and the results are summarized in **Table 4.7.** Additionally, these results are visually represented in **Figure 4.7.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The highest number of pods per plant (81.15) was observed in the C_4 pigeonpea + groundnut (1:2) treatment, while the lowest value (73.98) was observed in the C_1 pigeonpea sole treatment.

Effect of nutrient management:

The results presented in **Table 4.7** demonstrate significant differences in the number of pods per plant and number of seeds per pod of pigeonpea due to different levels of nutrient management. Statistically superior values (79.86 pods per plant) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (75.51 pods per plant) were observed under the F_1 level.

4.7.2 Number of seeds pod^{-1}

The statistical analysis of the data on the number of seed pod^{-1} under different treatments of pigeonpea was performed (refer to Appendix XXIV) were analyzed, and the results are summarized in **Table 4.7.** Additionally, these results are visually represented in **Figure 4.7.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The highest number of seeds per pod (3.62) was observed in the C_4 pigeonpea + groundnut (1:2) treatment, while the lowest value (3.13) was recorded in the C_1 pigeonpea sole treatment.

Effect of nutrient management:

The results presented in **Table 4.7** demonstrate significant differences in the number of seeds per pod of pigeonpea due to different levels of nutrient management application. Statistically superior values(3.49 seeds per pod) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (3.29 seeds per pod) were observed under the F_1 level.

4.7.3 Seed weight(g) plant^{-1}

The statistical analysis of the data on the seed weight(g) plant^{-1} under different treatments of pigeonpea was performed (refer to Appendix XXV) were analyzed, and the results are summarized in **Table 4.7.** Additionally, these results are visually represented in **Figure 4.7.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum seeds weight per plant (24.12) was observed in the C_4 pigeonpea + groundnut (1:2) treatment, while the lowest value (18.56) was recorded in the C_1 pigeonpea sole treatment.

Effect of nutrient management:

The results presented in **Table 4.7** demonstrate significant differences in the seeds weight per plant of pigeonpea due to different levels of nutrient management application. Statistically superior values(22.31 seed weight per plant) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (20.39 seed weight per plant) were observed under the F_1 level.

Table 4.7: Effect of cropping system and nutrient management on Number of pods plant^{-1}, Number of seeds pod^{-1}, Seed weight(g) plant^{-1} of pigeonpea under different treatments:

Treatments	No. of pods/ plant	No. of Seeds/ pod	Seed Wt./ plant (gm)
Cropping System			
C_1: Pigeonpea (Sole)	73.98	3.13	18.56
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	77.41	3.43	21.46
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	81.15	3.62	24.12
SE (diff.)	**1.60**	**0.07**	**0.49**
CD (P=0.05)	**3.40**	**0.16**	**1.04**
Nutrient management			
F_1: 100 % RDF	75.51	3.29	20.39
F_2: 100 % RDF + Borax 5 kg/ha	77.18	3.40	21.44
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	79.86	3.49	22.31
SE (diff.)	**1.60**	**0.07**	**0.49**
CD (P=0.05)	**3.40**	**0.16**	**1.04**

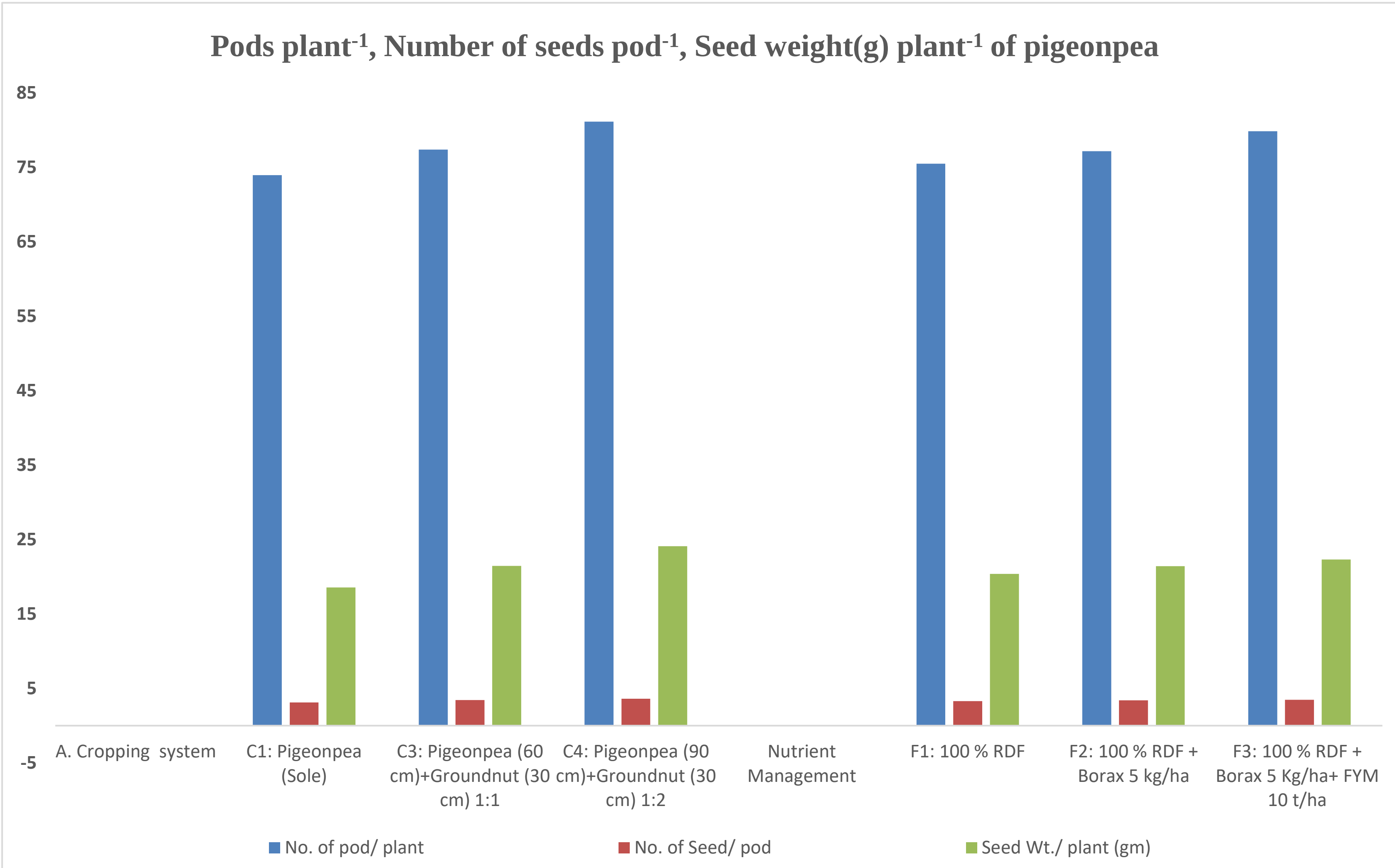

Fig 4.7 - Effect of cropping system and nutrient management on Number of pods plant^{-1}, Number of seeds pod^{-1}, Seed weight(g) plant^{-1} of pigeonpea under different treatments.

4.8 Seed yield (q/ha), straw yield (q/ha), stick yield (q/ha) and biological yield (q/ha)

4.8.1 Seed yield (q/ha)

The statistical analysis of the data on the seed yield under different treatments of pigeonpea was performed (refer to Appendix XXVI) were analyzed, and the results are summarized in **Table 4.8.** Additionally, these results are visually represented in **Figure 4.8.**

Effect of cropping systems

The analysis reveals those significant variations among different cropping systems in terms of their effects on seed yield of pigeonpea. The maximum seed yield (15.77 q/ha) was weighted in the C_{1-} treatment pigeonpea sole, while the lowest yield (11.37 q/ha) was recorded in the sole C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management:

The results presented in **Table 4.8** clearly indicated that significant differences in the seed yield of pigeonpea due to different combination of nutrient management. Statistically superior values of pigeonpea seed yield (13.97 q/ha) were obtained in F_3 treatment , followed by the F_2 (100% RDF+ Borax 5 kg/ha). The lowest value of seed yield (12.83 q/ha) were observed under the F_1 application of 100% RDF through chemical fertilizer.

4.8.2 Straw yield (q/ha)

The statistical analysis of the data on the straw yield under different treatments of pigeonpea was performed (refer to Appendix XXVII) were analyzed, and the results are summarized in **Table 4.8.** Additionally, these results are visually represented in **Figure 4.8.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum straw yield (16.24 q/ha) was observed in the C_1 pigeonpea sole, while the lowest value (12.90 q/ha) was recorded in the sole C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management :

The results presented in **Table 4.8** demonstrate significant differences in the straw yield (q/ha) of pigeonpea due to different levels of nutrient management application. Statistically superior values (15.08 q/ha) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (14.03 q/ha) were observed under the F_1 level.

4.8.3 Stick yield (q/ha)

The statistical analysis of the data on the stick yield under different treatments of pigeonpea was performed (refer to Appendix XXVIII) were analyzed, and the results are summarized in **Table 4.8.** Additionally, these results are visually represented in **Figure 4.8.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum stick yield (44.10 q/ha) was observed in the C_1 pigeonpea sole, while the lowest value (

42.26 q/ha) was recorded in the sole C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management :

The results presented in **Table 4.8** demonstrate significant differences in the stick yield (q/ha) of pigeonpea due to different levels of nutrient management application. Statistically superior values (43.61 q/ha) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (42.33 q/ha) were observed under the F_1 level.

4.8.4 Biological yield (q/ha)

The statistical analysis of the data on the biological yield under different treatments of pigeonpea was performed (refer to Appendix XXIX) were analyzed, and the results are summarized in **Table 4.8.** Additionally, these results are visually represented in **Figure 4.8.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum biological yield (76.02 q/ha) was observed in the C_1 pigeonpea sole, while the lowest value (68.96 q/ha) was recorded in the sole C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management:

The results presented in **Table 4.8** demonstrate significant differences in the biological yield (q/ha) of pigeonpea due to different levels of nutrient management application. Statistically superior values (72.71 q/ha) were obtained in F_3 treatment , followed by the F_2 (100 % RDF+ Borax 5 kg/ha) . The lowest values (69.92 q/ha) were observed under the F_1 level.

Table 4.8: Effect of cropping system and nutrient management on Seed yield (q/ha), Straw Yield (q/ha), Stick Yield (q/ha), Biological yield (q/ha) of pigeonpea under different treatments:

Treatments	Seed yield (q/ ha)	Straw Yield (q/ha)	Stick Yield (q/ ha)	Biological yield (q/ha)
A. Cropping system				
C_1: Pigeonpea (Sole)	15.77	16.24	44.10	76.02
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	12.73	14.49	43.05	71.07
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	11.37	12.90	42.26	68.96
SE (diff.)	**0.32**	**0.34**	**0.49**	**1.42**
CD (P=0.05)	**0.67**	**0.72**	**1.03**	**3.01**
B. Nutrient management				
F_1: 100 % RDF	12.83	14.03	42.33	69.92
F_2: 100 % RDF + Borax 5 kg/ha	13.07	14.52	43.47	72.42
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	13.97	15.08	43.61	73.71
SE (diff.)	**0.32**	**0.34**	**0.49**	**1.42**
CD (P=0.05)	**0.67**	**0.72**	**1.03**	**3.01**

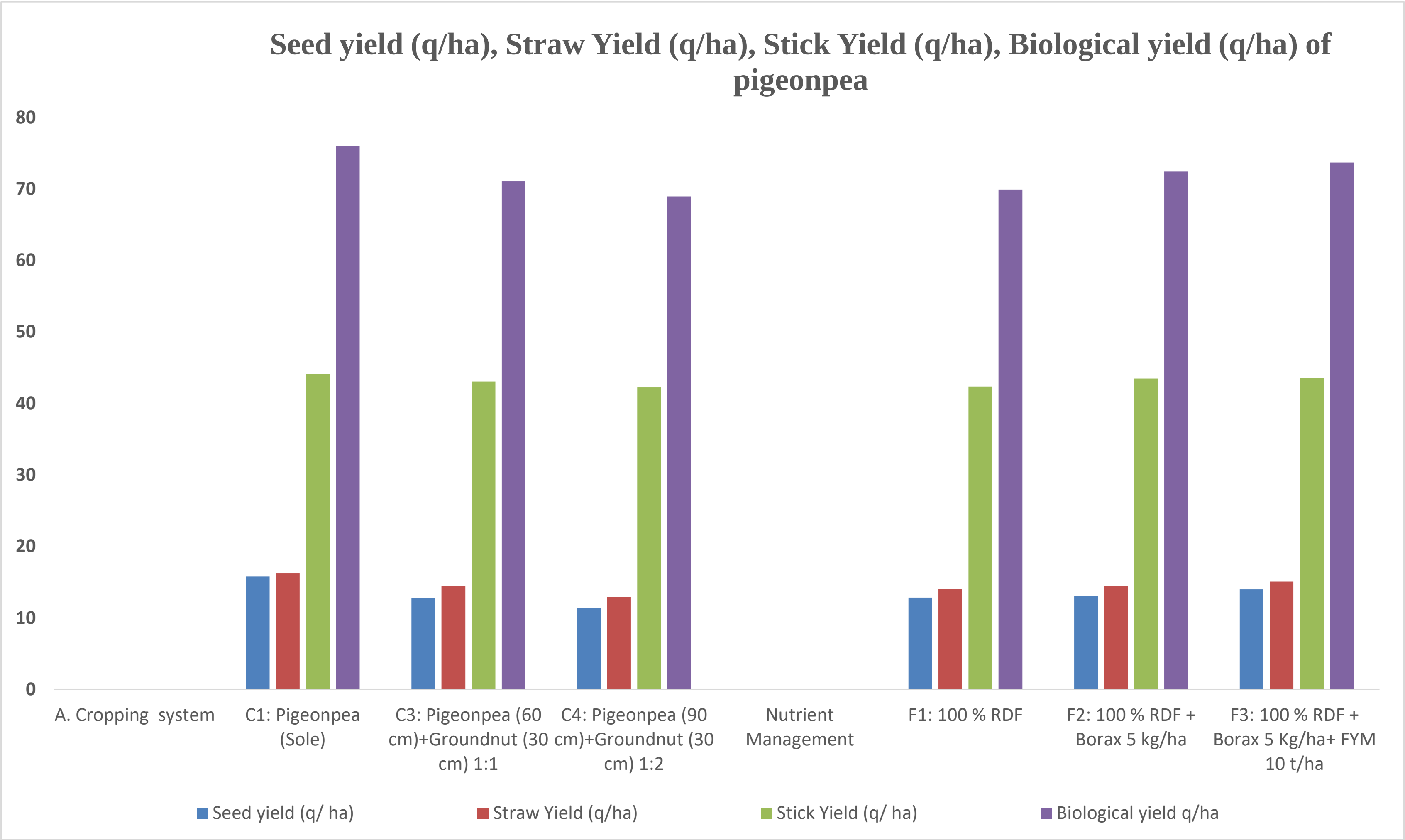

Fig 4.8 -Effect of cropping system and nutrient management on Seed yield (q/ha), Straw Yield (q/ha), Stick Yield (q/ha), Biological yield (q/ha) of pigeonpea under different treatments.

4.9 1000-Seed weight (g), no. of seed/ plant and harvest index (%)

4.9.1 1000- Seed weight(g)

The statistical analysis of the data on the 1000- seed weight(g) under different treatments of pigeonpea was performed (refer to Appendix XXX) were analyzed, and the results are summarized in **Table 4.9.** Additionally, these results are visually represented in **Figure 4.9.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum 1000-seed weight (83.58 g) was observed in the C_4 pigeonpea + groundnut (1:2) treatment, while the lowest value (81.44 g) was recorded in the C_1 pigeonpea sole treatment.

Effect of nutrient management:

The results presented in **Table 4.9** demonstrate significant differences in the 1000- seed weight of pigeonpea due to different levels of nutrient management application. Statistically superior values (83.59 g) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (81.92 g) were observed under the F_1 level.

4.9.2 No. of seed/plant

The statistical analysis of the data on the seed weight(g) plant^{-1} under different treatments of pigeonpea was performed (refer to Appendix XXXI) were analyzed, and the results are summarized in **Table 4.9.** Additionally, these results are visually represented in **Figure 4.9.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The highest number of seeds per plant (291.30) was observed in the C_4 pigeonpea + groundnut (1:2) treatment, while the lowest value (227.88) was recorded in the C_1 pigeonpea sole treatment.

Effect of nutrient management :

The results presented in **Table 4.9** demonstrate significant differences in the number of seeds per plant of pigeonpea due to different levels of nutrient management application. Statistically superior values(270.78 seeds per plant) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (248.82 seeds per plant) were observed under the F_1 level.

4.9.3 Harvest index (%)

The statistical analysis of the data on the harvest index (%) under different treatments of pigeonpea was performed (refer to Appendix XXXII) were analyzed, and the results are summarized in **Table 4.9.** Additionally, these results are visually represented in **Figure 4.9.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum harvest index (%) (20.87) was observed in the C_1 pigeonpea sole, while the lowest value (17.45) was recorded in the sole C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management :

The results presented in **Table 4.9** demonstrate significant differences in the harvest index (%) of pigeonpea due to different levels of nutrient management application. Statistically superior values (18.98 %) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (18.60 %) were observed under the F_1 level.

Table 4.9: Effect of cropping system and nutrient management on 1000-Seed weight, No. of Seed/ plant, Harvest Index (%) of pigeonpea under different treatments:

Treatments	1000 seed weight (gm)	No. of seeds/ plant	Harvest index (%)
A. Cropping system			
C_1: Pigeonpea (Sole)	81.44	227.88	20.87
C_3: Pigeonpea (60 cm) + Groundnut (30 cm) 1:1	82.63	261.30	17.87
C_4: Pigeonpea (90 cm) + Groundnut (30 cm) 1:2	83.58	291.30	17.45
SE (diff.)	**0.68**	**5.97**	**0.15**
CD (P=0.05)	**1.43**	**12.65**	**0.32**
B. Nutrient management			
F_1: 100 % RDF	81.92	248.82	18.60
F_2: 100 % RDF + Borax 5 kg/ha	82.14	260.89	18.61
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	83.59	270.78	18.98
SE (diff.)	**0.68**	**5.97**	**0.15**
CD (P=0.05)	**1.43**	**12.65**	**0.32**

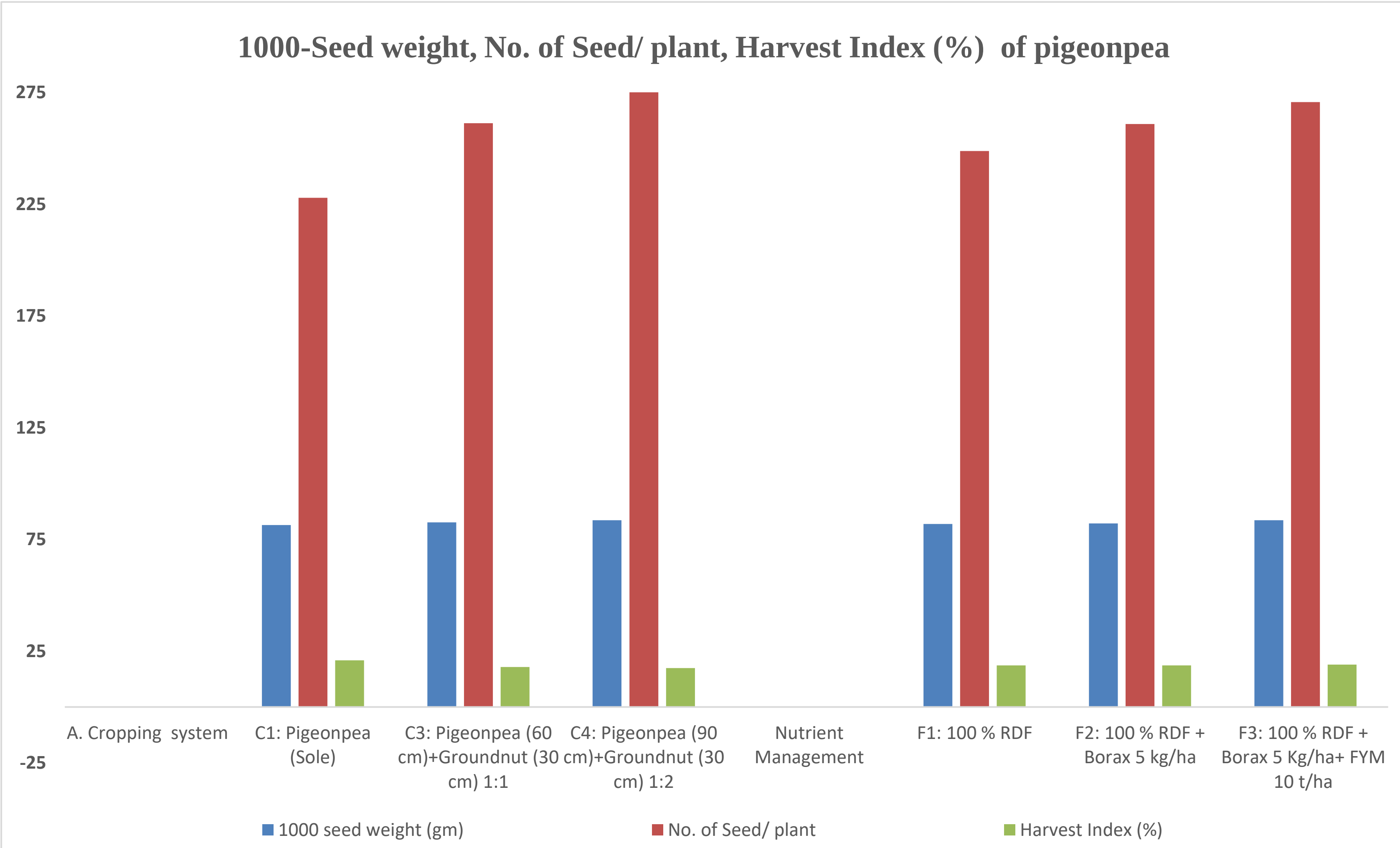

Fig 4.9 - Effect of cropping system and nutrient management on 1000-Seed weight, No. of Seed/ plant, Harvest Index (%) of pigeonpea under different treatments.

4.9 (a) Stubbles of previous pigeonpea crop (q/ha)

The statistical analysis of the data on the harvest index (%) under different treatments of pigeonpea was performed were analyzed, and the results are summarized in **Table 4.9(a).** Additionally, these results are visually represented in **Figure 4.9(a).**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum stubbles of previous pigeonpea crop (q/ha) (16.14 q/ha) was observed in the C_1 pigeonpea sole, while the lowest value (8.23 q/ha) was recorded in the sole C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management :

The results presented in **Table 4.9(a)** demonstrate significant differences in the stubbles of previous pigeonpea crop (q/ha) of pigeonpea due to different levels of nutrient management application. Statistically superior values(14.63 q/ha) were obtained in F_3 treatment , followed by the F_2 level of application. The lowest values (10.46 q/ha) were observed under the F_1 level.

Table 4.9(a) : Effect of cropping system and nutrient management on stubbles of previous pigeonpea crop (q/ha) under different treatments

Treatments	Stubbles of previous pigeonpea crop (q/ha)
A. Cropping System	
C_1: Pigeonpea (Sole)	16.14
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	14.36
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	8.23
B. Nutrient management	
F_1: 100 % RDF	10.46
F_2: 100 % RDF + Borax 5 kg/ha	13.64
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	14.63

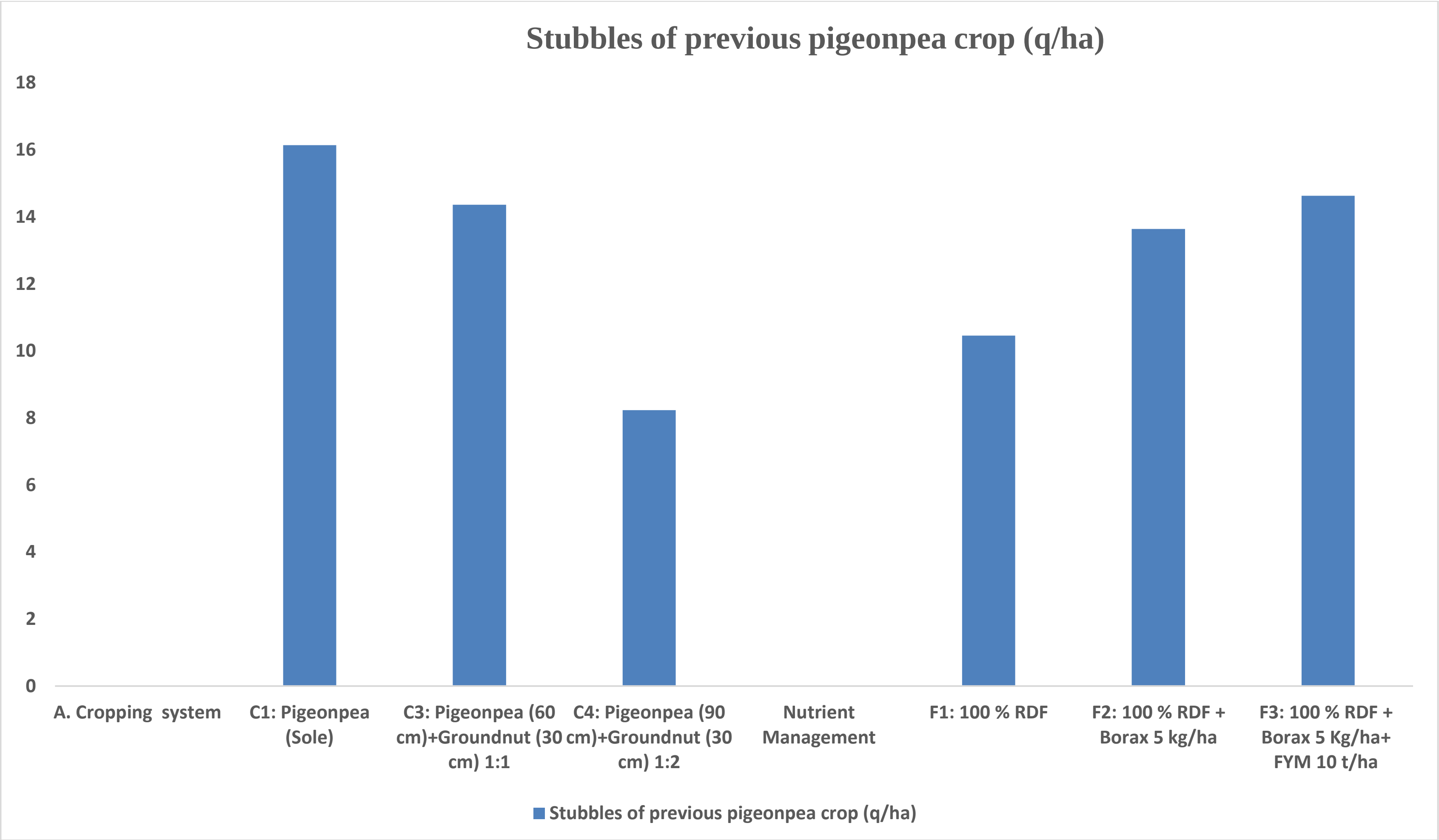

Fig 4.9(a) - Effect of cropping system and nutrient management on stubbles of previous pigeonpea crop under different treatments.

Groundnut

4.10 Plant height (cm)

Statistical analysis was conducted on the recorded data of plant height (refer to Appendix XXXIII, XXXIV and XXXV), and the findings are presented in **Table 4.10** and illustrated in **Figure 4.10.**

Effect of cropping systems

The impact of different cropping systems on the plant height of groundnut was found to be significant, as indicated in **Table 4.10**. The plant height of the groundnut crop was measured at different stages 30 DAS, 60 DAS, and when the plants were fully grown. At 30 DAS, the tallest plants were found in treatment C_3 (17.55 cm), while the shortest plants were in treatment C_2 (15.20 cm). In the cropping system, the tallest and shortest plants at 60 DAS were observed in treatment C_3 (45.07 cm) and C_2 (42.44 cm) respectively. The final measurements were taken when the plants reached maturity, and treatment C_3 had the tallest plants (54.21 cm) while treatment C_2 had the shortest plants (52.21 cm).

Effect of nutrient management

The levels of nutrient management had the effect on groundnut observed in 30 DAS, the tallest plant height was observed in F_3 (16.72 cm), and the shortest plant height was found in F_1 (15.94 cm) while the significant effect except at 30 DAS at which it was found to be non-significant on increasing the plant height of groundnut compared to F_1. At 60 DAS, the highest and lowest plant heights were recorded in F_3 (44.96 cm) and F_1 (42.97 cm) respectively. Finally, at maturity, the tallest and shortest plant heights were measured in F_3 (54.14 cm) and F_1 (52.24 cm) respectively**.**

Table 4.10: Effect of cropping system and nutrient management on Plant height under different treatments:

Treatments	Plant height (cm)		
	30 DAS	**60 DAS**	**At maturity**
Cropping System			
C_2: Groundnut (Sole)	15.20	42.44	52.21
C_3: Pigeonpea (60 cm) + Groundnut (30 cm) 1:1	17.55	45.07	54.21
C_4: Pigeonpea (90 cm) + Groundnut (30 cm) 1:2	16.25	44.43	54.06
SE (diff.)	**0.41**	**0.73**	**0.78**
CD (P=0.05)	**0.86**	**1.56**	**1.66**
Nutrient management			
F_1: 100 % RDF	15.94	42.97	52.24
F_2: 100 % RDF + Borax 5 kg/ha	16.34	44.01	54.10
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	16.72	44.96	54.14
SE (diff.)	**0.41**	**0.73**	**0.78**
CD (P=0.05)	**N.S.**	**1.56**	**1.66**

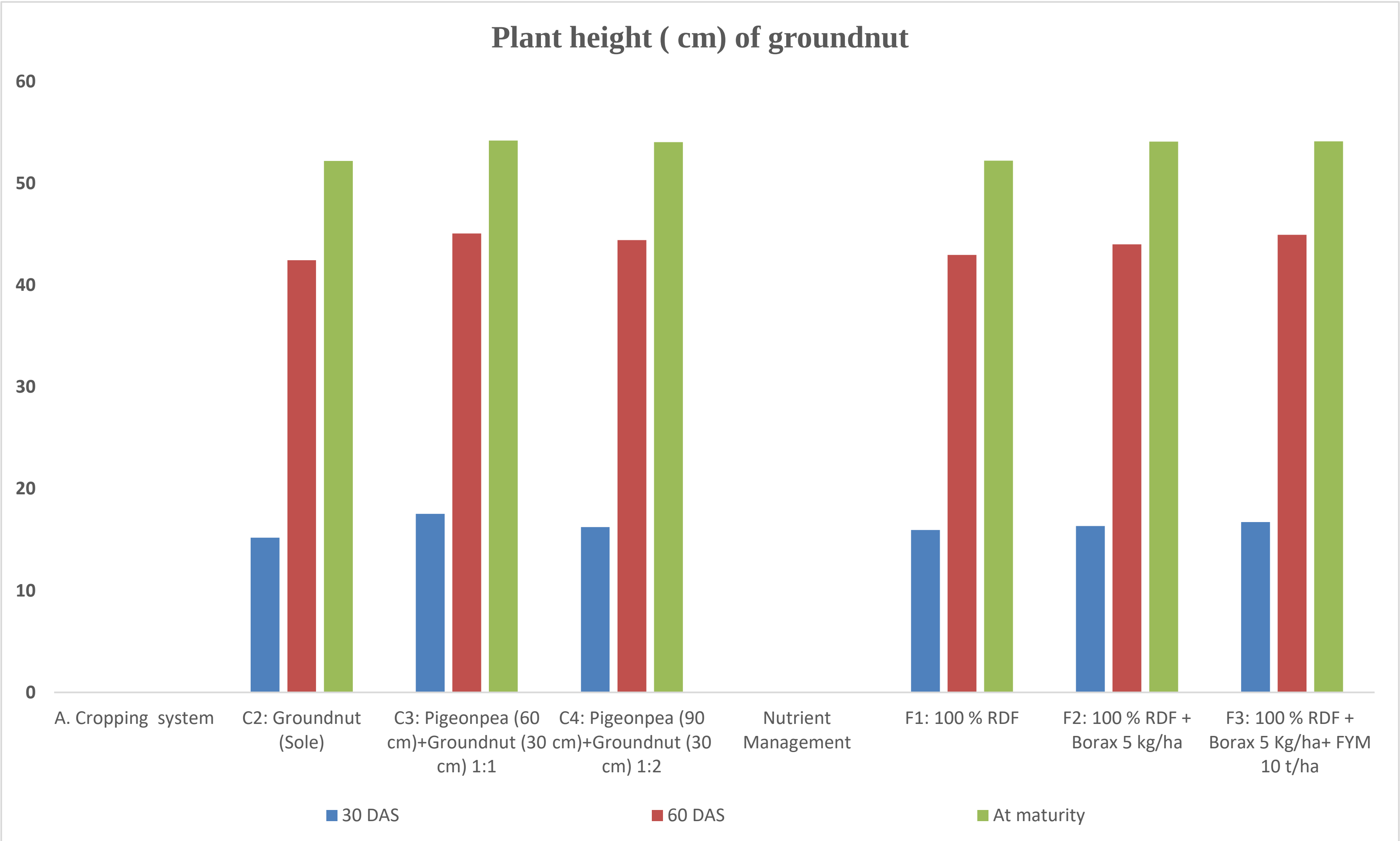

Fig 4.10 - Effect of cropping system and nutrient management on Plant height of groundnut under different treatments.

4.11 Number of branches

Statistical analysis was conducted on the recorded data of number of branches (refer to Appendix XXXVI, XXXVII and XXXVIII), and the findings are presented in **Table 4.11** and illustrated in **Figure 4.11.**

Effect of cropping systems

The impact of different cropping systems on the number of branches of groundnut was found to be significant, as indicated in **Table 4.11**. The number of branches of the groundnut crop was measured at different stages 30 DAS, 60 DAS, and when the plants were fully grown. At 30 DAS, maximum number of branches were found in treatment C_2 (2.51), while the minimum number of branches were in treatment C_3 (1.55). In the cropping system, the maximum and minimum number of branches at 60 DAS were observed in treatment C_2 (3.54) and C_3 (2.54) respectively. The final measurements were taken when the plants reached maturity, and treatment C_2 had the maximum number of branches (6.12) while treatment C_3 had the minimum number of branches (4.56).

Effect of nutrient management

The levels of nutrient management had the significant effect on groundnut observed in 30 DAS, the maximum number of branches was observed in F_3 (2.15), and the minimum number of branches was found in F_1 (1.87) while the significant effect on increasing the number of branches of groundnut compared to F_1. At 60 DAS, the highest and lowest number of branches were recorded in F_3 (3.23) and F_1 (2.89) respectively. Finally, at maturity, the maximum and minimum number of branches were measured in F_3 (5.56) and F_1 (5.06) respectively**.**

Table 4.11: Effect of cropping system and nutrient management on Number of branches of groundnut at different stages under different treatments:

Treatments	Number of branches/plants		
	30 DAS	60 DAS	At maturity
Cropping System			
C_2: Groundnut (Sole)	2.51	3.54	6.12
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	1.55	2.54	4.56
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	1.99	3.06	5.24
SE (diff.)	**0.05**	**0.07**	**0.13**
CD (P=0.05)	**0.11**	**0.16**	**0.27**
Nutrient management			
F_1: 100 % RDF	1.87	2.89	5.06
F_2: 100 % RDF + Borax 5 kg/ha	2.02	3.02	5.29
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	2.15	3.23	5.56
SE (diff.)	**0.05**	**0.07**	**0.13**
CD (P=0.05)	**0.11**	**0.16**	**0.27**

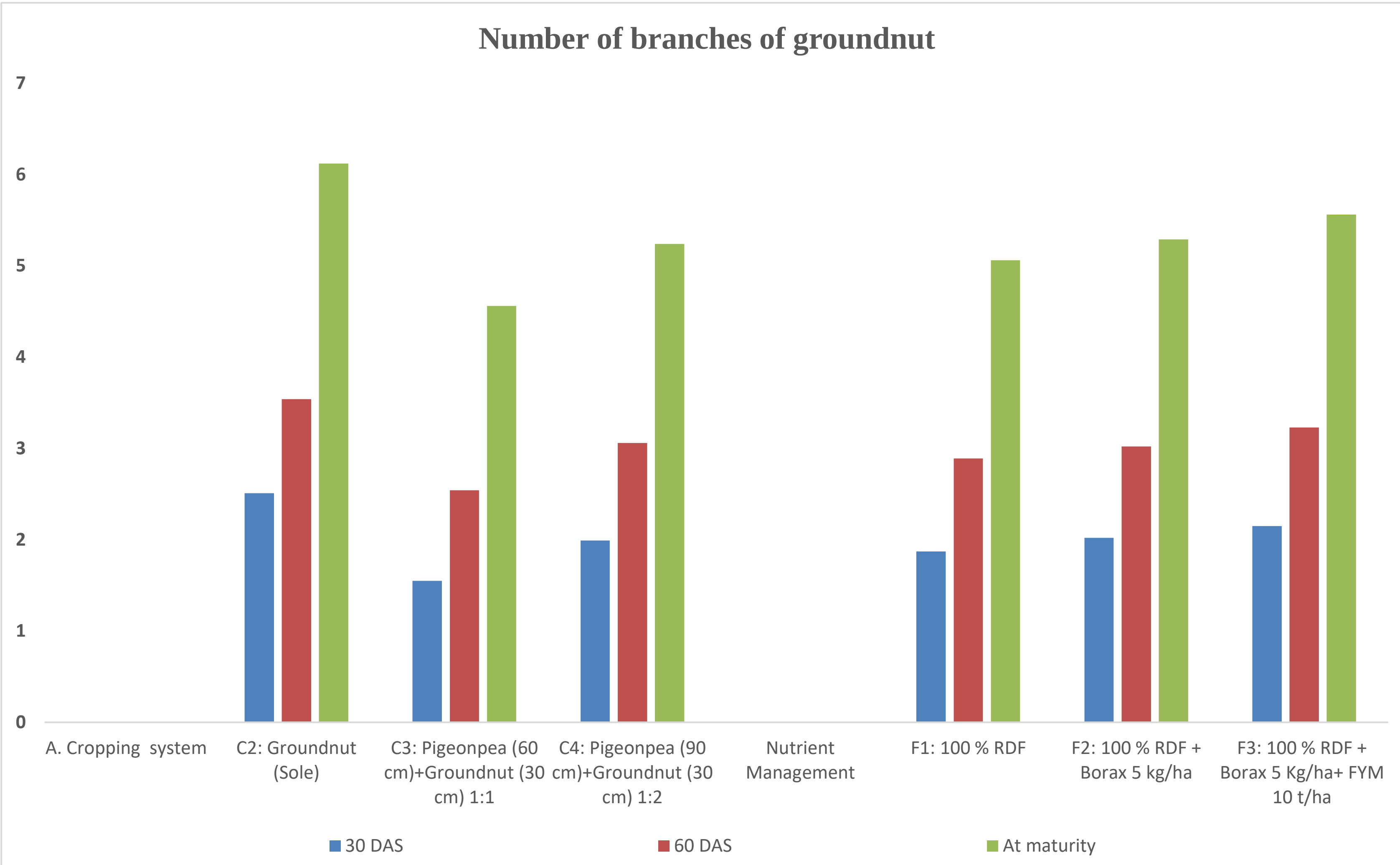

Fig 4.11 - Effect of cropping system and nutrient management on Number of branches of groundnut at different stages under different treatments.

4.12 Number of pods plant^{-1} and 100-Kernel weight

4.12.1 Number of pods plant^{-1}

The statistical analysis of the data on the number of pods plant^{-1} under different treatments of groundnut was performed (refer to Appendix XXXIX) were analyzed, and the results are summarized in **Table 4.12.** Additionally, these results are visually representedin **Figure 4.12.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest number of pods per plant (53.68) was observed in the C_3 pigeonpea + groundnut (1:1) treatment, while the lowest value (49.17) was recorded in the C_2 groundnut sole treatment.

Effect of nutrient management:

The results presented in **Table 4.12** demonstrate significant differences in the number of pods per plant of groundnut due to different levels of nutrient management application. Statistically superior values(52.80 pods per plant) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (50.25 pods per plant) were observed under the F_1 level.

4.12.2 100-Kernel weight

The statistical analysis of the data on the 100-kernel weight under different treatments of groundnut was performed (refer to Appendix XL) were analyzed, and the results are summarized in **Table 4.12.** Additionally, these results are visually representedin **Figure 4.12.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest 100-kernel weight (42.55 g) was observed in the C_3 pigeonpea + groundnut (1:1) treatment, while the lowest value (40.48 gm) was recorded in the C_2 groundnut sole treatment.

Effect of nutrient management :

The results presented in **Table 4.12** demonstrate significant differences in the 100-kernel weight of groundnut due to different levels of nutrient management application. Statistically superior values(42.90 g) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (40.65 g) were observed under the F_1 level.

Table 4.12: Effect of cropping system and nutrient management on Number of pods plant^{-1}, 100-kernel weight under different treatments:

Treatments	Number of Pods/ plant	100 kernel weight (g)
Cropping System		
C_2: Groundnut (Sole)	49.17	40.48
C_3: Pigeonpea (60 cm) + Groundnut (30 cm) 1:1	53.68	42.55
C_4: Pigeonpea (90 cm) + Groundnut (30 cm) 1:2	52.16	42.32
SE (diff.)	**0.95**	**0.80**
CD (P=0.05)	**2.02**	**1.70**
Nutrient management		
F_1: 100 % RDF	50.25	40.65
F_2: 100 % RDF + Borax 5 kg/ha	51.96	41.80
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	52.80	42.90
SE (diff.)	**0.95**	**0.80**
CD (P=0.05)	**2.02**	**1.70**

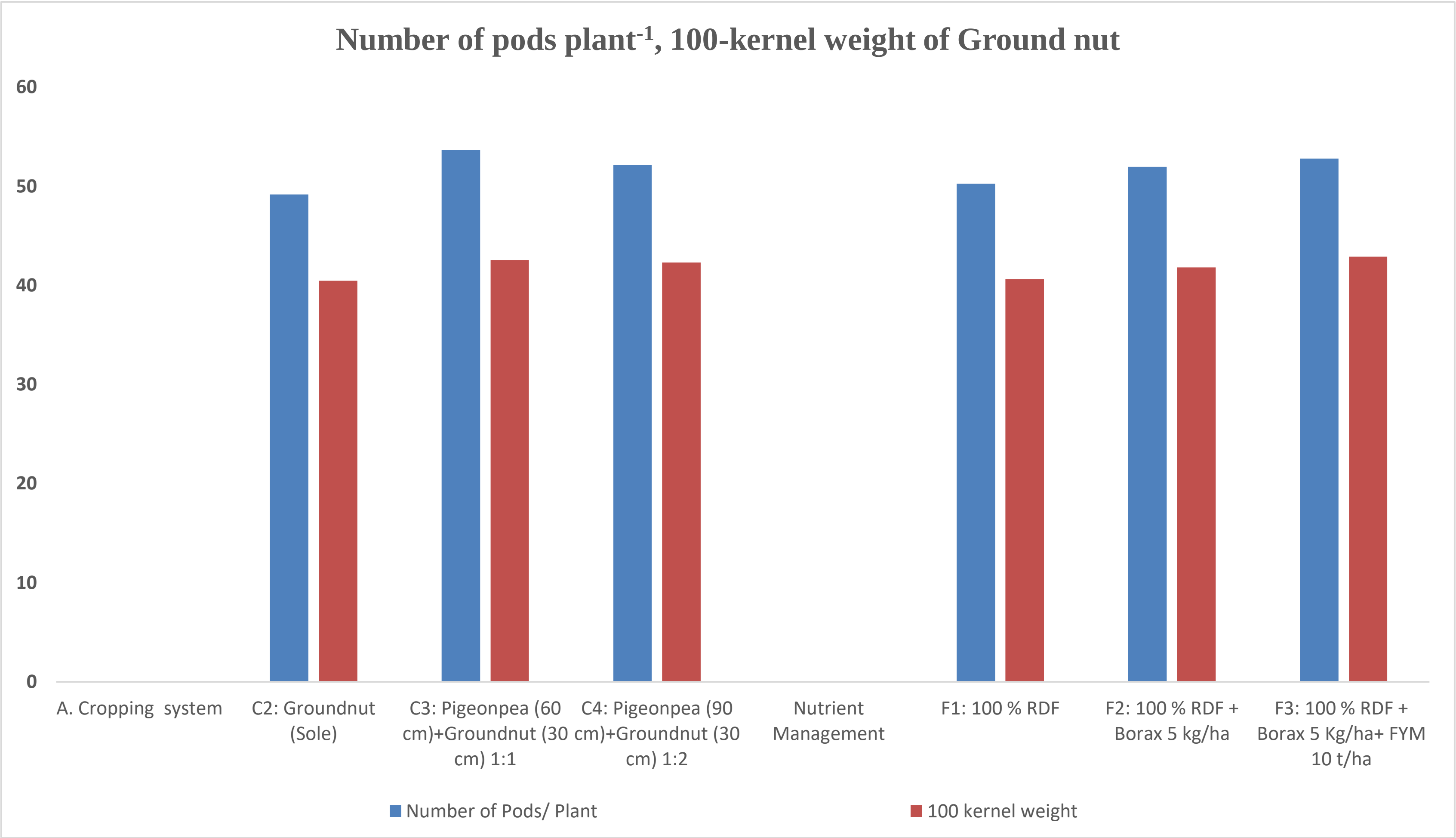

Fig 4.12 - Effect of cropping system and nutrient management on Number of pods plant^{-1}, 100-kernel weight of groundnut under different treatments.

4.13 Pod yield (q/ha) and Biological yield (q/ha)

4.13.1 Pod yield(q/ha)

The statistical analysis of the data on the pod yield (q/ha) under different treatments of groundnut was performed (refer to Appendix XLI) were analyzed, and the results are summarized in **Table 4.13.** Additionally, these results are visually represented in**Figure 4.13.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest pod yield (24.17 q/ha) was observed in the C_2 groundnut sole treatment, while the lowest value (14.40 q/ha) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.13** showed significant differences in the pod yield (q/ha) of groundnut due to different levels of nutrient management application. Statistically superior values (19.70 q/ha) were obtained in F_3 - treatment, followed by the F_2 . The lowest values (17.60 q/ha) were observed under the F_1 treatment .

4.13.2 Biological yield (q/ha)

The statistical analysis of the data on the biological yield(q/ha) under different treatments of groundnut was performed (refer to Appendix XLII) were analyzed, and the results are summarized in **Table 4.13.** Additionally, these results are visually represented in **Figure 4.13.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest biological yield (60.38 q/ha) was observed in the C_2 groundnut sole treatment, while the lowest value (45.34 q/ha) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.13** demonstrate significant differences in the biological yield (q/ha) of groundnut due to different levels of nutrient management application. Statistically superior values (54.02 q/ha) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (50.60 q/ha) were observed under the F_1 level.

Table 4.13: Effect of cropping system and nutrient management on Pod yield (q/ha), Biological yield (q/ha) under different treatments:

Treatments	Pod Yield (q/ha)	Biological Yield (q/ha)
Cropping System		
C_2: Groundnut (Sole)	24.17	60.38
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	14.40	45.34
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	17.30	51.20
SE (diff.)	**0.45**	**1.24**
CD (P=0.05)	**0.96**	**2.62**
Nutrient management		
F_1: 100 % RDF	17.60	50.60
F_2: 100 % RDF + Borax 5 kg/ha	18.57	52.31
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	19.70	54.02
SE (diff.)	**0.45**	**1.24**
CD (P=0.05)	**0.96**	**2.62**

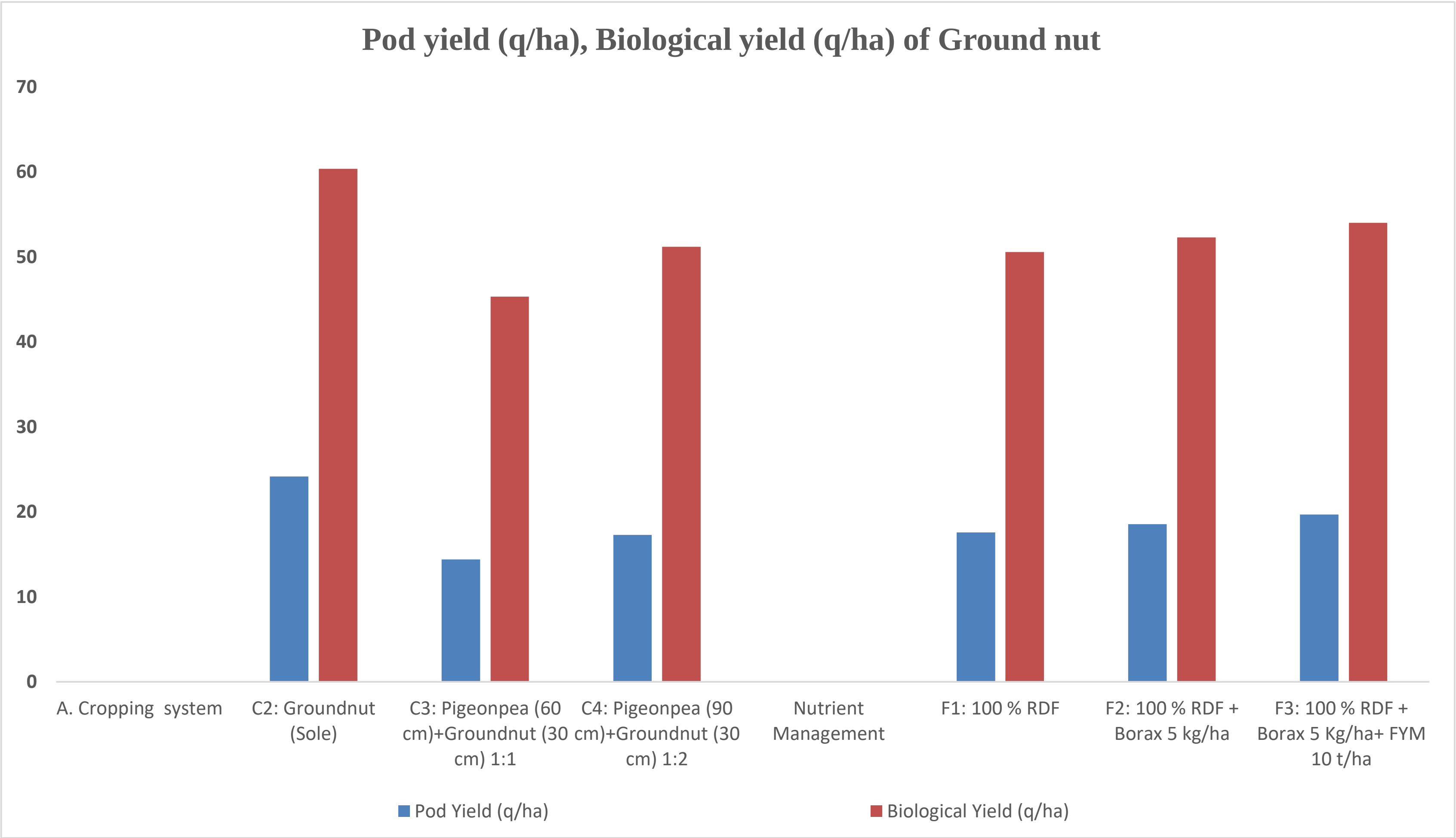

Fig 4.13 - Effect of cropping system and nutrient management on Pod yield (q/ha), Biological yield (q/ha) of groundnut under different treatments.

4.14 Shelling percentage (%) and harvest index (%)

4.14.1 Shelling percentage (%)

The statistical analysis of the data on the shelling percentage (%) under different treatments of groundnut was performed (refer to Appendix XLIII) were analyzed, and the results are summarized in **Table 4.14.** Additionally, these results are visually represented in **Figure 4.14.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest shelling percentage (%) (69.69) was observed in the C_2 groundnut sole treatment, while the lowest value (67.26) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.14** demonstrate significant differences in the shelling percentage (%) of groundnut due to different levels of nutrient management application. Statistically superior values (69.83 %) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (67.49 %) were observed under the F_1 level.

4.14.2 Harvest index (%)

The statistical analysis of the data on the harvest index(%) under different treatments of groundnut was performed (refer to Appendix XLIV) were analyzed, and the results are summarized in **Table 4.14.** Additionally, these results are visually represented in **Figure 4.14.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest harvest index(%) (40.11) was observed in the C_2 groundnut sole treatment, while the lowest value (37.85) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.14** demonstrate significant differences in the harvest index(%) of groundnut due to different levels of nutrient management application. Statistically superior values (39.93 %) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (38.11 %) were observed under the F_1 level.

Table 4.14: Effect of cropping system and nutrient management on shelling percentage (%), harvest index (%) under different treatments:

Treatments	Shelling %	Harvest index (%)
Cropping System		
C_2: Groundnut (Sole)	69.41	39.40
C_3: Pigeonpea (60 cm) + Groundnut (30 cm) 1:1	67.26	37.85
C_4: Pigeonpea (90 cm) + Groundnut (30 cm) 1:2	69.69	40.11
SE (diff.)	**0.87**	**0.60**
CD (P=0.05)	**1.84**	**1.28**
Nutrient management		
F_1: 100 % RDF	67.49	38.11
F_2: 100 % RDF + Borax 5 kg/ha	69.03	39.32
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	69.83	39.93
SE (diff.)	**0.87**	**0.60**
CD (P=0.05)	**1.84**	**1.28**

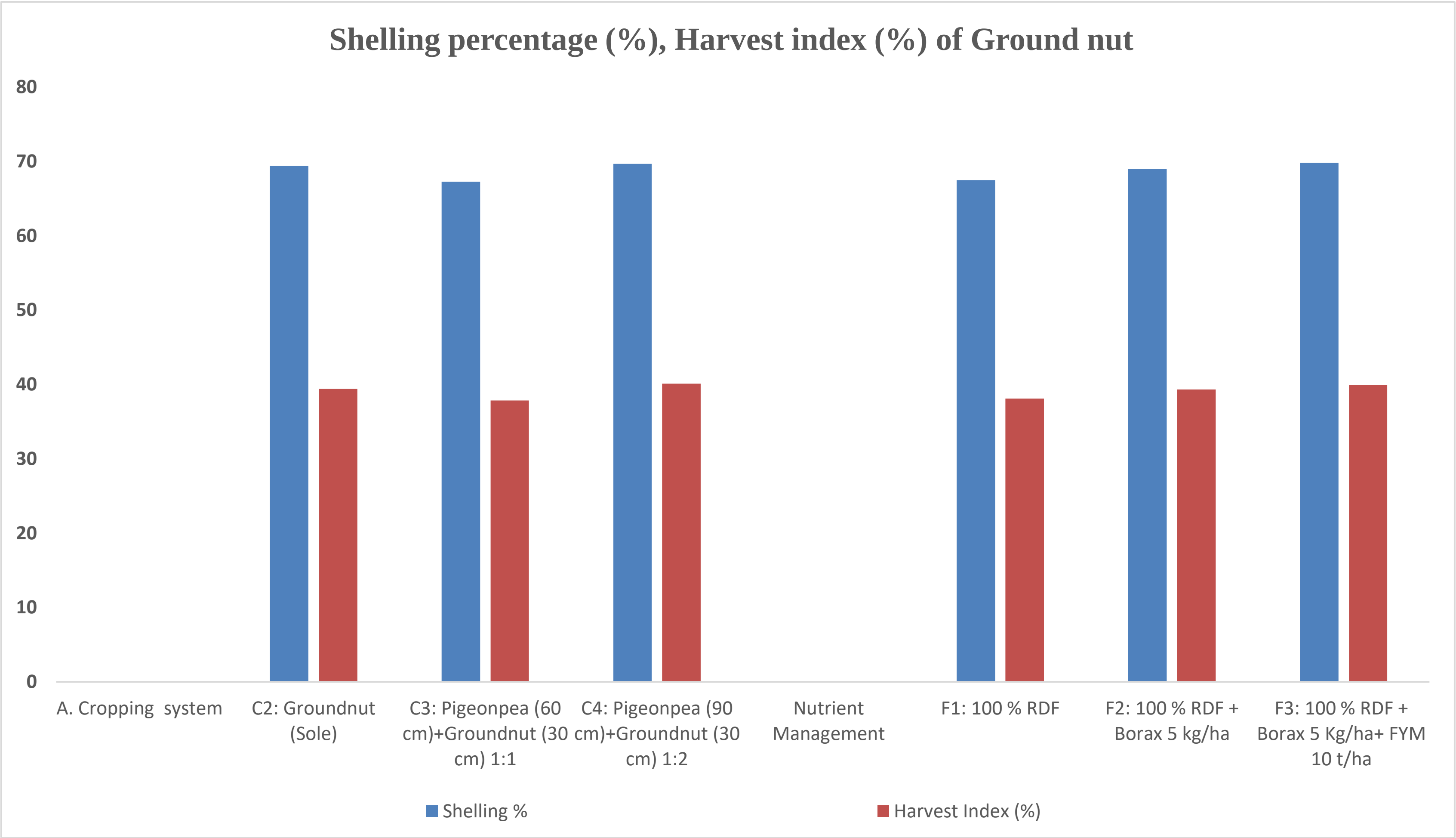

Fig 4.14 - Effect of cropping system and nutrient management on Shelling percentage (%), Harvest index (%) of groundnut under different treatments.

4.15 Kernel yield (q/ha) and Haulm yield (q/ha)

4.15.1 Kernel yield (q/ha)

The statistical analysis of the data on the kernel yield (q/ha) under different treatments of groundnut was performed (refer to Appendix XLV) were analyzed, and the results are summarized in **Table 4.15.** Additionally, these results are visually represented in **Figure 4.15.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest kernel yield (16.88 q/ha) was observed in the C_2 groundnut sole treatment, while the lowest value (9.65 q/ha) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.15,** clearly indicated that significant differences in the kernel yield (q/ha) of groundnut due to different levels of nutrient management application. Statistically superior values (13.59 q/ha) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (11.99 q/ha) were observed under the F_1 level.

4.15.2 Haulm yield (q/ha)

The statistical analysis of the data on the haulm yield (q/ha) under different treatments of groundnut was performed (refer to Appendix XLVI) were analyzed, and the results are summarized in **Table 4.15.** Additionally, these results are visually represented in **Figure 4.15.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest haulm yield (36.34 q/ha) was observed in the C_2 groundnut sole treatment, while the lowest value (31.26 q/ha) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.15** indicate significant differences in the haulm yield (q/ha) of groundnut due to different levels of nutrient management application. Statistically superior values (34.95 q/ha) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (33.00 q/ha) were observed under the F_1 level.

Table 4.15: Effect of cropping system and nutrient management on kernel yield (q/ha), haulm yield (q/ha) under different treatments:

Treatments	Kernel yield (q/ha)	Haulm yield (q/ha)
Cropping System		
C_2: Groundnut (Sole)	16.88	36.34
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	9.65	31.26
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	11.82	34.20
SE (diff.)	**0.31**	**0.69**
CD (P=0.05)	**0.66**	**1.45**
Nutrient management		
F_1: 100 % RDF	11.99	33.00
F_2: 100 % RDF + Borax 5 kg/ha	12.77	33.86
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	13.59	34.95
SE (diff.)	**0.31**	**0.69**
CD (P=0.05)	**0.66**	**1.45**

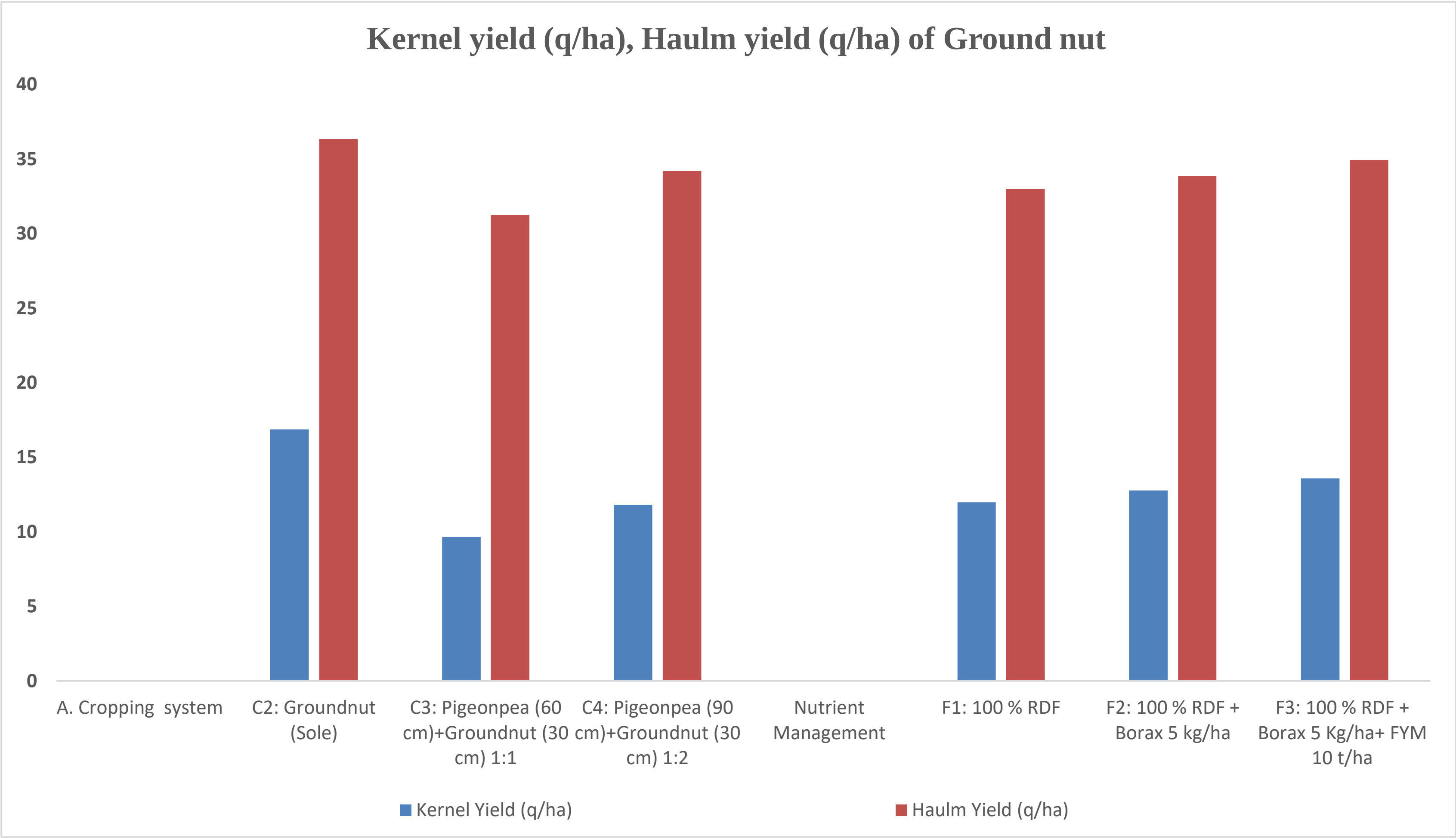

Fig 4.15 - Effect of cropping system and nutrient management on Kernel yield (q/ha), Haulm yield (q/ha) of groundnut under different treatments.

4.16 Protein content (%) and protein yield (q/ha)

4.16.1 Protein content (%)

The statistical analysis of the data on the protein content (%) under different treatments of groundnut was performed (refer to Appendix XLVII) were analyzed, and the results are summarized in **Table 4.16.** Additionally, these results are visually represented in **Figure 4.16.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest protein content (%) (22.61) was observed in the C_2 groundnut sole treatment, while the lowest value (20.79) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management :

The results presented in **Table 4.16** demonstrate significant differences in the protein content (%) of groundnut due to different levels of nutrient management application. Statistically superior values (21.97 %) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (21.38 %) were observed under the F_1 level.

4.16.2 Protein yield (q/ha)

The statistical analysis of the data on the protein yield (q/ha) under different treatments of groundnut was performed (refer to Appendix XLVIII) were analyzed, and the results are summarized in **Table 4.16.** Additionally, these results are visually represented in **Figure 4.16.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest protein yield (379.31 q/ha) was observed in the C_2 groundnut sole treatment, while the lowest value (200.77 q/ha) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.16** demonstrate significant differences in the protein yield (q/ha) of groundnut due to different levels of nutrient management application. Statistically superior values (299.10 q/ha) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (258.59 ha) were observed under the F_1 level.

Table 4.16: Effect of cropping system and nutrient management on protein content(%), protein yield (q/ha) of groundnut under different treatments:

Treatments	Protein content (%)	Protein yield (q/ha)
Cropping System		
C_2: Groundnut (Sole)	22.61	379.31
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	20.79	200.77
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	21.64	255.95
SE (diff.)	**0.20**	**6.92**
CD (P=0.05)	**0.43**	**14.67**
Nutrient management		
F_1: 100 % RDF	21.38	258.59
F_2: 100 % RDF + Borax 5 kg/ha	21.70	278.34
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	21.97	299.10
SE (diff.)	**0.20**	**6.92**
CD (P=0.05)	**0.43**	**14.67**

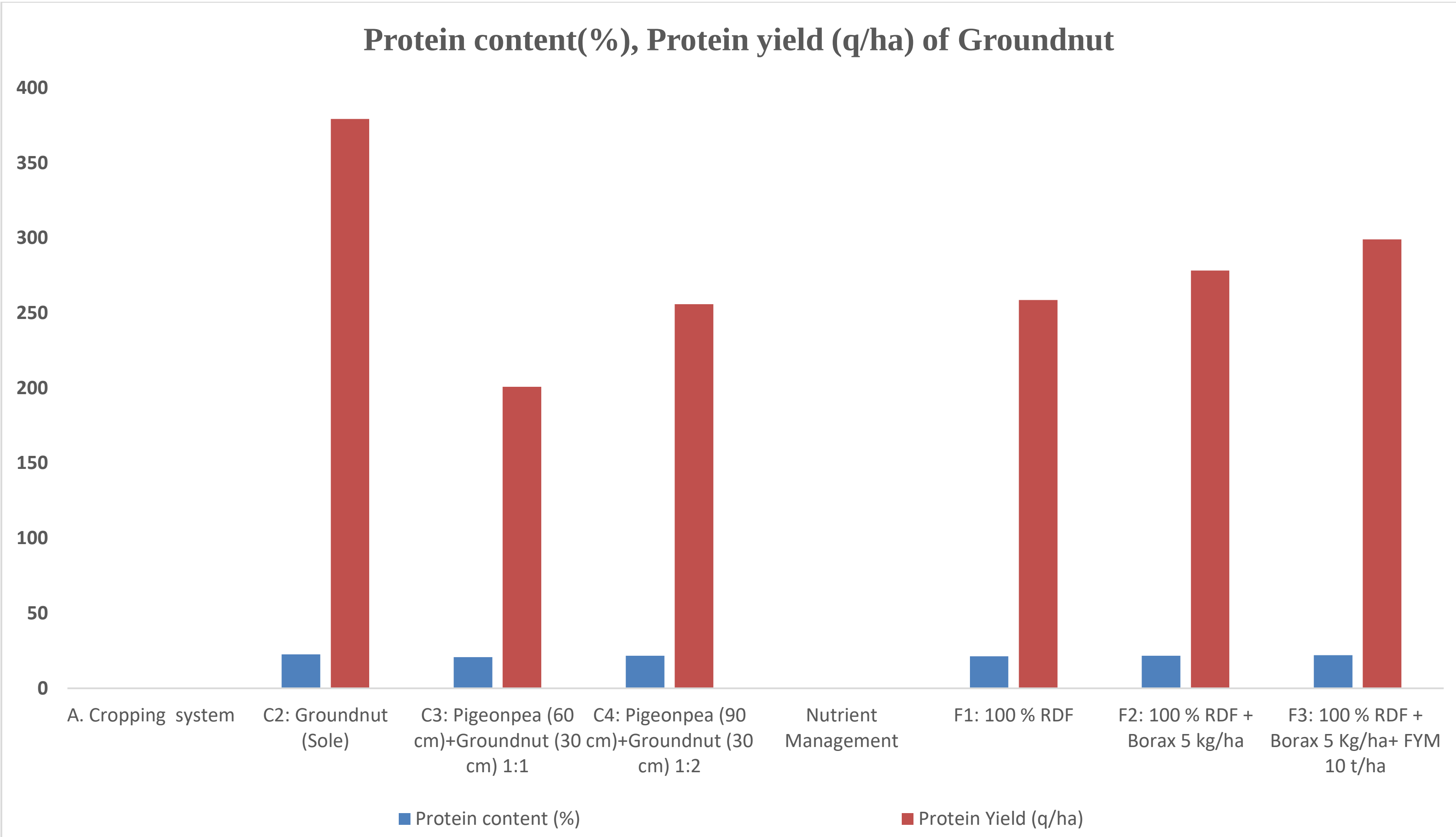

Fig 4.16 - Effect of cropping system and nutrient management on Protein content (%), Protein yield (q/ha) of Groundnut under different treatments.

4.17 Oil content (%) And Oil yield (q/ha)

4.17.1 Oil content (%)

The statistical analysis of the data on the oil content (%) under different treatments of groundnut was performed (refer to Appendix XLIX) were analyzed, and the results are summarized in **Table 4.17.** Additionally, these results are visually represented in **Figure 4.17.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest oil content (%) (43.34 %) was observed in the C_2 groundnut sole treatment, while the lowest value (41.84 %) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management:

The results presented in **Table 4.17** demonstrate significant differences in the oil content (%) of groundnut due to different levels of nutrient management application. Statistically superior values (43.48 %) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (41.97 %) were observed under the F_1 level.

4.17.2 Oil yield (q/ha)

The statistical analysis of the data on the oil yield (q/ha) under different treatments of groundnut was performed (refer to Appendix L) were analyzed, and the results are summarized in **Table 4.17.** Additionally, these results are visually represented in **Figure 4.17.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on groundnut. The highest oil yield (735.34 q/ha) was observed in the C_2 groundnut sole treatment, while the lowest value (401.04 q/ha) was recorded in the C_3 pigeonpea + groundnut (1:1) treatment.

Effect of nutrient management :

The results presented in **Table 4.17** demonstrate significant differences in the oil yield (q/ha) of groundnut due to different levels of nutrient management application. Statistically superior values (585.16 q/ha) were obtained in F_3 treatment, followed by the F_2 level of application. The lowest values (510.09 q/ha) were observed under the F_1 level.

Table 4.17: Effect of cropping system and nutrient management on Oil content (%), Oil yield (q/ha) of groundnut under different treatments:

Treatments	Oil content (%)	Oil yield (q/ha)
Cropping System		
C_2: Groundnut (Sole)	43.34	735.34
C_3: Pigeonpea (60 cm) +Groundnut (30 cm) 1:1	41.84	401.04
C_4: Pigeonpea (90 cm) +Groundnut (30 cm) 1:2	43.13	505.12
SE (diff.)	**0.56**	**13.53**
CD (P=0.05)	**1.19**	**28.68**
Nutrient management		
F_1: 100 % RDF	41.97	510.09
F_2: 100 % RDF + Borax 5 kg/ha	42.86	546.25
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	43.48	585.16
SE (diff.)	**0.56**	**13.53**
CD (P=0.05)	**1.19**	**28.68**

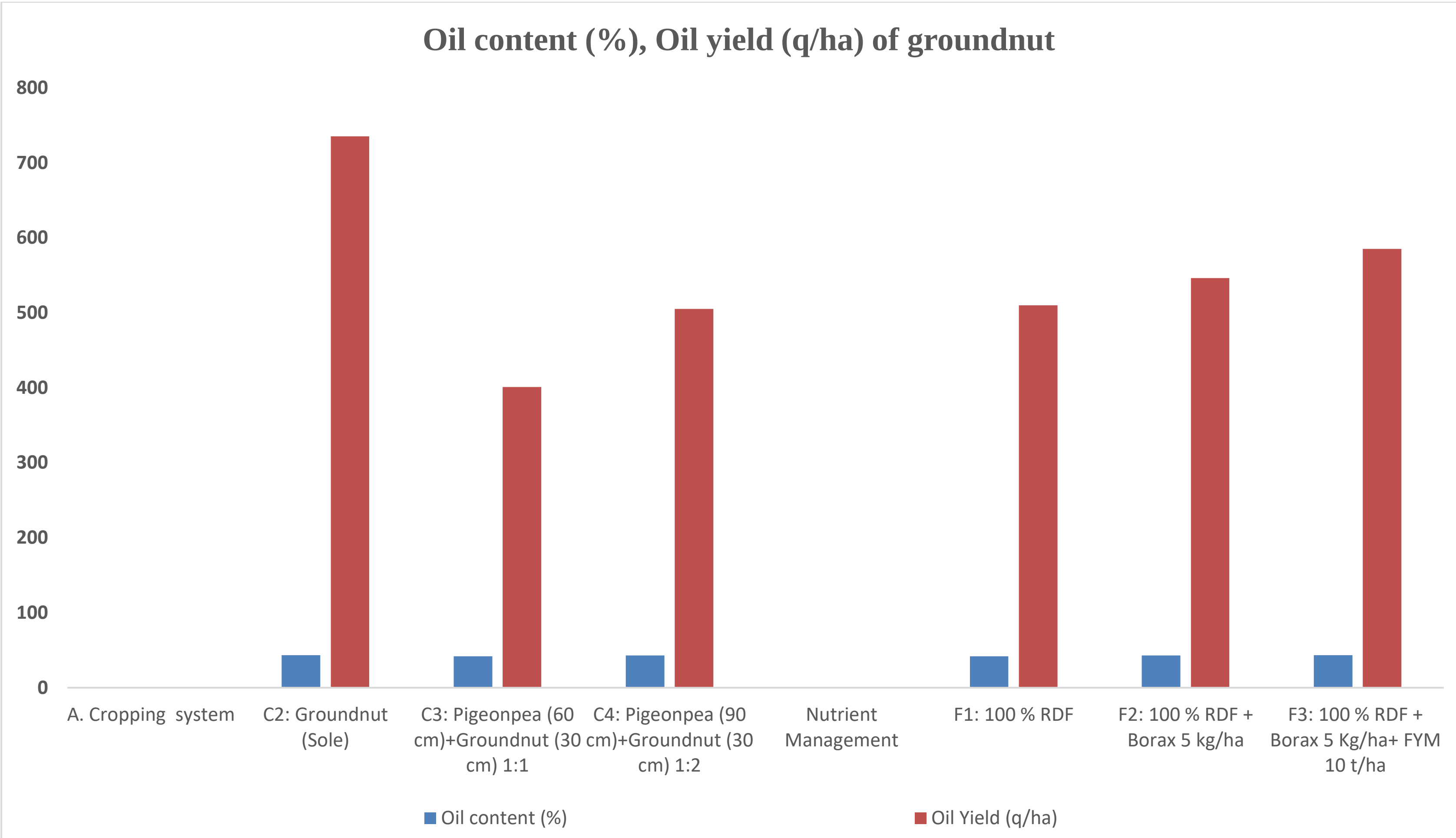

Fig 4.17 - Effect of cropping system and nutrient management on Oil content (%), Oil yield (q/ha) of groundnut under different treatments.

4.18 Pigeonpea seed equivalent yield and LER:

The pigeonpea seed equivalent yield and Land Equivalent Ratio (LER) of various treatments were subjected to statistical analysis, as detailed in Appendix (LI and LII). The summarized results can be found in **Table 4.18** and visually represented in **Figure 4.18**.

Effect of cropping systems:

The data clearly indicate that intercropping treatments generally produced higher pigeonpea equivalent yields and LER compared to sole crops. In the intercropping treatment of pigeonpea + groundnut (1:2) yielded the highest pigeonpea equivalent yield of 22.13 q ha^{-1}, followed by pigeonpea + groundnut (1:1), while the lowest yield of 15.37 q ha^{-1} was obtained C_1 groundnut sole. Similarly, the treatment of by pigeonpea + groundnut (1:2) also exhibited the highest (1.42) LER value, while the lowest (1.38) LER value was observed in the pigeonpea + groundnut (1:1) treatment**.**

Effect of nutrient management :

The data presented in **Table 4.18** clearly demonstrate that different nutrient management had a significant impact on the pigeonpea equivalent yields. The application of 100% RDF resulted in a substantial increase in the equivalent yield, but it was surpassed by the application of 100% RDF+ Borax (5kg/ha) + FYM (10 t/ha). The trend for LER was consistent with the nutrient management application. The highest LER value (1.21) was observed in the F_3 application, while the lowest value (1.19) was found in the F_1 application

Table 4.18: Effect of cropping system and nutrient management on Land equivalent Ratio, Pigeonpea seed equivalent Yield (q/ha) under different treatments:

Treatments	Land equivalent ratio	Pigeonpea seed equivalent yield (q/ha)
Cropping System		
C_1: Pigeonpea (Sole)	1.00	15.77
C_2: Groundnut (Sole)	1.00	15.37
C_3: Pigeonpea (60 cm) +Groundnut (30 cm) 1:1	1.38	21.52
C_4: Pigeonpea (90 cm) +Groundnut (30 cm) 1:2	1.42	22.13
SE (diff.)	**0.02**	**0.45**
CD (P=0.05)	**0.05**	**0.94**
Nutrient management		
F_1: 100 % RDF	1.19	17.82
F_2: 100 % RDF + Borax 5 kg/ha	1.20	18.52
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	1.21	19.76
SE (diff.)	**0.02**	**0.39**
CD (P=0.05)	**N.S.**	**0.81**

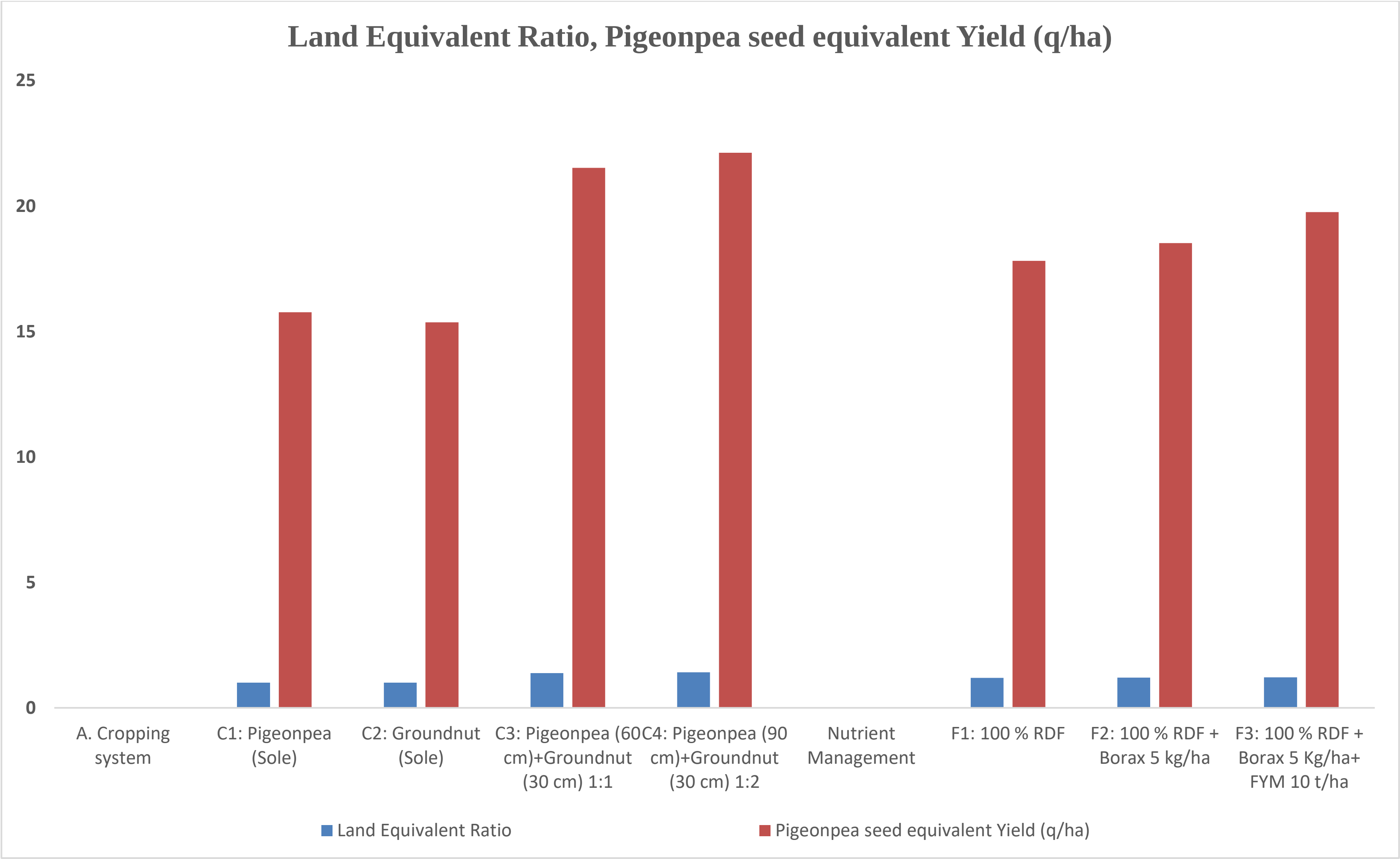

Fig 4.18 - Effect of cropping system and nutrient management on Land Equivalent Ratio, Pigeonpea seed equivalent Yield (q/ha) under different treatments.

4.19 Total water use and water use efficiency

4.19.1 Water use:

The data on water usage for different treatments were provided in **Table 4.19** and graphically represented in **Fig. 4.19.**

Effect of cropping systems:

The data regarding water uses indicate that the treatment with a intercropping of pigeonpea and groundnut (1:2) had the highest (334.42 mm) water uses, followed by pigeonpea and groundnut (1:1), while the lowest values 282.17 mm water use were observed in the groundnut sole treatment during the investigation.

Effect of nutrient management:

The results clearly show that increasing the nutrients increase the water uses. The treatment F_3 exhibited the highest (310.11 mm) water uses compared to the F_1 level, whereas the lowest values (291.21 mm) were recorded in the treatment F_1.

4.19.2 Water use efficiency:

Effect of cropping systems:

The data presented in **Table 4.19** and depicted in **Fig 4.19** demonstrate that water use efficiency varied significantly due to different cropping systems. The C_4 Pigeonpea + groundnut (1:2) treatment exhibited the highest water use efficiency, with a value of 6.71 kg seed ha- mm^{-1} of water, followed by C_3 Pigeonpea + groundnut (1:1). The treatment with groundnut sole recorded the lowest WUE of 5.52 kg seed ha^{-1} mm^{-1} of water.

Effect of nutrient management:

The data suggest that increasing the nutrient management factors improved the water use and water use efficiency of the treatment. The application of 100% RDF + Borax (5kg/ha) + FYM (10 t/ha) enhanced the WUE compared to 100 % RDF , and therewas a further considerable increase.

Table 4.19 : Effect of cropping system and nutrient management on Water use and water use efficiency(WUE) under different treatments:

Treatment	Water use (mm)	WUE (kg seed ha^{-1} mm^{-1} of water)
A. Cropping System		
C_1: Pigeonpea (sole)	269.44	5.86
C_2: Groundnut (sole)	278.17	5.53
C_3: Pigeonpea +Groundnut (1:1)	323.23	6.65
C_4: Pigeonpea +Groundnut (1:2)	330.22	6.71
B. Nutrient management		
F_1: 100% RDF	291.21	6.11
F_2: 100%RDF+Borax (5kg/ha)	300.27	6.16
F_3: 100% RDF+ Borax (5kg/ha)+ FYM (10 t/ha)	310.11	6.37

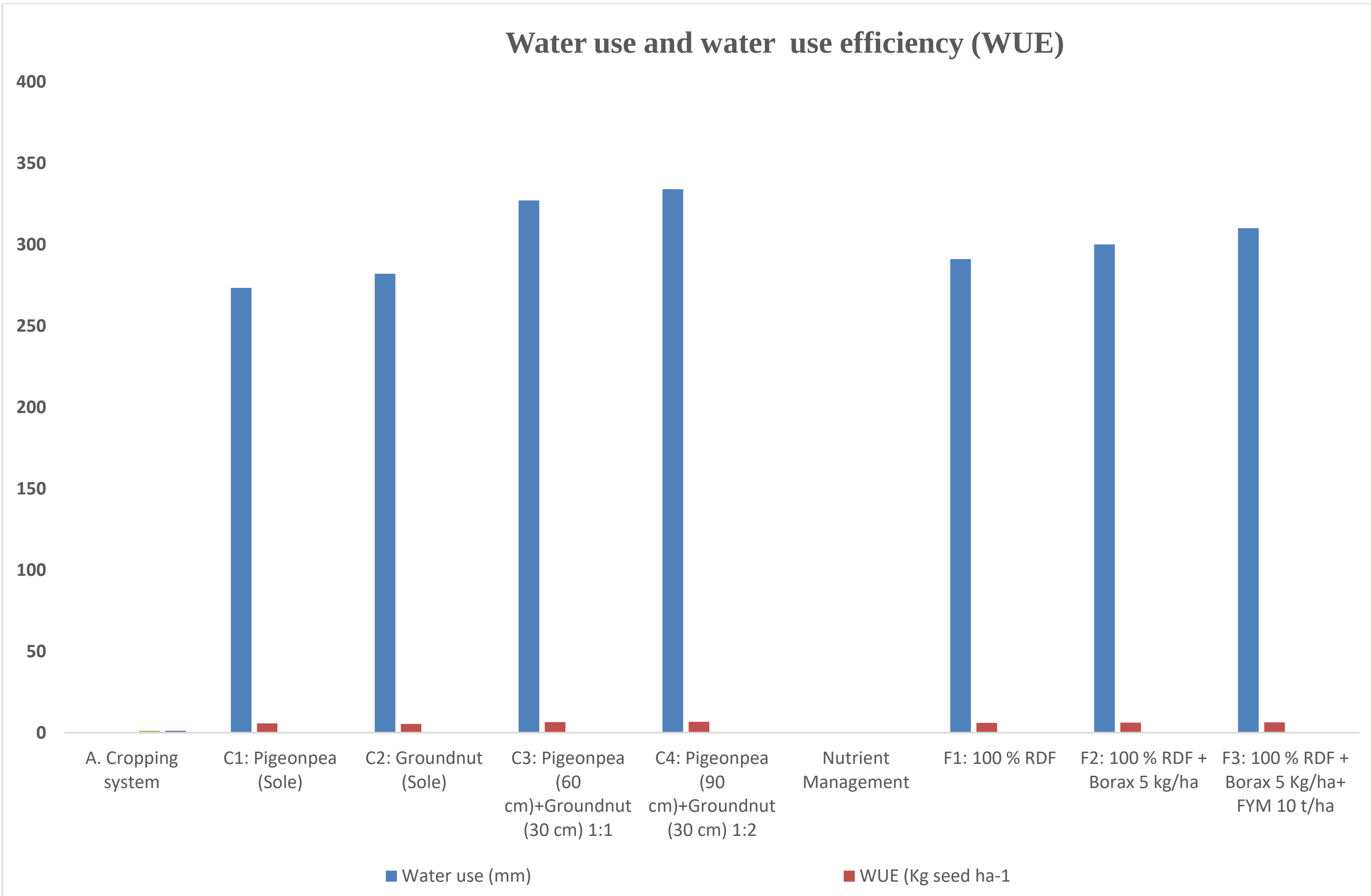

Fig 4.19 - Effect of cropping system and nutrient management on Water use and water use efficiency(WUE) under different treatments.

4.20 Economics:

The economic evaluation of various treatments has been summarized in **Table 4.20** and illustrated in **Fig. 4.20.**

The data analyzed in **Table-4.20** shows that the impact of cropping system and FYM on the total cost of cultivation. The treatment with the highest total cost of cultivation was C_2, amounting to 50,799 Rs. /ha, while the lowest cost was observed in treatment C_1, which was 44,566 Rs./ha. When considering the nutrient management, the highest total cost was seen in F_3, totaling 50,303 Rs./ha, while the lowest cost was observed in F_1, which was 47303 Rs./ha. In terms of gross return, the treatment with the highest value was C_4, reaching 1,85,376 Rs./ha, while the lowest gross return was recorded in treatment C_2, which was 1,23,160 Rs./ha. Among the nutrient management, the highest gross return was seen in F_3, amounting to 1,61,872 Rs./ha, while the lowest gross return was observed in F_1, which was 1,47,601 Rs./ha.

When analyzing net return the highest value was found in C_4 treatment, with 1,35,583 Rs./ha followed by C_3 treatment, while the lowest net return was seen in treatment C_2, 72,360 Rs./ha. Among the nutrient management, the highest net return was observed in F_3, 1,11,569 Rs./ha, while the lowest net return was observed in F_1, which was 1,00,298 Rs./ha.

Considering the benefit-cost ratio (B:C ratio) the highest ratio was found in C_4 treatment, with a value of 3.72, while the lowest ratio was seen in treatment C_2, which was 2.42. Among the nutrient management, the highest B:C ratio was observed in F_3, with a value of 3.24, while the lowest ratio wasseen in F_1, which was 3.12.

The results indicate that increasing the level of nutrient management resulted in higher values of cultivation cost, gross return, net return, and B:C ratio. Consequently, the highest values for these parameters were observed in F_3, followed by F_2, while the lowest values were found in F_1 during the experimentation period

Table 4.20 : Effect of cropping system and nutrient management on economics under different treatments:

Treatment	**Total cost of cultivation (Rs. ha^{-1})**	**Gross return (Rs.ha^{-1})**	**Net return (Rs.ha^{-1})**	**B:C ratio**
A. Cropping System				
C_1: Pigeonpea (sole)	44566	128413	83847	2.88
C_2: Groundnut (sole)	50799	123160	72360	2.42
C_3: Pigeonpea +Groundnut (1:1)	48724	180467	131743	3.70
C_4: Pigeonpea +Groundnut (1:2)	49793	185376	135583	3.72
B. Nutrient management				
F_1: 100% RDF	47303	147601	100298	3.12
F_2: 100% RDF+ Borax (5kg/ha)	47803	154587	105784	3.23
F_3: 100% RDF+ Borax(5kg/ha) + FYM (10 t/ha)	50303	161872	111569	3.24

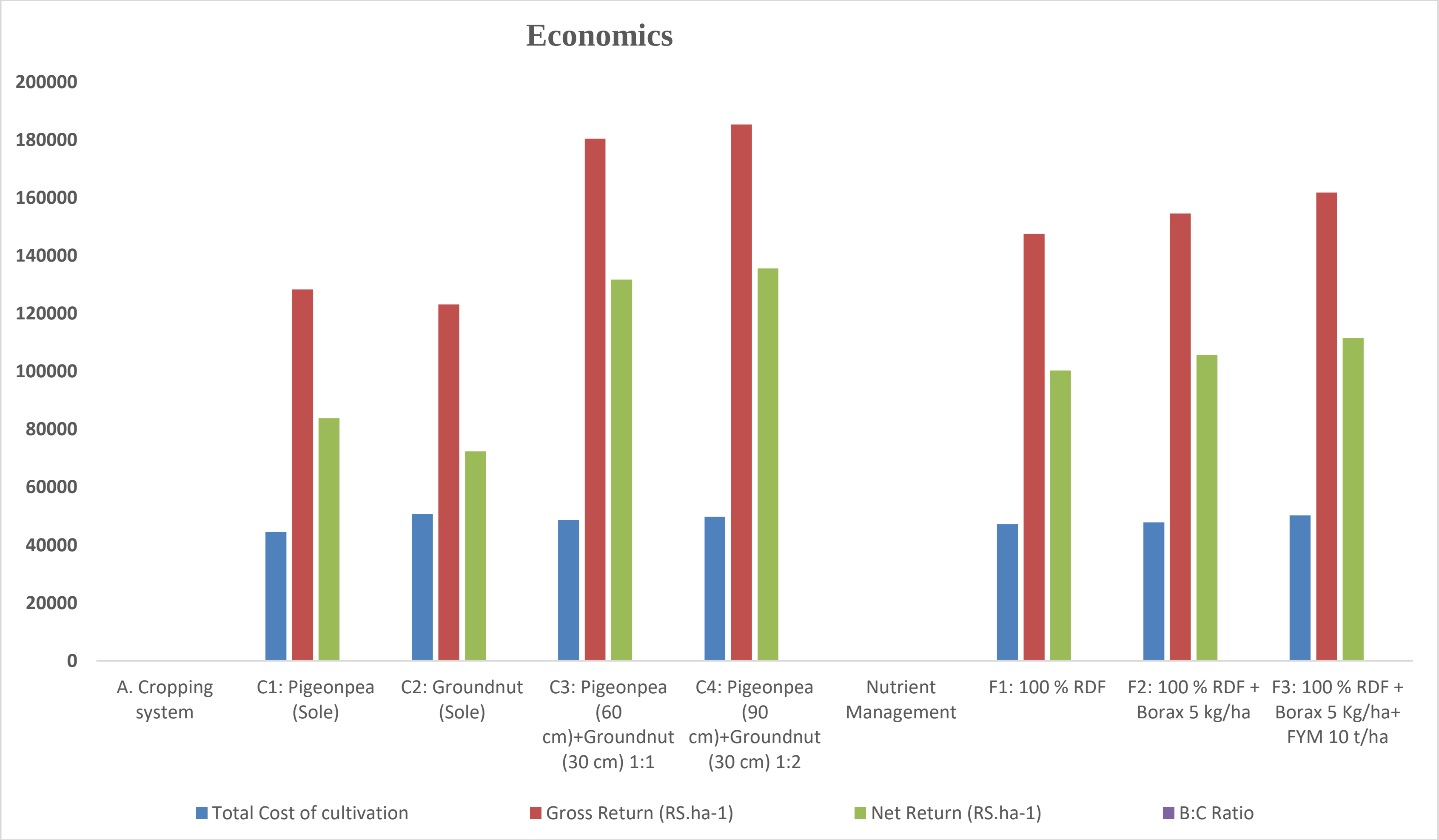

Fig 4.20 - Effect of cropping system and nutrient management on economics under different treatments.

4.21 Effect of cropping systems and nutrient management on OC, N,P,K content

The data presented in **Table 4.21** demonstrate that OC, N, P, K content (kg/ha) varied due to different cropping systems. The C_1 Pigeonpea Sole treatment exhibited the highest OC, N, P, K content (0.41%, 198kg/ha, 14.8 kg/ha, 23.3 kg/ha) , followed by C_3 Pigeonpea + groundnut (1:2). The treatment with C_2 groundnut sole recorded the lowest OC, N, P, K content capacity of 0.34%, 174 kg/ha, 12.9 kg/ha, 21.5 kg/ha.

Effect of nutrient management:

The data suggest that increasing the nutrient management factors improved the OC, N, P, K content of the treatment. The application of F_3 (100% RDF + Borax (5kg/ha) + FYM (10 t/ha) enhanced the OC, N, P, K content capacity compared to F_1 100 % RDF , and there was a further considerable increase.

Table 4.21: Effect of cropping system and nutrient management on OC, N, P, K under different treatments:

Treatment	OC (%)	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)
C1F1	0.39	192	14.4	22.9
C1F2	0.40	195	14.5	23.1
C1F3	0.41	198	14.8	23.3
C2F1	0.32	168	12.6	21.2
C2F2	0.33	169	12.8	21.3
C2F3	0.34	174	12.9	21.5
C3F1	0.36	187	13.9	22.4
C3F2	0.37	189	14.0	22.5
C3F3	0.38	193	`14.2	22.7
C4F1	0.34	175	13.1	21.8
C4F2	0.35	178	13.2	21.9
C4F3	0.36	182	13.3	22.1

4.22 Fresh and dry weed weight (q/ha)

The statistical analysis of the data on the fresh and dry weed weight under different treatments of pigeonpea was performed were analyzed, and the results are summarized in **Table 4.22.**

Effect of cropping systems

The analysis reveals significant variations among different cropping systems in terms of their effects on pigeonpea. The maximum amount of fresh and dry weed weight (33.11 & 8.23 q/ha) was observed in the C_1 pigeonpea sole, while the lowest value (29.18 & 7.11 q/ha) was recorded in the C_4 pigeonpea + groundnut (1:2) treatment.

Effect of nutrient management:

The results presented in **Table 4.22** indicate differences in the fresh and dry weed weight (30.01 & 7.44 q/ha) of pigeonpea due to different levels of nutrient management application. Statistically superior values(32.23 & 7.87 q/ha) were obtained in F_3 treatment , followed by the F_2 (100 % RDF+ Borax 5 kg/ha).

Table 4.22: Effect of cropping system and nutrient management on fresh and dry weight of weed under different treatments:

Treatments	Fresh weed weight (q/ha)	Dry weed weight (q/ha)
Cropping System		
C_1: Pigeonpea (Sole)	33.11	8.23
C_2: Groundnut (Sole)	31.28	7.72
C_3: Pigeonpea (60 cm)+Groundnut (30 cm) 1:1	30.94	7.56
C_4: Pigeonpea (90 cm)+Groundnut (30 cm) 1:2	29.18	7.11
SE (diff.)	**0.97**	**0.16**
CD (P=0.05)	**2.01**	**0.34**
Nutrient management		
F_1: 100 % RDF	30.01	7.44
F_2: 100 % RDF + Borax 5 kg/ha	31.15	7.66
F_3: 100 % RDF + Borax 5 Kg/ha+ FYM 10 t/ha	32.23	7.87
SE (diff.)	**0.84**	**0.14**
CD (P=0.05)	**1.74**	**0.30**

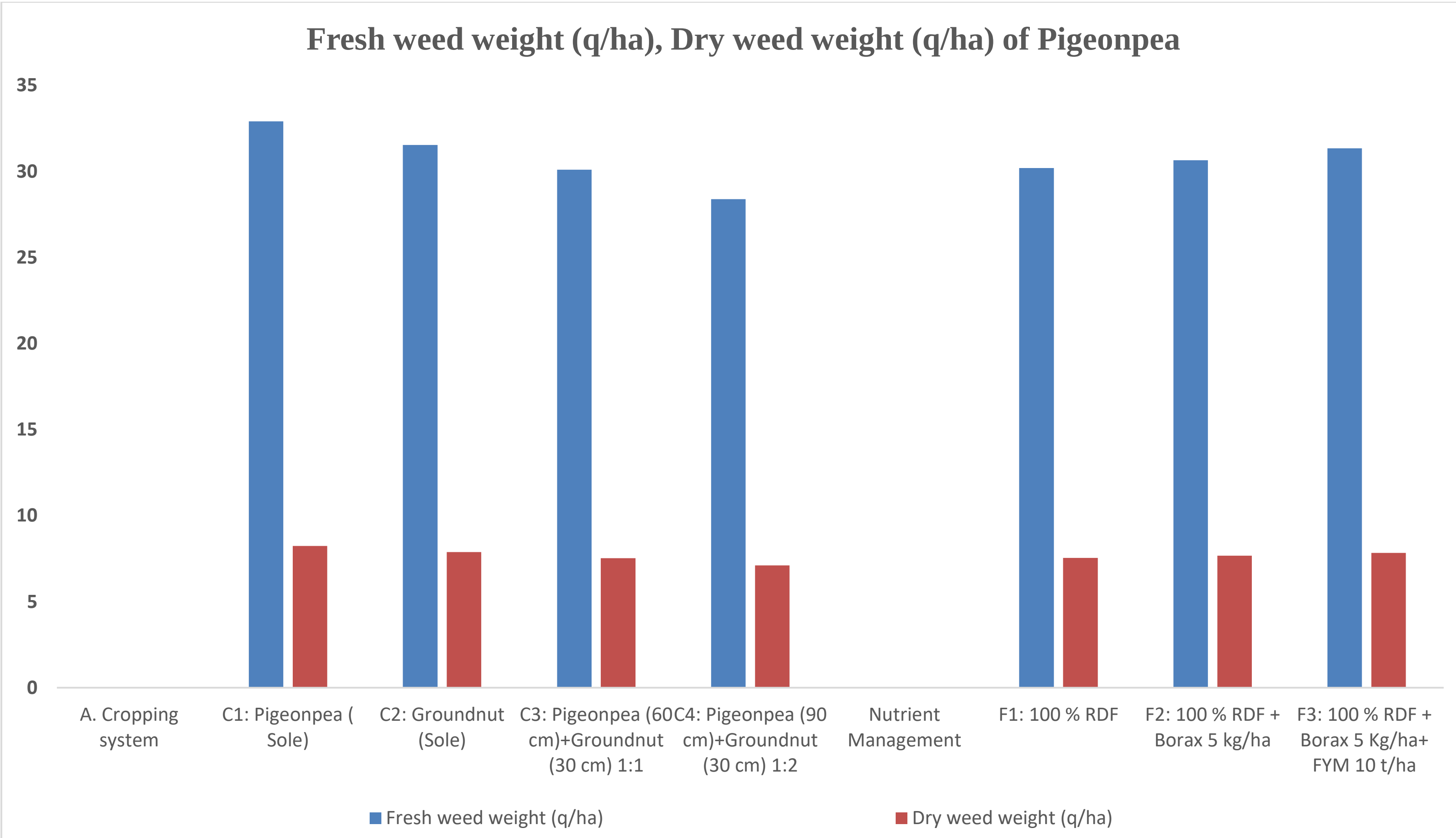

Table 4.22 Effect of cropping system and nutrient management on fresh and dry weed weight under different treatments.

CHAPTER-V

DISCUSSION

Results from the experimental project "Effect of Cropping system and nutrient management on production and water use efficiency of intercrops," which was carried out in the Zaid season of 2022–2023 at the Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, at the Soil Conservation and Water Management Farm.

Numerous points of general interest in crop production are covered in this chapter. These include the data on the relationships between the various characteristics of intercropping systems, growth parameter and yield attributes, and the economics of intercropping pigeonpea and groundnut in relation to production under different nutrient management factors that were explained in the previous chapter. Attempts are being made to distinguish between potential sources of treatment effects when interpreting the data. When deemed essential, the literature references that were obtained are also included, based on their availability. The current investigation produced several results that are of general interest, which are briefly described below.

5.1 Pigeonpea

5.1.1 Initial and final plant stand (‘000 per ha)

Effect of cropping system:

Different cropping systems appear to reflect significant effect on initial and final plant stands **(refer to Table 4.1).** The maximum initial and final plant stand were recorded in Pigeonpea sole while the marked reduction in initial and final plant stand in intercropping systems. It may be due to the reason that intercropping was tested in replacement series where replacement by intercrop might have reduced pigeonpea population. Similar result have been emphasized by **Sharma *et al.* (2010)** who highlighted that pigeonpea intercropped with groundnut showed a reduction in plant population due to competition for below-ground resources, despite both crops having complementary above-ground growth habits.

Effect of Nutrient management:

Additionally, varying amounts of Nutrient management demonstrated non-significant effect on plant population higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.2 Plant height (cm):

Effect of cropping system:

The cropping system displayed considerable variation in the height of pigeonpea plants at all stages of growth **(refer to Table 4.2).** Furthermore, plant height increased at the 60, 90, 120, 150 days after sowing (DAS) progressed until maturity. The tallest plants were observed in sole pigeonpea crops at 60, 90, 120, 150 DAS and maturity stage, followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The shortest plants were found in the pigeonpea + groundnut intercropping treatment with a 1:2 ratio. It may be due to increase the competition foe space, light, water and nutrient within the intercropping system. The findings are in line with those of **Yadav**

***et al.* (2015)**.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on plant height higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.3 Diameter of stem (stem girth):

Effect of cropping system:

The cropping system displayed considerable variation in the diameter of stem of pigeonpea plants at all stages of growth **(refer to Table 4.3).** Furthermore, diameter of stem increased at the 60, 90, 120, 150 days after sowing (DAS) progressed until maturity. The maximum diameter of stems were observed in pigeonpea + groundnut intercropping (1:2) crops at 60, 90, 120, 150 DAS and maturity stage, followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum diameter of stem were found in pigeonpea sole. The findings are in line with those of **Chaudhary *et al.* (2017)**

Effect of Nutrient management:

Additionally, varying amounts of Nutrient management demonstrated significant effect on diameter of stem higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.4 Number of branches – primary, secondary and tertiary branches:

Effect of cropping system:

The cropping system displayed considerable variation in the number of branches – primary, secondary and tertiary branches of pigeonpea plants at all stages of growth **(refer to Table 4.4).** Furthermore, number of branches – primary, secondary and tertiary branches of pigeonpea plants increased at the 60, 90, 120, 150 days after sowing (DAS) progressed until maturity. The maximum number of branches were observed in sole pigeonpea crops at 60, 90, 120, 150 DAS and maturity stage, followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The shortest plants were found in the pigeonpea + groundnut intercropping treatment with a 1:2 ratio. It may be due to improved soil fertility and moisture availability in intercropping system. The findings are in line with those of **Singh *et al.* (2016).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on number of branches – primary, secondary and tertiary branches higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.5 Number of leaves:

Effect of cropping system:

The cropping system displayed considerable variation in the number of leaves of pigeonpea plants at all stages of growth except at maturity **(refer to Table 4.5).** The number of leaves fell and reduced at maturity **Furthermore**, the number of leaves increased at the 60, 90, 120, 150 days after sowing (DAS). The number of leaves reduced at maturity. The maximum number of leaves were observed in pigeonpea + groundnut intercropping (1:2) crops at 60, 90, 120, 150 DAS, followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of leaves were found in pigeonpea sole. The findings are in line with those of **Patil *et al.* (2013).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on number of branches – primary, secondary and tertiary branches higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.6 Litter fall of pigeonpea (q/ha)

Effect of cropping system:

The data indicate **(refer to Table 4.21) significant variations** in litter fall of pigeonpea after harvest among different cropping systems. The C_1 Pigeonpea sole exhibited the maximum amount of litter fall of pigeonpea (18.64 q/ha) , while the minimum amount of litter fall of pigeonpea (13.04 q/ha) of was observed in the C_4 Pigeonpea + Groundnut (1:2).

Effect of Nutrient management:

The data indicates that on increasing nutrient management levels led to more litter fall of pigeonpea. Specifically, applying F_1 100% RDF gave (14.96 q/ha) , and highest (16.25 q/ha) when F_3 100% RDF + Borax 5kg/ha + FYM 10 t/ha was used.

5.1.7 Number of pod/plant:

Effect of cropping system:

The cropping system displayed considerable variation in the number of pods/plants of pigeonpea plants at all stages of growth **(refer to Table 4.7)** . The maximum number of pods/plant were observed in pigeonpea + groundnut intercropping (1:2) followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of pods/plants were found in pigeonpea sole. The findings are in line with those of **Patel *et al.* (2014).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a number of pods /plants higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.8 Number of seed/pod:

Effect of cropping system:

The cropping system displayed considerable variation in the number of seed/pod of pigeonpea plants at all stages of growth **(refer to Table 4.7)** . The maximum number of seed/pod were observed in pigeonpea + groundnut intercropping (1:2) followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of seed/pod were found in pigeonpea sole. The findings are in line with those of Patel *et al.* (2013)**.**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a number of seed/pod higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.9 Seed weight (g)/plant :

Effect of cropping system:

The cropping system displayed considerable variation in the seed weight/plant of pigeonpea plants at all stages of growth **(refer to Table 4.7)**. The maximum number of seed weight/plant were observed in pigeonpea + groundnut intercropping (1:2) followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of seed/pod were found in pigeonpea sole. The findings are in line with those of **Patel *et al.* (2013).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a number of seed/pod higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.10 Seed yield(q/ha) :

Effect of cropping system:

The cropping system displayed considerable variation in the seed yield of pigeonpea plants at all stages of growth **(refer to Table 4.8)**. The maximum seed yield were observed in pigeonpea sole followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of 1000 seed weight were found in pigeonpea + groundnut intercropping (1:2).

This is due to intense competition for below-ground resources and suboptimal plant growth conditions. . The findings are in line with those of **Kumar *et al.* (2012)**.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a seed yield higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.11 Straw yield (q/ha) :

Effect of cropping system:

The cropping system displayed considerable variation in the straw yield of pigeonpea plants at all stages of growth . The maximum straw yield were observed in pigeonpea sole followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum straw yield were found in pigeonpea + groundnut intercropping (1:2). This is due to competition for resources such as nutrients, water, and light .

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a straw yield higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.12 Stick yield (q/ha) :

Effect of cropping system:

The cropping system displayed considerable variation in the stick yield of pigeonpea plants at all stages of growth **(refer to Table 4.8)**. The maximum stick yield were observed in pigeonpea sole followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum stick yield were found in pigeonpea + groundnut intercropping (1:2). This is due to competition for resources such as nutrients, water, and light . The findings are in line with those of **Yadav *et al.* (2013)**.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a stick yield higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.13 Biological yield (q/ha):

Effect of cropping system:

The cropping system displayed considerable variation in the biological yield of pigeonpea plants at all stages of growth **(refer to Table 4.8)**. The maximum biological yield were observed in pigeonpea sole followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum biological yield were found in pigeonpea + groundnut intercropping (1:2). This is due to increased competition for resources and suboptimal growth conditions created by the presence of groundnut. The findings are in line with those of **Yadav *et al.* (2015)**.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a biological yield higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.14 1000 Seed weight (g) :

Effect of cropping system:

The cropping system displayed considerable variation in the 1000 seed weight of pigeonpea plants at all stages of growth **(refer to Table 4.9)**. The maximum number of seed weight/plant were observed in pigeonpea + groundnut intercropping (1:2) followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of 1000 seed weight were found in pigeonpea sole. This was due to enhanced nutrient uptake and reduced competition stress, resulting in better seed development. The findings are in line with those of **Reddy *et al.* (2016)**.

Effect of Nutrient management:

Additionally, varying amounts of Nutrient management demonstrated significant effect on a 1000-seed weight higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.15 Number of seed/plant:

Effect of cropping system:

The cropping system displayed considerable variation in the number of seed /plant of pigeonpea plants at all stages of growth **(refer to Table 4.9)**. The maximum number of seed weight/plant were observed in pigeonpea +

groundnut intercropping (1:2) followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum number of seed/plant were found in pigeonpea sole. This is due to reduced competition for light and nutrients, which allowed pigeonpea plants to develop more pods and seeds. The findings are in line with those of **Kumar *et al.* (2014)**.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a number of seed/ plant higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF)

5.1.16 Harvest index (%):

Effect of cropping system:

The cropping system displayed considerable variation in the harvest index of pigeonpea plants at all stages of growth **(refer to Table 4.9)**. The maximum harvest index were observed in pigeonpea sole followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum harvest index were found in pigeonpea + groundnut intercropping (1:2). This is due to increased competition for resources and suboptimal growth conditions created by the presence of groundnut.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a harvest index higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.1.16 Stubbles of previous pigeonpea crop (q/ha):

Effect of cropping system:

The cropping system displayed considerable variation in the stubbles of previous pigeonpea crop of pigeonpea plants at all stages of growth **(refer to Table 4.9(a))**. The maximum stubbles of previous pigeonpea crop were observed in pigeonpea sole followed by the pigeonpea + groundnut intercropping treatment in a 1:1 ratio. The minimum stubbles of previous pigeonpea crop were found in pigeonpea + groundnut intercropping (1:2). This is due to increased competition for resources and suboptimal growth conditions created by the presence of groundnut.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on a stubbles of previous pigeonpea crop higher results were obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2 Groundnut

5.2.1 Initial and final plant stand ('000 per ha)

Effect of cropping system:

Different cropping systems appear to reflect significant effect on initial and final plant stands **(Table 4.1).** The maximum initial and final plant stand were recorded in Groundnut sole while the marked reduction in initial and final plant stand in intercropping systems. This is due to the reason that aggressive growth and resource utilization of pigeonpea, which overshadowed the groundnut plants. Similar result have been emphasized by **Singh *et al.* (2012)**.

Effect of Nutrient Management:

Additionally, varying amounts of Nutrient management demonstrated significant effect on plant population higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.3 Plant height (cm):

Effect of cropping system:

The cropping system displayed considerable variation in the height of groundnut plants at all stages of growth **(refer to Table 4.10).** Furthermore, plant height increased at the 30, 60 days after sowing (DAS) progressed until maturity. The tallest plants were observed in pigeonpea + groundnut intercropping treatment in a 1:1 ratio at 30, 60 DAS and maturity stages, followed by the pigeonpea + groundnut intercropping treatment with a 1:2 ratio. The shortest plants were found in the sole groundnut crops. It is due to reason that the nitrogen-fixing ability of pigeonpea, which improved the soil nitrogen content and benefited groundnut growth. The findings are in line with those of **Sharma *et al.* (2010)**.

Effect of Nutrient management:

Additionally, varying amounts of Nutrient management demonstrated a significant effect on plant height higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.4 Number of branches :

Effect of cropping system:

The cropping system displayed considerable variation in the number of branches of groundnut plants at all stages of growth **(refer to Table 4.11).** Furthermore, number of branches of pigeonpea plants increased at the 30, 60 days after sowing (DAS) progressed until maturity. The maximum number of branches were observed in sole groundnut crops at 30, 60 DAS and maturity stage, followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The shortest plants were found in the pigeonpea + groundnut intercropping treatment with a 1:1 ratio. It is due to the competitive effects of pigeonpea, especially in terms of below-ground resource allocation. . The findings are in line with those of **Reddy *et al.* (2018).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on number of branches – primary, secondary and tertiary branches higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.5 Number of pods/plant :

Effect of cropping system:

The cropping system displayed considerable variation in the number of pods/plant of groundnut plants at all stages of growth **(refer to Table 4.12).** The maximum number of pods/plant were observed in pigeonpea + groundnut intercropping (1:1) crops at 30, 60 DAS, followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum number of leaves were found in groundnut sole. This is due to the nitrogen fixation by pigeonpea which improved soil fertility, which positively affected groundnut pod production. The findings are in line with those of **Kumar *et al.* (2012).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on number of pods/plant higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.6 100-Kernel weight:

Effect of cropping system:

The cropping system displayed considerable variation in the 100-kernel weight of groundnut plants at all stages of growth **(refer to Table 4.12).** The maximum 100-kernel weight were observed in pigeonpea + groundnut intercropping (1:1) , followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum 100-kernel weight were found in groundnut sole. This is due to the increase to enhanced soil fertility and improved moisture retention due to the presence of pigeonpea.. The findings are in line with those of **Srinivasan *et al.* (2014).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on 100-kernel weight higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.7 Pod yield (q/ha) :

Effect of cropping system:

The cropping system displayed considerable variation in pod yield of groundnut plants **(refer to Table 4.13).** The maximum pod yield were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum pod yield were found in pigeonpea + groundnut intercropping (1:1). This is due to increased competition for soil nutrients and water. The findings are in line with those of **Reddy *et al.* (2005).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on pod yield higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.8 Biological yield (q/ha) :

Effect of cropping system:

The cropping system displayed considerable variation in biological yield of groundnut plants **(refer to Table 4.13).** The maximum pod yield were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum pod yield were found in pigeonpea + groundnut intercropping (1:1). The decrease was due to the shading effect and resource competition.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on biological yield higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.9 Shelling percentage (%):

Effect of cropping system:

The cropping system displayed considerable variation in shelling percentage of groundnut plants **(refer to Table 4.14).** The maximum shelling percentage were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum pod yield were found in pigeonpea + groundnut intercropping (1:1). This is due to reduced pod filling due to resource competition and the altered microenvironment. The findings are in line with those of **Reddy *et al.* (2018).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on shelling percentage(%) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.10 Harvest index (%):

Effect of cropping system:

The cropping system displayed considerable variation in harvest index of groundnut plants **(refer to Table 4.14).** The maximum harvest index were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum harvest index were found in pigeonpea + groundnut intercropping (1:1). This is due to the shading effects of pigeonpea and competition for below-ground resources.. The findings are in line with those of **Singh *et al.* (2008).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on harvest index(%) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.11 Kernel yield(q/ha):

Effect of cropping system:

The cropping system displayed considerable variation in kernel yield of groundnut plants **(refer to Table 4.15).** The maximum kernel yield were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum kernel yield were found in pigeonpea + groundnut intercropping (1:1). This is due to the shading effects of pigeonpea and competition for below-ground resources. The findings are in line with those of **Singh *et al.* (2008).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on harvest index(%) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.12 Haulm yield(q/ha):

Effect of cropping system:

The cropping system displayed considerable variation in haulm yield of groundnut plants **(refer to Table 4.15).** The maximum haulm yield were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum kernel yield were found in pigeonpea + groundnut intercropping (1:1). This is due to competition for nutrients and water, as well as reduced light availability due to pigeon pea's shading effect. The findings are in line with those of **Yadav *et al.* (2008).**

Effect of Nutrient management:

Additionally, varying amounts of Nutrient management demonstrated significant effect on haulm yield higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.13 Protein content (%):

Effect of cropping system:

- The cropping system displayed considerable variation in of groundnut plants **(refer to Table 4.16).** The maximum protein content (%) were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum protein content (%) were found in pigeonpea + groundnut intercropping (1:1). This is due to competition for nitrogen and other essential nutrients. The findings are in line with those of **Reddy *et al.* (2012).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated Significant effect on protein content(%) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.14 Protein yield (kg/ha):

Effect of cropping system:

The cropping system displayed considerable variation in of groundnut plants **(refer to Table 4.16).** The maximum protein yield(kg/ha) were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum protein yield(kg/ha) were found in pigeonpea + groundnut intercropping (1:1). This is due to competitive interaction for resources led to lower seed protein content compared to sole cropping.

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on protein yield (kg/ha) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.15 OIL CONTENT(%):

Effect of cropping system:

The cropping system displayed considerable variation in of groundnut plants **(refer to Table 4.17).** The maximum oil content (%) were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum oil content(%) were found in pigeonpea + groundnut intercropping (1:1). This is due to increased competition for nutrients and water, which affected the overall seed quality and oil accumulation. The findings are in line with those of **Kumar *et al.* (2014).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on oil content(%) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.2.16 Oil yield (kg/ha):

Effect of cropping system:

The cropping system displayed considerable variation in of groundnut plants **(refer to Table 4.17).** The maximum oil yield(kg/ha) were observed in groundnut sole followed by the pigeonpea + groundnut intercropping treatment in a 1:2 ratio. The minimum oil yield(kg/ha) were found in pigeonpea + groundnut intercropping (1:1). The reduced oil yield in intercropping was due to competition for resources and less favorable growing conditions. The findings are in line with those of **Singh *et al.* (2011).**

Effect of Nutrient management :

Additionally, varying amounts of Nutrient management demonstrated significant effect on oil yield (kg/ha) higher results obtained when F_3 (100% RDF + Borax 5kg /ha + FYM 10 t/ha) was incorporated into the soil, compared to the lowest results observed under F_1 (100% RDF).

5.3 Pigeonpea seed equivalent yield

Effect of cropping system:

The data on Pigeonpea equivalent yield for various treatments showed that the seed yield was notably affected by the significant different treatments throughout the observation period **(refer to Table 4.18)**. The pigeonpea equivalent yield was highest in the pigeonpea + groundnut intercropping treatment with a 1:2 ratio, while the lowest equivalent yield was observed in the groundnut sole among different cropping system. **Bhagat *et al*. (2013)** have also reported the similar trend in their studies.

Effect of nutrient management:

The pigeonpea equivalent yield significantly achieved by applying F_3 100% RDF+ Borax 5 kg/ha + FYM 10t/ha, likely because of the positive impact of combining fertilizer and organic sources while the lowest pigeonpea equivalent yield obtained in F_1 100% RDF these findings also are line with **Kumar *et al.*(2016).**

5.4 Land equivalent ratio

Effect of cropping system:

The intercropped treatments exhibited a land equivalent ratio greater than one presented **(refer to Table 4.18)**, indicating the positive impact of intercropping on the productivity of the individual crops. Among these treatments, the pigeonpea + groundnut intercropping in a 1:2 ratio achieved the highest value of (1.42) suggesting relatively higher productivity within this system compared to other intercropping system while the lowest in sole . This could be attributed to the efficient utilization of land and growth resources by the crops in intercropping systems. These findings also ascribed by **Patra and Nayak (2020).**

Effect of nutrient management:

The application of F_3 100% RDF+ Borax 5kg/ha + FYM 10t/ ha in the soil resulted in the most considerable LER value (1.21), followed by F_2, and the lowest LER value was observed under F_1 100% RDF similar result also reported by **Reddy and Rao (2022).**

5.5 Total water use:

Effect of cropping system:

The water use data for various treatments were collected and presented in **Table 4.19.** The results clearly indicate that the treatment with pigeonpea + groundnut in a 1:2 ratio recorded the highest water use of (333.42 mm), followed by the pigeonpea-groundnut intercropping treatment in 1:1 ratio with (323.23 mm), and the lowest water use was observed in the sole groundnut crop.

Effect of nutrient management :

The influence of water usage at varying levels of FYM application was demonstrated. The highest water usage was observed (310.11 mm) with the F_3 ,and minimum of 291.21 mm with F_1 100% RDF. Numerous other researchers have also noted the positive impact of FYM. **Kumar *et al.* (2020)**

5.6 Water use efficiency

Effect of cropping system:

The data indicate **(refer to Table 4.19)** significant variations in water use efficiency (WUE) among different cropping systems. The Pigeonpea + groundnut (1:2) intercropping exhibited the highest WUE (6.71 kg seed per hectare per mm of water), while the lowest WUE of was observed in the groundnut sole (5.53 kg seed per hectare per mm of water). The similar result reported by **Reddy *et al.* (2010)**

Effect of Nutrient management:

The data indicates that on increasing nutrient management levels led to improved water use efficiency. Specifically, applying F_1 100% RDF gave (6.11 kg seed per hectare per mm of water), and this improvement was further significant and highest (6.37 kg seed per hectare per mm of water) when F_3 100% RDF + Borax 5kg/ha + FYM 10t/ha was used. The increase in WUE with increasing nutrient management factors can be attributed to the rise in seed yield, which also showed a positive correlation with each increase in nutrient management . These findings are in line with those of **Saha *et al.* (2010).**

5.7 Economics

Effect of cropping system:

The data related to cost of cultivation, gross return, net return and B: C ratio presented in **(refer to Table 4.20).** Total cost of cultivation was higher in groundnut sole Rs. 50,799 compared to intercropping due to high cost of seed price and seed rate kg ha^{-1} and minimum in sole pigeonpea Rs. 44,566, while the Pigeonpea + groundnut (1:2) intercropping demonstrated a maximum gross income of Rs. 1,85,376 and a net return of Rs. 1,35,583 . On the other hand, the lowest net return was observed in the groundnut sole and pigeonpea sole while pigeonpea + groundnut (1:1) intercropping treatment compared to other intercropped treatments give the lowest gross return and net return. Intercropping, in general, proved to be commercially superior to sole crops. Additionally, the treatment of pigeonpea + groundnut (1:2) exhibited the highest benefit-cost (B:C) ratio of 3.72, while the lowest B:C ratio was observed in the pigeonpea sole (2.88) and groundnut sole (2.42) treatment throughout the investigation. Similar findings were reported by **Reddy & Reddy (2008)**.

Effect of nutrient management:

The cost of cultivation & gross return from F_3 amounted to Rs. 50,303 and 1,61,872 , while the lowest gross return was observed in F_1 100% RDF. The F_3 100% RDF + Borax 5kg/ha + FYM 10t/ha also recorded the highest net return of Rs. 1,11,569 with the lowest net return obtained from F_1. Additionally, F_3 had the highest B:C ratio of (3.24), while the lowest B:C ratio (3.12) was observed in F_1. The increase in gross and net returns, as well as the B:C ratio, across various treatments, can be attributed to higher yields and corresponding prices. These finding agreement with those reported by **Chandra & Singh (2019).**

5.8 OC, N, P, K content after harvest (kg/ha)

Effect of cropping system:

The data indicate **(refer to Table 4.21)** variations in OC, N, P, K content after harvest among different cropping systems. The C_1 Pigeonpea sole exhibited the highest OC, N, P, K content (118.80 kg/ha) , while the lowest OC, N, P, K content (0.41%, 198kg/ha, 14.8 kg/ha, 23.3 kg/ha) of was observed in the C_2 Groundnut sole (0.34%, 174 kg/ha, 12.9 kg/ha, 21.5 kg/ha).

Effect of Nutrient management:

The data indicates that on increasing nutrient management levels led to improved OC, N, P, K content capacity of soil. Specifically, applying F_1 100% RDF gave (86.38 kg/ha OC, N, P, K content) , and highest (99.16 kg/ha OC, N, P, K content) when F_3 100% RDF + Borax 5kg/ha + FYM 10t/ha was used.

5.10 Fresh and dry weed weight (q/ha)

Effect of cropping system:

The data indicate **(refer to Table 4.22)** fresh and dry weed weight after harvest among different cropping systems. The C_1 Pigeonpea sole exhibited the maximum amount of fresh and dry weed weight (32.91 & 8.23 q/ha) , while the minimum amount of fresh and dry weed weight (28.40 & 7.10 q/ha) of was observed in the C_4 Pigeonpea + Groundnut (1:2).

Effect of Nutrient management:

The data indicates that on increasing nutrient management levels led to more fresh and dry weed weight. Specifically, applying F_1 100% RDF gave (30.20 & 7.55 q/ha) , and highest (31.35 & 7.84 q/ha) when F_3 100% RDF + Borax 5kg/ha + FYM 10t/ha was used.

CHAPTER-VI

SUMMARY AND CONCLUSION

At the Chandra Shekhar Azad University of Agriculture & Technology in Kanpur's Soil Conservation and Water Management Farm, a field study named "Effect of cropping system and nutrient management on production and water use efficiency of intercrops" was conducted in Zaid 2022–2023. There were four intercropping systems in the trial. A. consists of C1 (pigeonpea sole 60 cm apart), C2 (groundnut sole 30 cm apart), C3 (pigeonpea(60 cm) + groundnut(30 cm) (1:1), C4 (pigeonpea (90 cm) + groundnut(30 cm) (1:2), and F1 (100% RDF), F2 (100% RDF + Borax 5kg/ha), and F3 (100% RDF + Borax 5kg/ha + FYM 10 t/ha) as nutrient management elements.

The base crop was taken pigeonpea and groundnut was taken as intercrop. The treatment was replicated thrice in randomised block design. The pigeonpea variety "UPAS-120" and groundnut variety "Avtar" were sown in the experiment.

An uniform dose of 20 kg N + 40 kg P_2O_5 + 20 kg K_2O / ha in sole pigeonpea and 20 kg N + 40 kg P_2O_5 + 30 kg K_2O / ha in sole groundnut. In intercropping each crop was fertilised at same rates but on the basis of actual area sown under component crop. The fertiliser were applied row wise. Seed for sowing was used @15 kg per hectare in pigeonpea and @100 kg per hectare in groundnut in sole cropping. Recommended package of tillage practises was followed. The crops were sown on 20th April, 2023 at a depth of 4-5 cm from the surface.

The salient findings emerged out during the investigation have been summarised below

6.1 Pigeonpea

6.1.1 Plant population

I) The maximum plant population was found in pigeonpea sole in both initial and final population. The lowest plant population was found in pigeonpea + groundnut (1:1) found in intercropping system in both initial and final stages.

II) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.2 Plant height

I) The maximum plant height was observed in pigeonpea sole in all the stages (60, 90, 120, 150 DAS and at maturity).

II) The plant height was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest plant height was observed in pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by

F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.3 Diameter of stem

I) The maximum diameter of stem was observed in pigeonpea + groundnut (1:2) intercropping system at all stages of growth(60,90,120,150 DAS and at maturity).

II) The diameter of stem was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The least diameter of stem was found in pigeonpea sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.4 Number of branches – primary, secondary and tertiary

I) The maximum number of branches – primary, secondary and tertiary was observed in pigeonpea + groundnut (1:2) intercropping system.

II) The number of branches – primary, secondary and tertiary was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The least number of branches – primary, secondary and tertiary was found in pigeonpea sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.5 Number of leaves

I) The maximum number of leaves was observed in pigeonpea + groundnut (1:2) intercropping system at all stages of growth(60,90,120,150 DAS and at maturity).

II) The number of leaves was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The least number of leaves was found in pigeonpea sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.6 Number of pods per plant

I) The maximum number of pods per plant was observed in pigeonpea + groundnut (1:2) intercropping system at all stages of growth(60,90,120,150 DAS and at maturity).

II) The number of pods per plant was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The least number of pods per plant was found in pigeonpea sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.7 Number of seeds per pod

I) The maximum number of seeds per pod was observed in pigeonpea + groundnut (1:2) intercropping system at all stages of growth(60,90,120,150 DAS and at maturity).

II) The number of seeds per pod was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The least number of seeds per pod was found in pigeonpea sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.8 Seed weight(g) per plant

I) The maximum seed weight per plant was observed in pigeonpea + groundnut (1:2) intercropping system at all stages of growth(60,90,120,150 DAS and at maturity).

II) The seed weight per plant was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The least seed weight per plant was found in pigeonpea sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.9 1000-Seed weight

- **I)** The maximum 1000-seed weight was observed in pigeonpea + groundnut (1:2) intercropping system at all stages of growth(60,90,120,150 DAS and at maturity).
- **II)** The seed weight per plant was then followed by pigeonpea + groundnut (1:1) intercropping system.
- **III)** The least seed weight per plant was found in pigeonpea sole.
- **IV)** Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.10 Seed yield (q/ha)

- **I)** The maximum seed yield was observed in pigeonpea sole in all the stages (60, 90, 120, 150 DAS and at maturity).
- **II)** The seed yield was then followed by pigeonpea + groundnut (1:1) intercropping system.
- **III)** The lowest seed yield was observed in pigeonpea + groundnut (1:2) intercropping system.
- **IV)** Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.11 Biological yield (q/ha)

- **I)** The maximum biological yield was observed in pigeonpea sole in all the stages (60, 90, 120, 150 DAS and at maturity).

II) The biological yield was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest biological yield was observed in pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.12 Harvest index (%)

I) The maximum harvest index was observed in pigeonpea sole.

II) The harvest index was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest harvest index was observed in pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.13 Stick yield (q/ha)

I) The maximum stick yield was observed in pigeonpea sole.

II) The stick yield was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest stick yield was observed in pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by

F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.14 Number of seed per plant

I) The maximum number of seed per plant was observed in pigeonpea sole.

II) The number of seed per plant was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest number of seed per plant was observed in pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.1.15 Stubbles of previous pigeonpea crop

I) The maximum stubbles of previous pigeonpea crop was observed in pigeonpea sole.

II) The stubbles of previous pigeonpea crop was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest stubbles of previous pigeonpea crop was observed in pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2 Groundnut

6.2.1 Plant population

I) The maximum plant population was found in groundnut sole in both initial and final population. It was followed by pigeonpea + groundnut (1:2) intercropping system. The lowest plant population was found in pigeonpea + groundnut (1:1) found in intercropping system in both initial and final stages.

II) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.2 Plant height

I) The maximum plant height was observed in pigeonpea + groundnut (1:1) intercropping system all the stages (30,60 DAS and at maturity).

II) The plant height was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest plant height was observed in groundnut sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.3 Number of branches

I) The maximum number of branches was observed in pigeonpea + groundnut (1:1) intercropping system all the stages (30,60 DAS and at maturity).

II) The plant height was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest plant height was observed in groundnut sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.4 Number of pods per plant

I) The maximum number of pods per plant was observed in pigeonpea + groundnut (1:1) intercropping system all the stages (30,60 DAS and at maturity).

II) The number of pods per plant was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest number of pods per plant was observed in groundnut sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.5 100-Kernel weight

I) The maximum 100-kernel weight was observed in pigeonpea + groundnut (1:1) intercropping system all the stages (30,60 DAS and at maturity).

II) The 100-kernel weight was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest 100-kernel weight was observed in groundnut sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.6 Pod yield (q/ha)

I) The maximum pod yield was observed in groundnut sole.

II) The pod yield was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest pod yield was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.7 Biological yield (q/ha)

I) The maximum biological yield was observed in groundnut sole.

II) The biological yield was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest biological yield was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.8 Shelling percentage (%)

I) The maximum shelling percentage was observed in groundnut sole.

II) The shelling percentage was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest shelling percentage was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.9 Harvest index (%)

I) The maximum harvest index was observed in groundnut sole.

II) The harvest index was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest harvest index was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.10 Kernel yield (q/ha)

I) The maximum kernel yield was observed in groundnut sole.

II) The kernel yield was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest kernel yield was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.11 Haulm yield (q/ha)

I) The maximum haulm yield was observed in groundnut sole.

II) The haulm yield was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest haulm yield was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.12 Protein content (%)

I) The maximum protein content(%) was observed in groundnut sole.

II) The protein content(%) was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest protein content(%) was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.13 Protein yield (kg/ha)

- **I)** The maximum protein yield (kg/ha) was observed in groundnut sole.
- **II)** The protein yield (kg/ha) was then followed by pigeonpea + groundnut (1:2) intercropping system.
- **III)** The lowest protein yield (kg/ha) was observed in in pigeonpea + groundnut (1:1) intercropping system.
- **IV)** Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.14 Oil content (%)

- **I)** The maximum oil content(%) was observed in groundnut sole.
- **II)** The oil content(%) was then followed by pigeonpea + groundnut (1:2) intercropping system.
- **III)** The lowest oil content(%) was observed in in pigeonpea + groundnut (1:1) intercropping system.
- **IV)** Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.2.15 Oil yield (kg/ha)

- **I)** The maximum oil yield (kg/ha) was observed in groundnut sole.
- **II)** The oil yield (kg/ha) was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest oil yield (kg/ha) was observed in in pigeonpea + groundnut (1:1) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.3 Pigeonpea seed equivalent yield

I) The maximum pigeonpea seed equivalent yield was observed in pigeonpea + groundnut (1:2) intercropping system.

II) The pigeonpea seed equivalent yield was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest pigeonpea seed equivalent yield was observed in in groundnut sole

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.4 Land equivalent ratio (LER)

I) The maximum land equivalent ratio (LER) was observed in pigeonpea + groundnut (1:2) intercropping system.

II) The land equivalent ratio (LER) was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest land equivalent ratio (LER) was observed in in groundnut sole and pigeonpea.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2

which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.5 Economics

I) The highest cost of cultivation was recorded under groundnut sole followed by Pigeonpea+ groundnut (1:2) and thereafter followed by Pigeonpea + groundnut (1:1) and minimum was in pigeonpea sole.

II) Highest Gross return was recorded under Pigeonpea+ groundnut (1:2) followed by Pigeonpea + groundnut (1:1) and thereafter followed by Pigeonpea sole and minimum was in groundnut sole.

III) The highest net return was recorded under pigeonpea + groundnut (1:2) intercropping (Rs 135583/ha) followed by pigeonpea + groundnut(1:1) (131743/ha) respectively and lowest under groundnut sole (Rs. 72360/ha).

IV) The maximum cost: benefit ratio was recorded under pigeonpea + groundnut (1:2) intercropping (3.72) followed by pigeonpea + groundnut(1:1) (3.70) respectively and lowest under groundnut sole (2.42).

6.6 OC, N, P, K content after harvest (kg/ha)

I) The maximum OC, N, P, K content was observed in C_1 pigeonpea sole.

II) The OC, N, P, K content was then followed by pigeonpea + groundnut (1:2) intercropping system.

III) The lowest OC, N, P, K content was observed in C_2 groundnut sole.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2

which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.7 Litter fall of pigeonpea (q/ha)

I) The maximum litter fall of pigeonpea was observed in C_1 pigeonpea sole.

II) The amount of litter fall of pigeonpea was then followed by pigeonpea + groundnut (1:1) intercropping system.

III) The lowest amount of litter fall of pigeonpea (q/ha) was observed in C_4 pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the least result was shown by F_1 which contained only 100 % RDF.

6.8 Fresh and dry weed weight (q/ha)

I) The maximum fresh and dry weed weight was observed in C_1 pigeonpea sole (32.91 & 8.23 q/ha).

II) The amount of fresh and dry weed weight was then followed by C_2 groundnut sole intercropping system.

III) The lowest amount of fresh and dry weed weight (28.40 & 7.10 q/ha) was observed in C_4 pigeonpea + groundnut (1:2) intercropping system.

IV) Effect of nutrient management viz. of F_3 which contained 100% RDF + Borax 5 kg /ha + FYM 10 t/ha showed the best result followed by F_2 which contained 100% RDF + Borax 5kg /ha and the lowest result was shown by F_1 which contained only 100 % RDF.

Conclusion:

The result of present study can be concluded as under:

- The base crop of pigeonpea performed better in intercropping. The sole pigeonpea attaining more values of growth and yield attributes than intercrop and groundnut also performed almost similar in sole and intercropping system.
- The intercropping system of C_4: Pigeonpea + Groundnut (1:2) gave significantly maximum (22.13 q ha^{-1}) pigeonpea equivalent grain yield and also had the highest land equivalent ratio (LER) of 1.42 compared to other cropping systems.
- Regarding water use efficiency, the treatment of C_4: pigeonpea + groundnut (1:2) system exhibited the maximum water use efficiency (WUE) of (6.61 kg seed ha^{-1} mm^{-1} of water) and lowest (5.45 kg seed ha^{-1} mm^{-1} of water)in groundnut (sole). The application of F_3 (100% RDF+ Borax+ FYM 10 t/ha) further improve the water use efficiency.
- The maximum net return of Rs. 1,35,583 ha^{-1} was recorded in the treatment of C_4: pigeonpea + groundnut (1:2) exhibiting the commercially superior over the sole cropping. Moreover, maximum B:C ratio (3.72) also recorded inC_4: pigeonpea + groundnut (1:2) treatment and the increasing nutrient management showed increasing values of these parameters including net return and B:C ratio.

In conclusion, it can be inferred that the combination of C_4: pigeonpea + groundnut (1:2) with F_3 (100% RDF+ Borax 5kg/ha+ FYM 10 t/ha) has proven to be highly effective and profitable in sustaining yields in terms of pigeonpea equivalent yield, land equivalent ratio, water use efficiency, economic return and benefit-cost ratio (B:C ratio), while the lowest in F_1. Therefore, these cropping systems are recommended for practice.

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APPENDIX-I: Analysis of variance for initial plant population of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.118			
C	2	8268.31	4134.15	84978.01	3.63
F	2	0.03	0.02	0.35	3.63
C x F	4	0.002	0.000	0.01	3.01
Error	16	0.778	0.049		
Total	26	8269.24			

APPENDIX-II: Analysis of variance for final Plant population of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.035			
C	2	8268.33	4134.17	477398.30	3.63
F	2	0.02	0.01	1.40	3.63
CxF	4	0.003	0.001	0.08	3.01
Error	16	0.139	0.009		
Total	26	8268.53			

APPENDIX-III: Analysis of variance for initial Plant population of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.028			
C	2	19768.77	9884.38	33006.35	3.63
F	2	21.88	10.94	36.53	3.63
CxF	4	6.780	1.695	5.66	3.01
Error	16	4.792	0.299		
Total	26	19802.25			

APPENDIX-IV: Analysis of variance for Final Plant population of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	1.030			
C	2	19825.18	9912.59	46340.85	3.63
F	2	23.69	11.85	55.38	3.63
CxF	4	7.485	1.871	8.75	3.01
Error	16	3.422	0.214		
Total	26	19860.81			

APPENDIX-V: Analysis of variance for plant height of Pigeonpea at 60 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.028			
C	2	1938.08	969.04	3230.44	3.63
F	2	236.70	118.35	394.54	3.63
CxF	4	2.928	0.732	2.44	3.01
Error	16	4.800	0.300		
Total	26	2182.54			

APPENDIX-VI: Analysis of variance for plant height of Pigeonpea at 90 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.578			
C	2	1867.72	933.86	2606.21	3.63
F	2	217.22	108.61	303.11	3.63
CxF	4	1.562	0.390	1.09	3.01
Error	16	5.733	0.358		
Total	26	2092.82			

APPENDIX-VII: Analysis of variance for plant height of Pigeonpea at 120 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.896			
C	2	1519.05	759.53	2027.90	3.63
F	2	179.78	89.89	240.01	3.63
CxF	4	53.259	13.315	35.55	3.01
Error	16	5.993	0.375		
Total	26	1758.98			

APPENDIX-VIII: Analysis of variance for plant height of Pigeonpea at 150 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	3.189			
C	2	4960.12	2480.06	3454.97	3.63
F	2	547.15	273.57	381.11	3.63
CxF	4	23.679	5.920	8.25	3.01
Error	16	11.485	0.718		
Total	26	5545.62			

APPENDIX-IX: Analysis of variance for plant height of Pigeonpea at maturity

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.523			
C	2	4510.05	2255.03	4553.90	3.63
F	2	501.38	250.69	506.25	3.63
CxF	4	16.281	4.070	8.22	3.01
Error	16	7.923	0.495		
Total	26	5036.16			

APPENDIX-X: Analysis of variance for diameter of Stem of Pigeonpea at 60 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.003			
C	2	0.45	0.23	27.86	3.63
F	2	0.06	0.03	3.69	3.63
CxF	4	0.006	0.002	0.19	3.01
Error	16	0.131	0.008		
Total	26	0.65			

APPENDIX-XI: Analysis of variance for diameter of Stem of Pigeonpea at 90 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.009			
C	2	1.04	0.52	20.09	3.63
F	2	0.10	0.05	1.93	3.63
CxF	4	0.001	0.000	0.01	3.01
Error	16	0.415	0.026		
Total	26	1.57			

APPENDIX-XII: Analysis of variance for diameter of Stem of Pigeonpea at 120 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.004			
C	2	0.97	0.48	13.75	3.63
F	2	0.29	0.14	4.10	3.63
CxF	4	0.010	0.003	0.07	3.01
Error	16	0.563	0.035		
Total	26	1.83			

APPENDIX-XIII: Analysis of variance for diameter of Stem of Pigeonpea at 150 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.027			
C	2	1.25	0.63	7.20	3.63
F	2	0.63	0.32	3.65	3.63
CxF	4	0.077	0.019	0.22	3.01
Error	16	1.391	0.087		
Total	26	3.38			

APPENDIX-XIV: Analysis of variance for diameter of stem pigeonpea at maturity

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.022			
C	2	1.57	0.79	8.24	3.63
F	2	0.69	0.35	3.63	3.63
CxF	4	0.048	0.012	0.13	3.01
Error	16	1.525	0.095		
Total	26	3.86			

APPENDIX-XV: Analysis of variance for no. of primary branches of pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.005			
C	2	2.47	1.23	32.43	3.63
F	2	0.34	0.17	4.45	3.63
CxF	4	0.004	0.001	0.03	3.01
Error	16	0.609	0.038		
Total	26	3.42			

APPENDIX-XVI: Analysis of variance for no. of Secondary branches of pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.624			
C	2	45.47	22.73	31.37	3.63
F	2	6.12	3.06	4.22	3.63
CxF	4	0.351	0.088	0.12	3.01
Error	16	11.595	0.725		
Total	26	64.15			

APPENDIX-XVII: Analysis of variance for no. of Tertiary branches of pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	1.015			
C	2	83.48	41.74	20.14	3.63
F	2	16.17	8.08	3.90	3.63
CxF	4	0.665	0.166	0.08	3.01
Error	16	33.155	2.072		
Total	26	134.49			

APPENDIX-XVIII: Analysis of variance for no. of leaves of Pigeonpea at 60 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.015			
C	2	26.51	13.26	6.62	3.63
F	2	2.17	1.08	0.54	3.63
CxF	4	0.697	0.174	0.09	3.01
Error	16	32.058	2.004		
Total	26	61.45			

APPENDIX-XIX: Analysis of variance for no. of leaves of Pigeonpea at 90 DAS

ANOVA					
Source of Variation	DF	SUM OF SQUARES	MEAN SQUARES	F-Calculated	F tab
Rep	2	1.489			
C	2	118.42	59.21	26.67	3.63
F	2	17.88	8.94	4.03	3.63
CxF	4	0.938	0.235	0.11	3.01
Error	16	35.522	2.220		
Total	26	174.24			

APPENDIX-XX: Analysis of variance for no. of leaves of Pigeonpea at 120 DAS

ANOVA					
Source of Variation	DF	SUM OF SQUARES	MEAN SQUARES	F-Calculated	F tab
Rep	2	3.111			
C	2	169.77	84.88	16.94	3.63
F	2	37.11	18.55	3.70	3.63
CxF	4	3.783	0.946	0.19	3.01
Error	16	80.176	5.011		
Total	26	293.94			

APPENDIX-XXI: Analysis of variance for no. of leaves of Pigeonpea at 150 DAS

ANOVA					
Source of Variation	DF	SUM OF SQUARES	MEAN SQUARES	F-Calculated	F tab
Rep	2	4.229			
C	2	138.24	69.12	16.30	3.63
F	2	31.44	15.72	3.71	3.63
CxF	4	3.720	0.930	0.22	3.01
Error	16	67.855	4.241		
Total	26	245.48			

APPENDIX-XXII: Analysis of variance for no. of leaves of Pigeonpea at harvesting

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	4.916			
C	2	113.23	56.62	20.79	3.63
F	2	25.92	12.96	4.76	3.63
CxF	4	2.543	0.636	0.23	3.01
Error	16	43.578	2.724		
Total	26	190.19			

APPENDIX-XXIII: Analysis of variance for no. of pods/ plant of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.088			
C	2	231.60	115.80	10.00	3.63
F	2	86.77	43.38	3.75	3.63
CxF	4	15.757	3.939	0.34	3.01
Error	16	185.241	11.578		
Total	26	519.45			

APPENDIX-XXIV: Analysis of variance for no. of Seed/ pod of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.003			
C	2	1.10	0.55	22.55	3.63
F	2	0.18	0.09	3.76	3.63
CxF	4	0.023	0.006	0.23	3.01
Error	16	0.389	0.024		
Total	26	1.69			

APPENDIX-XXV: Analysis of variance for seed weight/ plant(gm) of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.351			
C	2	139.37	69.69	64.41	3.63
F	2	16.64	8.32	7.69	3.63
CxF	4	0.023	0.006	0.01	3.01
Error	16	17.310	1.082		
Total	26	173.69			

APPENDIX-XXVI: **Analysis of variance for Seed Yield q/ ha of Pigeonpea**

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.269			
C	2	91.29	45.64	102.05	3.63
F	2	6.45	3.22	7.21	3.63
CxF	4	0.513	0.128	0.29	3.01
Error	16	7.156	0.447		
Total	26	105.67			

APPENDIX-XXVII: Analysis of variance for straw Yield of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.309			
C	2	50.14	25.07	48.94	3.63
F	2	4.95	2.47	4.83	3.63
CxF	4	0.037	0.009	0.02	3.01
Error	16	8.196	0.512		
Total	26	63.63			

APPENDIX- XVIII : Analysis of variance for stick Yield of Pigeonpea (q/ha)

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	2.742			
C	2	15.41	7.70	7.22	3.63
F	2	8.88	4.44	4.16	3.63
CxF	4	1.967	0.492	0.46	3.01
Error	16	17.071	1.067		
Total	26	46.06			

APPENDIX- XXIX: Analysis of variance for biological Yield q/ ha of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	19.091			
C	2	236.41	118.20	13.04	3.63
F	2	67.04	33.52	3.70	3.63
CxF	4	12.792	3.198	0.35	3.01
Error	16	145.046	9.065		
Total	26	480.37			

APPENDIX-XXX: Analysis of variance for 1000 Seed weight/ plant (gm) of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.817			
C	2	20.63	10.32	5.03	3.63
F	2	14.88	7.44	3.63	3.63
CxF	4	4.736	1.184	0.58	3.01
Error	16	32.815	2.051		
Total	26	73.88			

APPENDIX-XXXI: Analysis of variance for no of seed/ plant of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	53.212			
C	2	18116.84	9058.42	56.56	3.63
F	2	2176.54	1088.27	6.80	3.63
CxF	4	5.234	1.308	0.01	3.01
Error	16	2562.414	160.151		
Total	26	22914.24			

APPENDIX-XXXII: Analysis of variance for harvest Index % of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.115			
C	2	62.73	31.36	314.47	3.63
F	2	0.82	0.41	4.12	3.63
CxF	4	1.553	0.388	3.89	3.01
Error	16	1.596	0.100		
Total	26	66.81			

APPENDIX-XXXIII: Analysis of variance for plant height of Groundnut at 30 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.245			
C	2	24.94	12.47	16.79	3.63
F	2	2.71	1.36	1.83	3.63
CxF	4	0.229	0.057	0.08	3.01
Error	16	11.881	0.743		
Total	26	40.01			

APPENDIX-XXXIV: Analysis of variance for plant height of Groundnut at 60 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	1.775			
C	2	33.72	16.86	6.95	3.63
F	2	17.81	8.90	3.67	3.63
CxF	4	1.804	0.451	0.19	3.01
Error	16	38.830	2.427		
Total	26	93.94			

APPENDIX-XXXV: Analysis of variance for plant height of Groundnut at maturity

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	4.042			
C	2	22.38	11.19	4.04	3.63
F	2	21.24	10.62	3.83	3.63
CxF	4	4.600	1.150	0.41	3.01
Error	16	44.350	2.772		
Total	26	96.60			

APPENDIX-XXXVI: Analysis of variance for number of branches of Groundnut at 30 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.003			
C	2	4.15	2.08	182.84	3.63
F	2	0.35	0.18	15.54	3.63
CxF	4	0.011	0.003	0.23	3.01
Error	16	0.182	0.011		
Total	26	4.70			

APPENDIX-XXXVII: Analysis of variance for number of branches of Groundnut at 60 DAS

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.007			
C	2	4.50	2.25	89.87	3.63
F	2	0.53	0.26	10.55	3.63
CxF	4	0.007	0.002	0.07	3.01
Error	16	0.401	0.025		
Total	26	5.44			

APPENDIX-XXXVIII: Analysis of variance for number of branches of Groundnut at maturity

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.025			
C	2	11.02	5.51	73.31	3.63
F	2	1.11	0.56	7.40	3.63
CxF	4	0.068	0.017	0.23	3.01
Error	16	1.202	0.075		
Total	26	13.42			

APPENDIX-XXXIX: Analysis of variance for number of pods/ plant of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	5.817			
C	2	94.68	47.34	11.60	3.63
F	2	30.32	15.16	3.72	3.63
CxF	4	2.004	0.501	0.12	3.01
Error	16	65.286	4.080		
Total	26	198.11			

APPENDIX-XL: Analysis of variance for 100-kernel weight of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	2.540			
C	2	23.18	11.59	4.02	3.63
F	2	22.63	11.32	3.93	3.63
CxF	4	4.276	1.069	0.37	3.01
Error	16	46.088	2.880		
Total	26	98.71			

APPENDIX-XLI: Analysis of variance for pod yield (q/ha) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.363			
C	2	453.18	226.59	245.14	3.63
F	2	19.95	9.98	10.79	3.63
CxF	4	0.423	0.106	0.11	3.01
Error	16	14.789	0.924		
Total	26	488.71			

APPENDIX-XLII: Analysis of variance for biological yield (q/ha) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	2.731			
C	2	1034.44	517.22	75.15	3.63
F	2	52.63	26.32	3.82	3.63
CxF	4	0.997	0.249	0.04	3.01
Error	16	110.126	6.883		
Total	26	1200.93			

APPENDIX-XLIII: Analysis of variance for shelling (%) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	15.967			
C	2	31.89	15.94	4.72	3.63
F	2	25.49	12.75	3.77	3.63
CxF	4	2.669	0.667	0.20	3.01
Error	16	54.098	3.381		
Total	26	130.11			

APPENDIX-XLIV: Analysis of variance for harvest Index (%) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	5.385			
C	2	23.96	11.98	7.34	3.63
F	2	15.45	7.73	4.73	3.63
CxF	4	2.825	0.706	0.43	3.01
Error	16	26.118	1.632		
Total	26	73.74			

APPENDIX-XLV: Analysis of variance for kernel Yield (q/ha) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.168			
C	2	247.53	123.77	281.05	3.63
F	2	11.43	5.72	12.98	3.63
CxF	4	0.150	0.038	0.09	3.01
Error	16	7.046	0.440		
Total	26	266.33			

APPENDIX-XLVI: Analysis of variance for haulm Yield (q/ha) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	1.641			
C	2	117.43	58.71	27.71	3.63
F	2	17.21	8.61	4.06	3.63
CxF	4	2.506	0.626	0.30	3.01
Error	16	33.906	2.119		
Total	26	172.69			

APPENDIX-XLVII: Analysis of variance for protein content (%) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	1.274			
C	2	14.93	7.46	40.57	3.63
F	2	1.55	0.78	4.22	3.63
CxF	4	0.032	0.008	0.04	3.01
Error	16	2.944	0.184		
Total	26	20.73			

APPENDIX-XLVIII: Analysis of variance for protein Yield (q/ha) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	82.069			
C	2	150412.49	75206.24	348.93	3.63
F	2	7387.53	3693.76	17.14	3.63
CxF	4	141.427	35.357	0.16	3.01
Error	16	3448.549	215.534		
Total	26	161472.06			

APPENDIX-XLIX: Analysis of variance for oil content (%) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	2.339			
C	2	11.84	5.92	4.16	3.63
F	2	10.35	5.17	3.64	3.63
CxF	4	1.572	0.393	0.28	3.01
Error	16	22.766	1.423		
Total	26	48.87			

APPENDIX-L: Analysis of variance for oil Yield (q/ha) of Groundnut

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	311.190			
C	2	526768.63	263384.32	319.81	3.63
F	2	25375.57	12687.78	15.41	3.63
CxF	4	293.618	73.405	0.09	3.01
Error	16	13177.165	823.573		
Total	26	565926.17			

APPENDIX-LI: Analysis of variance for Land Equivalent Ratio (LER)

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.005			
C	3	1.434	0.478	210.05	3.05
F	2	0.001	0.000	0.21	3.44
C x F	6	0.001	0.000	0.08	2.55
Error	22	0.050	0.002		
Total	35	1.491			

APPENDIX-LII: Analysis of variance for pigeonpea seed Equivalent Yield (q/ha)

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.499			
C	3	354.895	118.298	128.17	3.05
F	2	23.154	11.577	12.54	3.44
C x F	6	0.855	0.143	0.15	2.55
Error	22	20.306	0.923		
Total	35	399.709			

APPENDIX-LIII : Analysis of variance for litter fall of Pigeonpea

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.370			
C	2	146.32	73.16	118.90	3.63
F	2	7.81	3.91	6.35	3.63
CxF	4	0.107	0.027	0.04	3.01
Error	16	9.845	0.615		
Total	26	164.46			

APPENDIX-LIV: Analysis of variance for Fresh weed weight (q/ha)

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	2.139			
C	3	69.884	23.295	5.52	3.05
F	2	29.534	14.767	3.50	3.44
C x F	6	2.738	0.456	0.11	2.55
Error	22	92.758	4.216		
Total	35	197.054			

APPENDIX-LV: Analysis of variance for Dry weed weight (q/ha)

ANOVA					
Source of Variation	**DF**	**SUM OF SQUARES**	**MEAN SQUARES**	**F-Calculated**	**F tab**
Rep	2	0.172			
C	3	5.746	1.915	15.64	3.05
F	2	1.080	0.540	4.41	3.44
C x F	6	0.169	0.028	0.23	2.55
Error	22	2.694	0.122		
Total	35	9.861			

APPENDIX-LIII RATE OF INPUTS, OPERATION AND PRTICE OF CROPS PRODUCE CONSIDERED IN

Unit charge used in cost of cultivation

S.NO.	Input and operation	Rate
1	Tractor charge / hours	450
2	bullock charge/pair/day	300
3	labour charge/labour/day	201
4	Cost of seed	
	Pigeonpea (per kg)	150
	Groundnut (per kg)	80
5	Fertilizer cost	
	Urea (per kg)	6
	DAP (per kg)	27
	MOP (per kg)	18
	FYM (per q)	25
	Transportation charge of per trolly (T)	500
6	Pendimethalin 30% EC	365/litre
7	Borax(per kg)	400
8	Malathion dust (per kg)	22
9	Land rent/year/ha	12000/year

	Sale price of crop produce (MSP rate)	
1	Pigeonpea Grain (Rs./q)	7000
2	Pigeonpea stick (Rs./q)	300
3	Groundnut Grain (Rs./q)	6377
4	Groundnut haulm (Rs./q)	400

APPENDIX-LIV Variable and common cost of cultivation for

A. Cropping system.

Particulars	Pigeonpea sole		Groundnut sole		Pigeonpea + groundnut 1:1		Pigeonpea + groundnut (1:2)	
	Unit	Rs	Unit	Rs	Unit	Rs	Unit	Rs
1. Field preparation								
I.A cross ploughing by tractor drawn Cultivator followed by planking	2.5 hr @ 450 Rs./hr	1125	2.5 hr @ 450 Rs./hr	1125	2.5 hr @ 450 Rs./hr	1125	2.5 hr @ 450 Rs./hr	1125
II.A cross ploughing by tractor drawn Disc harrow followed by planking	2.5 hr @ 450 Rs./hr	1125	2.5 hr @ 450 Rs./hr	1125	2.5 hr @ 450 Rs./hr	1125	2.5 hr @ 450 Rs./hr	1125
III. Soil treated with Malathion dust (5%) @ 20 kg/ha with last ploughing to prevent the infestation of Termites	22	440		440		440		440
IV Ridge making of plot and replication border	4 L/DAY @ 201	804	4 L/DAY @ 201	804	4 L/DAY @ 201	804	4 L/DAY @ 201	804
2.Sowing								
(i) Cost of seed	15 kg/ha @ Rs 120	1800	100kg/ha @ Rs8 0	8000	7.5 kg/ha +50 kg/ha	4900	5 kg/ha +66 kg/ha	5880
(ii)Cost of Sowing	2P+6L	1806	2P+6L	1806	2P+6L	1806	2P+6L	1806
3. Fertilizer								
(i) Cost of fertilizer	20:40:20 kg NPK/ha	3000	20:40:30 kg N P_2O_5/ha	3300	20:40:25 kg NPK/ha	3150	20:40:26 kg NPK/ha	3180
(ii) Cost of fertilizer	3 L/DAY	603	3 L/DAY @	603	3 L/DAY	603	3 L/DAY @	603

application	@ Rs.201		Rs.201		@ Rs.201		Rs.201	
4. Interculture operation								
(i)Weedicide Pendimethlin 30% EC	3.0 lit/ha+1 L @Rs 365 /lit	1296	3.0 lit/ha+1 L @Rs 365 /lit	1296	3.0 lit/ha+1 L @Rs 365 /lit	1296	3.0 lit/ha+1 L @Rs 365 /lit	1296
(ii)Weedicide Imazethapyr	1.5 lit/ha+1 L @ Rs 199.50/ lit	500.25	1.5 lit/ha+1 L @ Rs 199.50/ lit	500.25	1.5 lit/ha+1 L @ Rs 199.50/ lit	500.25	1.5 lit/ha+1 L @ Rs 199.50/ lit	500.25
(iii)Thinning	15 L	3015	15 L	3015	15 L	3015	15 L	3015
(iv) Weeding and hoeing by khurpi	13 L	2613	13 L	2613	13 L	2613	13 L	2613
5. Harvesting	11 L	2211	10 L	2010	11 L	2211	11 L	2211
6. Bundle making and lifting	1 P @ 300 +8 L	1908	1 P @ 300 +8 L	1908	1 P @ 300 + 10 L	2310	1 P @ 300 + 10 L	2310
7. Threshing or beating produce with wooden sticks by manual	1 P @ 300 + 10 L	2310	1 P @ 300 + 10 L	2310	1 P @ 300 + 10 L	2310	1 P @ 300 + 10 L	2310
8. Drying and cleaning	4 L/DAY @ 201	804	4 L/DAY @ 201	804	4 L/DAY @ 201	804	4 L/DAY @ 201	804
9. Repair to dead stock @ Rs 1.00 per unit hours	50 Unit per hour	50	50 Units per hours	50	50 Unit per hour	50	50 Units per hours	50
10. Land rent for 6 month	Rs. 12500 @ 6 month	12500	Rs. 12500 @ 6 month	12500	Rs. 12500 @ 6 month	12500	Rs. 12500 @ 6 month	12500
Total		**34307**		**39502**		**37809**		**38789**
11. Interest on working capital @ 14.2 % for half of the crop period		**4871**		**5609**		**5368**		**5508**

12.Miscellaneous		15		15		24		23
Total		**39193**		**45126**		**43201**		**44240**

APPENDIX-LV Cost of cultivation, Gross return, Net return and benefit-cost ratio under various treatment combinations.

	Treatment combination	Cost of cultivation			Gross return				
		Variable							
		Cropping system	Nutrient management	Total	By Grain	By stover	Total	**Net return**	B:C
	C1F1	39193	4206	43399	105700	17607	123307	79908	2.84
C 1	F2	39193	4706	43899	108500	18132	126632	82733	2.88
	F3	39193	7206	46399	116900	18399	135299	88900	2.91
	C2F1	45126	4506	49362	102478	14320	116798	67166	2.35
C 2	F2	45126	5006	50132	106942	14556	124498	74366	2.40
	F3	45126	7506	52632	113446	14736	128182	75550	2.43
	C3F1	43201	4356	47557	143619	29240	172859	125302	3.63
C 3	F2	43201	4856	48057	149484	29782	179266	131209	3.73
	F3	43201	7356	50557	158910	30366	189276	138719	3.74
	C4F1	44240	4386	48626	147847	29594	177441	128815	3.65
C 4	F2	44240	4886	49126	153712	30242	183954	134828	3.74
	F3	44240	7386	51626	163969	30764	194733	143107	3.77