PERFORMANCE OF PIGEONPEA BASED CROPPING SYSTEMS UNDER RAINFED CONDITIONS OF NAGALAND

Thesis

submitted to

NAGALAND UNIVERSITY

in partial fulfillment of requirements for the Degree

of

Doctor of Philosophy

in

Agronomy

by

LENMEM YOSUNG

Admn. No. Ph- 292/19 Regn. No. Ph.D./AGR/00330

Department of Agronomy

School of Agricultural Sciences

Nagaland University, Medziphema Campus – 797 106

Nagaland

2024

Affectionately dedicated to

Meme (Lt. Rongili Mibang),

Papa (Lt. Prof. Tamo Mibang)

and Adi (Lt. Valentino Adi Mize)

DECLARATION

I, **LENMEM YOSUNG,** hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to SAS, Nagaland University for the degree of Doctor of Philosophy in Agronomy.

Date:

Place:

…………………………..

(**Lenmem Yosung**)

(T. GOHAIN)

Supervisor

NAGALAND UNIVERSITY
Medziphema Campus
School of Agricultural Sciences
Medziphema – 797 106, Nagaland

Prof. T. Gohain Professor & Head
Department of Agronomy

CERTIFICATE – I

This is to certify that the thesis entitled **"Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland"** submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in the discipline of Agronomy, is the record of research work carried out by Lenmem Yosung, Registration No. Ph.D./AGR/00330, under my personal supervision and guidance.

The result of the investigation reported in the thesis has not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

Date :
Place : SAS, Medziphema

(T. GOHAIN)
Supervisor

NAGALAND UNIVERSITY
Medziphema Campus
School of Agricultural Sciences
Medziphema – 797 106, Nagaland

CERTIFICATE – II

***VIVA VOCE* ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRONOMY**

This is to certify that the thesis entitled **"Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland"** submitted by Lenmem Yosung, Admission No. Ph- 292/19, Registration No. Ph.D./AGR/00330, to the Nagaland University in partial fulfillment of the requirements for the award of degree of **Doctor of Philosophy** in **Agronomy** has been examined by the Advisory Board and External examiner on ………………….

The performance of the student has been found **Satisfactory/Unsatisfactory.**

Member	**Signature**
1. Prof. T. Gohain (Supervisor)	………………………………..
2. ………………………….…… (External Examiner)	………………………………..
3. Dean. SAS, NU (Pro-Vice-chancellor Nominee)	………………………………..
4. Prof. L. T. Longkumer	………………………………..
5. Dr. Lanunola Tzudir	………………………………..
6. Prof. P. K. Singh	………………………………..
7. Dr. Pankaj Neog	………………………………..

Head
Department of Agronomy

Dean
School of Agricultural Sciences

ACKNOWLEDGEMENT

I would like to begin by expressing my deepest gratitude to God for his blessings and unwavering presence throughout this entire journey. I am truly humbled and thankful for his grace that blessed me with strength, wisdom and inspiration to overcome challenges and achieve this milestone.

I am incredibly grateful to my supervisor Prof. T Gohain, Head of the department, Department of Agronomy, Nagaland University, School of Agricultural Sciences for his invaluable guidance, expertise, and unending support throughout the completion of this thesis. His dedication to my growth as a research scholar has been instrumental in shaping the direction and quality of this work. I am truly fortunate to have had his mentorship and encouragement during the completion of my thesis.

I express my sincere and heartfelt thanks to my advisory committee members Prof. Tongpang Longkumer, Department of Agronomy, Dr. Lanunola Tzudir, Department of Agronomy, Prof. P.K Sharma, Department of Soil Science, Prof. Pankaj Neog, Department of Plant Pathology for their valuable cooperation, suggestions, guidance and liberal help rendered to me throughout the preparation of my manuscript.

With the same spirit, I express my fathomless gratitude to Prof. T. Gohain, Head, Department of Agronomy for his cordial support and providing all the requirements and facilities during the entire course of research.

My profound gratitude to Prof. Manoj Dutta, Head, and Sir. Y. Patton, STA, Department of Soil and Water Conservation for extending laboratory facilities and valuable help during the laboratory analysis required for the research work.

My sincere thanks to Sir. Zulutemjen Jamir, STA, Department of Agronomy, for his guidance and assistance throughout the completion of the laboratory analysis that was required during my thesis work. I would also like to further thank the non-teaching staffs and field workers for their tireless help during the entire research work.

I owe my sincere gratefulness to Dr. Damitre Lytan, Guest faculty, Department of Entomology for his guidance and necessary facilities that was required for the statistical data analysis required for completion of my thesis.

I sincerely express my deepest gratitude and thankfulness to the Ministry of Tribal Affairs, Government of India under the central sector Scheme-National Fellowship of ST students (NFST) for providing financial assistance during my entire process of completing my research work.

I am immensely thankful to my wonderful batch mates, juniors and friends namely Hillel Chishi, Takhelmayum Malemnganbi, Shivani Kumari, G.Zion, Paardensha Ivy Chinir, Mounika Kosgi, *Chandrika Umbon, Rinu Sakhong, Kili Awomi, Debia Yashi, Pura Sunya, Centy Ngasainao, Kivi Yeptho, and Mum Taggu for their kind help, laughter, companionship and moral support which enabled me in timely completion of my work.*

I fall short of words in expressing my love and appreciation to my loving parents and sisters who has supported me through their unceasing prayer, encouragement and support in completing this milestone.

Lastly, though many have not been mentioned, rest assured that none are forgotten.

Date

Place: *(Lenmem Yosung)*

CONTENTS

1.1 Plant height (cm)
1.2 Plant population (m^{-2}
1.3 Number of primary branches per plant^{-1}
1.4 Crop growth rate (g m^{-2} day^{-1})
1.5 Absolute growth rate (g day^{-1})
1.6 Relative growth rate (g g^{-1} day^{-1})
1.7 Net assimilation rate (g m^{-2} day^{-1})
1.8 Leaf area index

2. Yield attributes
   2.1 Plant stand at harvest (m^{-2})
   2.2 Number of pods plant^{-1}
   2.3 Number of seeds pod^{-1}
   2.4 Length of pods (cm)
   2.5 Weight of pod plant^{-1} (g)
   2.6 Seed index (g)
3. Yield
   3.1 Seed yield (kg ha^{-1})
   3.2 Stover yield (kg ha^{-1})
   3.3 Biological yield (kg ha^{-1})
   3.4 Harvest index (%)

B) Rice

1. Growth attributes
   1.1 Plant height (cm)
   1.2 Plant population (m^{-2})
   1.3 Crop growth rate (g m^{-2} day^{-1})
   1.4 Absolute growth rate (g day^{-1})
   1.5 Relative growth rate (g g^{-1} day^{-1})
   1.6 Net assimilation rate (g m^{-2} day^{-1})
   1.7 Leaf area index
2. Yield attributes
   2.1 Plant stand at harvest (m^{-2})
   2.2 Number of panicles m^{-2}
   2.3 Panicle length (cm)
   2.4 Weight of panicle (g)
   2.5 Filled grain (%)
   2.6 Test weight (g)
3. Yield
   3.1 Grain yield (kg ha^{-1})
   3.2 Straw yield (kg ha^{-1})
   3.3 Biological yield (kg ha^{-1})
   3.4 Harvest index (%)

C) Sesame

1. Growth attributes
   1.1 Plant height (cm)
   1.2 Plant population (m^{-2})
   1.3 Crop growth rate (g m^{-2} day^{-1})
   1.4 Absolute growth rate (g day^{-1})

1.5 Relative growth rate (g g^{-1} day^{-1})
1.6 Net assimilation rate (g m^{-2} day^{-1})
1.7 Leaf area index

2. Yield attributes
   2.1 Plant stand at harvest (m^{-2})
   2.2 Number of capsules $plant^{-1}$
   2.3 Number of seeds $capsule^{-1}$
   2.4 Capsule weight $plant^{-1}$ (g)
   2.5 Test weight (g)
3. Yield
   3.1 Seed yield (kg ha^{-1})
   3.2 Stover yield (kg ha^{-1})
   3.3 Biological yield (kg ha^{-1})
   3.4 Harvest index (%)

D) Greengram and soybean

1. Growth attributes
   1.1 Plant height (cm)
   1.2 Plant population (m^{-2})
   1.3 Crop growth rate (g m^{-2} day^{-1})
   1.4 Absolute growth rate (g day^{-1})
   1.5 Relative growth rate (g g^{-1} day^{-1})
   1.6 Net assimilation rate (g m^{-2} day^{-1})
   1.7 Leaf area index
2. Yield attributes
   2.1 Plant stand at harvest (m^{-2})
   2.2 Number of pods $plant^{-1}$
   2.3 Number of seed pod^{-1}
   2.4 Weight of pod $plant^{-1}$ (g)
   2.5 Test/ seed weight (g)
3. Yield
   3.1 Seed yield (kg ha^{-1})
   3.2 Stover yield (kg ha^{-1})
   3.3 Biological yield (kg ha^{-1})
   3.4 Harvest index (%)

II Plant analysis

1. N, P and K content (%) and nutrient uptake (kg ha^{-1})

III Intercropping competitive indices

1. Pigeonpea equivalent yield (PEY)
2. Land equivalent ratio (LER)
3. Area time equivalent ratio (ATER)
4. Relative crowding coefficient (RCC)
5. Aggressivity
6. Competitive ratio

IV Soil analysis

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	Percentage
@	at the rate of
°C	Degree celsius
₹/ Rs.	Rupees
$^{-1}$ or /	Per
ANOVA	Analysis of variance
ATER	Area time equivalent ratio
BCR	Benefit Cost ratio
CD	Critical Difference
cm	Centimeter
CR	Competition ratio
DAS	Days after sowing
df	Degree of freedom
et al.	*et allia* (and others/co- workers)
Fig.	Figure
g	Gram
ha^{-1}	Per hectare
i.e.	Id est (that is)
kg	Kilogram
Kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
LER	Land equivalent ratio
m	Meter
m^2	Meter square
Max.	Maximum
Min.	Minimum
mm	Millimeter

MOP	Muriate of Potash
msl	Mean sea level
Mss	Mean sum of squares
mt	Million tonnes
NPK	Nitrogen Phosphorus Potassium
No.	Number
NS	Not significant
NU	Nagaland University
OC	Organic carbon
PEY	Pigeonpea equivalent yield
pH	Negative log of H ion activity
ºC	Degree Celsius
RDF	Recommended Dose of Fertilizers
RCC	Relative crowding coefficient
SAS	School of Agricultural Sciences
SEm±	Standard error of mean
Sl. No.	Serial number
SOV	Source of Variation
ss	Sum of square
SSP	Single Superphosphate
t	Tonnes
viz.	Videlicet (Namely)

A B S T R A C T

A field experiment was carried out during the *kharif* season of 2021 and 2022 in the experimental farm, Department of Agronomy, SAS, NU: Medziphema campus to evaluate the "**Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland"**. The experiment was conducted with three different row ratios (1:1, 1:2 and 1:3) of pigeonpea and four intercrops (rice, sesame, greengram and soybean) respectively, consisting of 17 treatments combinations which was laid out in Randomized Block Design and replicated thrice. The variety used were PA-291for pigeonpea, CAU - R2 for rice, GT-10 for sesame, Pusa vishal for greengram and JS-9752 for soybean. The result revealed that intercropped pigeonpea numerically had lower seed yield to that of sole cropping. Among the intercropping system pigeonpea + soybean (1:1) performed better in terms of plant height (204.92 cm) at 120 DAS, no. of primary branches (19.04) at 120 DAS, crop growth rate at 90-120 DAS (7.27 g m^{-2} day^{-1}), absolute growth rate at 90-120 DAS (1.31 g day^{-1}), net assimilation rate at 30-60 DAS (0.769 g m^{-2} day^{-1}), leaf area index at 90 DAS (3.73), no. of pods $plant^{-1}$ (252.72), seed yield (1330.37 kg ha^{-1}), stover yield (3121.91 kg ha^{-1}), biological yield (4452.28 kg ha^{-1}), harvest index (29.86 %), land equivalent ratio (1.81), area time equivalent ratio (1.37), pigeonpea equivalent yield (1042.68 kg ha^{-1}), relative crowding coefficient (25.42) for the main crop and for the system (30.18). The results further revealed that the intercropping system pigeonpea + sesame (1:3) recorded the highest competition ratio (2.27) for the main crop whereas the competition ratio (0.99) for intercrops was recorded the highest in the intercropping system pigeonpea + rice (1:1). Intercropping system pigeonpea + soybean (1:3) recorded the highest aggressivity (1.45) for the main crop and lowest aggressivity (-1.45) for intercrops. In terms of economics, the intercropping system pigeonpea + soybean (1:1) recorded the highest B:C ratio (3.45). In conclusion, soybean as an intercrop in pigeonpea was found to perform better in comparison to other intercrops.

Key words: Intercropping, greengram, pigeonpea, rice, sesame, soybean.

CHAPTER I

INTRODUCTION

INTRODUCTION

Pulses are second to cereals in importance for human and animal dietary needs. Pulses hold a significant importance in Indian cuisine because of their affordability and accessibility and also, they are a rich source of protein. Its ability to fix atmospheric nitrogen, deep rooting characteristics, and huge leaf fall make pulses an important component of any cropping system. For ages, pulses have been a significant part of the farming system in our country. India is the largest producer, consumer and importer of pulses in the world. Pulses offer the most favourable and practical means of eradicating protein hunger, especially among children and nursing mothers. Pulses are known for their nutritional and health benefits and help to reduce several non-communicable diseases such as colon cancer and cardiovascular diseases (Jukanti *et al*., 2012). Pulses have sustainable characteristics such as low water requirements, deep-rooted systems for soil erosion prevention, extensive ground coverage, and seamless integration into crop rotation and mixtures, enhancing productivity and farming system resilience (Singh *et al*., 2020)

Among pulses, pigeonpea (*Cajanus cajan* L. Mill sp.) also known as red gram or arhar or Tur is mainly eaten in the form of the split pulse as ‘dal’ is one of the major grain legume crops of tropical and subtropical regions. India accounts for about 72% of the area grown to pigeonpea (Fatokimi and Tanimonure, 2021). Pigeonpea is highly nutritious and has a calorific value of an amount up to 350 Kcal 100 gm^{-1} it is a home for several macro and micronutrients and minerals, which help to provide good nutrition to the human body. It is commonly intercropped with a wide range of crops in India. The pigeonpea production in India was 4.34 million tonnes (leading producer) from an acreage of 5.05 million ha. with a productivity of 859 kg ha^{-1} (Anonymous, 2022). India is the leading importer (92.65% share in global pigeonpea imports in 2021) with an import volume of 674.44 million kg. India contributed to 77.61% of the global pigeonpea production in 2020. The global pigeon pea market reached a volume of 13.3 million tons in 2022 as per future market insight (FMI), a market research organization. The market is projected to reach 23.6 million tons by 2027, exhibiting a compound annual growth rate (CAGR) of 9.51% during 2022-2027. In 2022, the estimated market value of pigeon pea is US$ 14,334.5 million which is expected to touch US$ 23,798 million by 2032. Pigeonpea is an indispensable part of the vegan diet of the Indian subcontinent. Besides these pigeonpea crop is immensely important concerning diversification of the cropping cycle, low ecological footprint, improvement of soil health, bringing fallow lands under cultivation etc. Mozambique is the top exporter of pigeonpea. In India. Uttar Pradesh state is the leading producer (0.47 million tonnes from 0.49 million ha. with a productivity of 944 kg ha^{-1}) contributing to 34.87 % of the national production (Anonymous, 2022). It is followed by Madhya Pradesh (0.44 million tonnes, 34.55 % of national production), West Bengal (10.53 %), Bihar (8.84 %) and Jharkhand (4.53 %) for their contribution to the national production of pigeonpea. In Nagaland, area and production during 2022 - 2023 under pigeonpea were 663 ha and 630 metric tonnes, respectively (Anonymous, 2023). Pigeonpea is grown predominantly during the *kharif* season, both as a sole and intercrop under a wide range of agroecological situations. Pigeonpea is an important legume crop of rainfed agriculture in the semiarid tropics and considered as second most important pulse crop of India after chickpea. The optimum temperature required for germination of pigeonpea crop is 30 – 35^0C and for better growth, it requires a temperature of 20 – 35^0C. The ability of pigeonpea to adapt and grow well under moisture deficit makes it an important crop. Pigeonpea is considered one of the most important drought-tolerant pulse crops, due to its deep root system and germplasm with higher osmotic adjustment concerning other pulses. The pigeonpea perform well under low water potential, by moderating stomatal conductance and photosynthetic functions and delaying leaf senescence.

In recent times, pigeonpea has been gaining popularity due to its restorative nitrogen capacity in the soil and adding a lot of organic matter to the soil. Pigeonpea also acts as a soil ameliorant and is known to provide several benefits to the soil and its growing environment. The seeds, pods and leaves are used by humans and livestock being rich in nutrition and the crop generally enhances soil fertility through leaf litter and biological nitrogen fixation (Udhaya *et al.,* 2015). When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index (Willey *et al.,* 1980). Therefore, a short duration intercrop can be grown in between pigeonpea, which helps in the efficient utilization of available resources for enhancing productivity and profitability.

Intercropping can be defined as a multiple cropping system in which two or more crops are planted in a field during a growing season. (Mousavi and Eskandari, 2011). The intercropping system enables efficient utilization of available nutrients, reduces nutrient losses by leaching and increases nutrient cycling through complementary partitioning of resources which in turn reduces the demand for external fertilizer inputs. In intercropping, if one crop fails the other may survive which protects the farmers and insured from total crop loss (Agegnehu *et al.,* 2008). Intercropping results in higher yield over sole cropping with effective usage of existing resources along with diversified crops with diverse rooting ability, canopy arrangement, height and nutrient requirements, based on the corresponding exploitation of growth resources by the component sole crops (Lithourgidis *et al.,* 2011). The advantages of intercropping in comparison with sole cropping are due to the interaction between component crops and the difference in competition for the use of environmental resources (Mahapatra 2011). Intercropping will be more successful if the component crops have different growth requirements harvesting times and, have diverse rooting systems or distinctive morphology, particularly the heights of plants. The adoption of compatible crops and their appropriate row proportions are key factors in intercropping performance and have important effects on the balance of competition between component crops, productivity, economics, energetics and soil-fertility status. Intercrops are grown in two ways: in an additive or replacement series with the primary crops. With replacement series, intercrops are used to replace rows of main crops rather than the whole population of the main crop per unit area as is the case in additive series (Chaudhary *et al*., 2022). A series of agronomic activities that will alter interactions between the species can decide the success of intercrops in comparison to pure cropping. These procedures include the final density, the planting date, the availability of resources, and the intercropping models. (Mazaheri *et al*., 2006). If an appropriate row ratio of the main crop with a base like legumes for a specific area is adopted the farmers may use the available resources efficiently and effectively. While selecting crops for intercropping some of the most important factors to be considered, crops grown should always be compatible with each other, have minimum competition, and should have the potential to produce higher yields. In modern agriculture, this method can help farmers increase production, productivity, and efficiency of resources of small farms as it fulfils the diversified demands of the farmers. Productivity can be increased with good cropping technique and balanced fertilization. There is an urgent need to increase the productivity and profitability of the farmers per unit area per unit time as the land holdings of the farmers are shrinking day by day. Consequently, it is imperative to increase production levels by creating new production technologies to meet the nation's growing need for pulses and oilseeds. The majority of crops grown as intercrops or mixed crops in widely spaced rows are pulses and oilseeds.

In India, pigeonpea is generally taken up along with maize, sesame, soybean, urdbean, mungbean and groundnut. Different maturity periods, growth patterns, nutrient and water requirements and rooting patterns of these crops make them suitable to grow as intercrops with pigeonpea. Pigeonpea based intercropping systems have proved sustainable in respect of yield and income with short duration intercrops of cereals, pulses and oilseed crops across diverse rainfed agro-ecologies in India (Rao *et al.*, 2003; Vittal *et al.*, 2005; Kantwa *et al.*, 2005; Ravindra *et al.*,2012).

Rice (*Oryza sativa* L.) belonging to the family of grasses, Gramineae (Poaceae) is one of the three major food crops of the world and forms the staple diet of about half of the world's population and about 60% population of India. It is grown under upland conditions in the northern and northeastern parts of the country.

Sesame (*Sesamum indicum* L.) or gingelli commonly known as til is the oldest growing crop in India and is referred to as “Queen of oil seeds” given its higher oil content and drought tolerance. Sesame contains 50% oil, 25% protein and 15% carbohydrate. It is an integral part of rituals, religion and culture. Sesame oil and foods fried in sesame oil have a long shelf life because the oil contains an antioxidant called sesamol.

Greengram (*Vigna radiata*), belongs in the legume family and is commonly called mung bean or moong in India it can be grown both as summer or *kharif* crop. It is the third most important pulse crop in the country, which occupies nearly 16 % of the total pulse area in India. It contains protein-rich seeds with 20-25% protein, Greengram also plays an important role in sustaining soil fertility by improving soil physical properties and fixing atmospheric nitrogen.

Soybean (*Glycine max* L. Merr.) is one of the most valuable oilseed crops in the world. It is a crop considered both a pulse and oilseed crop. Also known as the ‘Miracle crop or wonder legume or golden bean’. It has outstanding nutritive value with 43% biological protein, 20% oil content and is a very rich source of vitamins, iron, minerals, salts and amino acids.

Presently, pigeonpea is grown as a sole crop in parts of Nagaland to take advantage of its initial slow growth period (45-60 days) and increase system productivity, some short duration crops like soybean and green gram and long duration with short plant height like groundnut can be grown. There is little information available on intercropping ratio, growth dynamics and related management practices, particularly for the pigeonpea based intercropping system under Nagaland condition. Thus, it becomes necessary to develop an efficient and profitable pigeonpea based intercropping system for this zone. Given this, the present investigation, "Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland." was planned with the following objectives:

1. To study the effect of different intercrops on the growth and yield of pigeonpea.
2. To find out suitable intercrops for pigeonpea.
3. To work out the economics of different treatments.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Intercropping and their importance

Intercropping plays an important role in improving the system productivity and sustainability. Intercropping produces higher yield and economic returns on a given piece of land by making more efficient use of the available growth resources by using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops.

Intercropping is a multiple cropping practice which involves growing of two or more crops simultaneously on the same piece of land. (Andrews and Kassam, 1976)

Pigeonpea when grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index Willey *et al.* (1980) therefore, it is grown as intercrop, which helps in efficient utilization of available resources for enhancing the productivity and profitability.

Rao and Mathuva (2000) revealed that, the annual grain legume-based cropping systems were 32-49 % more profitable than continuous sole maize, making them attractive to small farmers in semi-arid tropics.

Intercropping of legumes is an important aspect for biological farming system not only for weed control, but also reducing the leaching of nutrients, pest control and in reducing soil erosion (Kumar and Uthayakumar, 2006).

Intercropping of oilseed and pulse crops is one of the ways to increase their production because intercropping is more advantageous than sole cropping of either of these crops (Padhi and Panigrahi, 2006)

Choudhary *et al.* (2007) revealed in their experiment that inclusion of pulses such as chickpea in the existing cropping system not only increases the overall productivity of the system but also improves physic-chemical properties of the soil. This is possible because chickpea can increase the productivity both in terms of N saving from fertilizer source and build up soil fertility through biological source of N. The reason behind is mainly that resources such as water, light and nutrients can be utilized more effectively than in the respective sole cropping systems.

Intercropping of pigeonpea with soybean, greengram and blackgram reduce growth and yield of pigeonpea because of higher competitive ability over pigeonpea as they have a faster vegetative growth during early stage (Billore *et al*., 2009)

Lithourgidis *et al*. (2011) observed that intercropping provides insurance against crop failure or against unstable market prices for a given commodity, especially in areas which subject to extreme weather conditions such as flood, drought, and frost.

Intercropping can be defined as a multiple cropping system in which two or more crops planted in a field during a growing season. Intercropping is a way to increase diversity in agricultural ecosystem, ecological balance, and more utilization of resources; increases the quantity and quality of products and reduces the damage by pests, diseases and weeds (Mousavi and Eskandari, 2011).

Singh *et al.* (2011) found that cereal and legume intercropping has been recognized as a beneficial crop production system both for better resource use and higher dry matter production per unit area per unit time. A balanced diet of cereal-legume through intercropping should have suitable proportions, mineral matter and protein.

Intercropping involves growing two or more crops or varieties simultaneously on the same piece of land with a definite row ratio. Crop intensification is in both time and space dimensions. There is intercrop competition during all parts of crop growth (Prasad and Shrivastava, 2011).

Ravindra *et al.* (2012) revealed that pigeonpea based intercropping systems proved sustainablility in respect of yield and income with short duration intercrops of cereals, pulses and oilseed crops across diverse rainfed agroecologies in India.

Rusinamhodzi *et al.* (2012) in their study, found that maize-legume intercropping has the potential to reduce the risk of crop failure, improves productivity, income and increase food security in vulnerable production systems and is a feasible entry point to ecological intensification.

Siddique *et al*. (2012) found that crop diversification is also necessary to get higher yield and return to maintain soil health, conserve natural resources, preserve the environment, meet the daily food requirement of human and animals, withstand price fluctuation and ensure constant flow of income.

Timmegowda *et al.* (2016) opined that intercropping system offers solution to obtain higher productivity, diversified food products and reduced risk of crop failure under rainfed conditions.

Kumar *et al*. (2019) reported that growing pigeonpea with fodder crops under intercropping system is a profitable composition in terms of supply of good quantity and quality of fodder. It appears to make better use of sunlight, water and land.

Arpita *et al.* (2021) conducted a field experiment and the results indicated that sole sesame recorded the highest plant height, no. of branches plant^{-1}, dry matter and CGR at 15-30 DAS.

2.2 Effect of intercropping on the growth of crops:

Mandal *et al.* (1989) reported that the number of effective tillers m^{-2} was significantly higher in sole crop of rice than those intercropping system of rice+ soybean, rice + greengram and rice + blackgram and finally concluded that among legumes pure crops of soybean and peanut always gave rose to increased number of yield components than the other crops grown in association with rice.

Leaf area indices of all the component crops (pigeonpea, rice, finger millet, groundnut, green gram and blackgram) were reduced in intercropping and the reduction was about 35-46 percent at 60 days after sowing from their respective sole crop values (Mahapatra, 1991).

Rana and Paul (1997) reported that when pigeonpea was intercropped with short duration legumes like green gram and cowpea, a reduction in various growth parameters (plant height, branches plant^{-1}, leaf area index and dry matter production) was observed.

Singh and Pal (2003) found that pigeonpea + maize intercropping system significantly declined the growth parameters of pigeonpea *viz*., plant height, dry matter production and leaf area index and were higher at 1:1 row ratio of pigeonpea + maize intercropping system compared to 2:2 row ratio and a similar trend was observed in yield and yield attributes i.e., weight per pod and 1000-grain weight.

Sarkar *et al*. (2003) noted that plant height, branches plant^{-1}, pods plant^{-1}, 1000 seed weight and seed yield of pigeonpea were highest in pigeonpea sole.

Patra (2005) in an intercropping experiment of direct- seeded rice (cv. MW-10) and green gram (cv. B-105) was conducted at the University farm, Nadia, West Bengal, the CGR of rice increased with increase in the levels of N, the values and the rates of increase being much higher in sole cropping than in intercropping. The CGR of greengram was reduced in intercropping as compared to sole cropping.

Oad *et al.* (2007) conducted a field trial in to evaluate the agronomic and economic interference between cotton and pigeonpea. The intercropping pigeonpea with cotton showed adverse effect on all the growth and yield parameters. In pigeonpea taller plant height (300 cm), greater no. of branches (12.33 plant^{-1}), remarkably higher yield attributes and yield were observed in sole pigeonpea.

Lingaraju *et al.* (2008) reported that total dry matter production at maturity and plant population of sole maize and sole pigeonpea were significantly higher in pure crop which resulted in better performance than the intercropped maize.

Darshan *et al*. (2009) evaluated pigeonpea - sesame intercropping systems for sustained production in northern transition zone of Karnataka. The results indicated that sole PP (cv. Maruti) – 120 cm x 15 cm recorded higher total dry matter production 202.2 (g/plant) and LAI 0.633.

Shanwad *et al*. (2009) studied on the maize +pigeonpea intercropping at Dharwad, Karnataka in 1:1, 2:1, 2:2, 3:1 and 4:2 row arrangements. Plant height, dry matter plant^{-1}, pods plant^{-1}, grain weight plant^{-1} and grain yield ha^{-1} were recorded highest in pigeonpea sole than in all intercropping.

Rani and Reddy (2010) observed that pigeonpea + soybean intercropping system recorded lower plant height as compared with sole pigeonpea. Sole pigeonpea recorded significantly higher plant height, number of branches, seed yield and stalk yield than that intercropped with soybean.

Egbe and Bar-Anyam (2011) reported that pigeonpea when grown as intercrop with sorghum resulted in decreased dry root weight, leaf litter, shoot weight, total plant biomass and efficiency in land resource utilization.

Lawrence and Gohain (2011) indicated that maximum plant height (139.57 cm) of rice was recorded under sole cropping and the lowest (128.67 cm) was in rice + green gram intercropping planted at 1:4 ratio but in case of green gram, the highest plant height (57.87 cm) was recorded in sole green gram and lowest (47.10 cm) was in rice + green gram (1:4 ratio). All the growth parameters such as number of tillers/m^2, number of panicle/m^2, grain yield etc. of rice was maximum in pure stand, similarly in green gram also all the growth and yield contributing characters were highest in pure stand.

Ansari and Rana (2012) reported that the performance of pigeonpea was affected in intercropping with pearl millet when compared with its sole stand. The magnitude of increase was 6.5, 11.1 and 4.1% for plant height, dry weight at maturity and leaf area index at 90 DAS over intercropping system. Intercropped pigeonpea, on an average, decreased the crop growth rate by 26.1 and 11.5% during 30-60 DAS and 60-90 DAS as compared to its sole stand. The cumulative effect of reduction in plant height, dry weight, leaf area index and crop growth rate in intercropped pigeonpea lower the productivity (0.61 t ha^{-1}) when compared to its sole cropping (1.52 t ha^{-1}).

Kumar *et al.* (2013) reported significant superiority in growth and yield attributes as well as yield of pigeonpea under sole pigeonpea as compared to its intercropping with mungbean.

Patel *et al*. (2013) observed that the plant height of pigeonpea was not affected due to intercropping, however, number of branches and pods per plant and dry matter accumulation were significantly increased due to the cultivation of pigeonpea with black moong.

Dhandayuthapani *et al.* (2015) revealed that intercropping of pigeonpea (120 cm × 30 cm) + green gram with row ratio of 1:3 produced highest plant height (192.1 cm), total branches (23.3), stem girth (7.9 cm), LAI (2.00) and DMA (6342 kg ha^{-1}) over other treatments (pigeonpea 90 cm ×30 cm + green gram 1:2, pigeonpea 90 cm × 45cm + green gram 1:2, pigeonpea 90 cm × 60 cm + green gram 1:2, pigeonpea 120 cm × 45 cm + green gram 1:3, pigeonpea 120 cm × 60 cm + green gram 1:3, pigeonpea 150 cm × 30 cm + green gram 1:4, pigeonpea 150 cm × 45 cm + green gram 1:4, pigeonpea 150 cm × 60 cm + green gram 1:4, pigeonpea 180 cm × 30 cm + green gram 1:5, pigeonpea 180 cm × 45 cm + green gram 1:5 and pigeonpea 180 cm × 60 cm + green gram 1:5).

Kumar *et al.* (2015) observed that sole pigeonpea, recorded highest plant height, root length and grain yield (18.5 q ha^{-1}) in a pigeonpea based intercropping which was comparable with pigeonpea + sunhemp (18.0 q ha^{-1}).

Lavanya and Kurhade (2018) reported that sole crop of pigeonpea had significant influence on plant height (148.7 cm), maximum no. of functional leaves (217), no. of branches (14.8), leaf area (105.9 dm^2 $plant^{-1}$) and dry matter production (120 g $plant^{-1}$) due to less competition between plant to plant compared to other treatments.

Yang *et al.* (2018) in their studies on agronomic and economic benefits of pea/maize intercropping systems in relation to N fertilizer and maize density, reported that the CGR of sole maize was always greater than intercropped maize, and it increased by 3.2% to 93.6% during the period of 15 to 95 days after pea emergence in 2012 and 2013. Averaged over the four (for pea) and eight (for maize) measurements were conducted during the whole growth period, leaf area index (LAI) of pea/maize intercropping was 6.9% greater in 2012 and 45.4% greater in 2013 compared with the weighted average of sole maize and sole pea. The leaf area index was 6.7% to 10.2% higher for sole maize and 21.0% to 24.1% higher for sole pea on average.

Tripathi *et al.* (2019) revealed that growth parameters in sole pigeonpea plots, such as plant height, trifoliate leaves $plant^{-1}$, nodules $plant^{-1}$ and dry matter $plant^{-1}$, under RDF were superior to those with no fertilizers at 150 DAS during both the years of study.

Girisha *et al.* (2020) conducted a field investigation on ‘Intercropping of black gram (*Vigna mungo*) in finger millet (*Eleusine coracana* L.) under different methods of establishment' and the results revealed that significantly higher plant height (cm), no. of tillers (plant^{-1}), leaf area (cm^2 plant^{-1}), leaf area index and total dry matter accumulation (g plant^{-1}) was recorded on sole fingermillet over intercropping systems.

Kithan *et al*. (2020) conducted a study on yield potential of pigeonpea and soybean intercropping systems at the experimental farm of School of Agricultural Sciences (SAS) on AICRP on Pigeonpea Nagaland University Medziphema Campus, reported that sole Pigeonpea and sole soybean performed better with respect to growth and yield.

Amanullah *et al*. (2021) in their study, investigated the growth and dry matter partitioning response in cereal-legume intercropping and observed that in winter crops, both wheat and barley grown as sole crop or intercropped with fababean produced maximum crop growth rate (CGR), leaf dry weight (LDW), stem dry weight (SDW) and spike/head dry weight (S/H/PDW) than other intercrops. Among summer crops, sorghum intercropped either with pigeon pea or with mungbean produced maximum crop growth rate (CGR), leaf dry weight (LDW), stem dry weight (SDW), spike/head dry weight (S/H/PDW) at both growth stages. Sole mungbean and pigeon pea or pigeon pea and mungbean intercropping had higher crop growth rate (CGR), leaf dry weight (LDW), stem dry weight (SDW), spike/head dry weight (S/H/PDW) than millet and sorghum intercropping. On the other hand, wheat and barley grown as sole crops or intercropped with fababean produced maximum crop growth rate (CGR), leaf dry weight (LDW), stem dry weight (SDW), spike/head dry weight (S/H/PDW) than other intercrops. Fababean grown as sole crop or intercropped with wheat produced higher crop growth rate (CGR), leaf dry weight (LDW), stem dry weight (SDW), spike/head dry weight (S/H/PDW) at physiological maturity than intercropped with barley or rapeseed.

Yadav *et al.* (2021) conducted a field experiment during kharif season of 2017-18 at Agronomy Research Farm, Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India on silty loam soils as influence of integrated nutrient management in pigeonpea based intercropping system. Among the intercropping systems the maximum plant height, number of branches, number of nodules, effective nodules and nodulation index (290.43 cm, 19.92 plant^{-1}, 23.75 plant^{-1}, 0.84) were recorded with pigeonpea sole which was significantly higher than pigeonpea + sorghum (259.28 cm, 17.78 plant^{-1}, 21.20 plant^{-1}, 0.67) and pigeonpea + sesame (255.22 cm, 17.50 plant^{-1}, 20.87 plant^{-1}, 0.74) respectively.

Dhale *et al.* (2022) on the basis of the results, it was found that the growth attributes for sole soybean and sole pigeonpea was recorded the highest.

Rajashree *et al.* (2022) from an experiment reported that all the growth parameters of pigeonpea were significantly influenced by intercropping system with different fodder crops. Sole pigeonpea recorded highest values of plant height, number of primary branches per plant, number of secondary branches per plant, leaf area and leaf area index at 45 DAS, 90 DAS, 135 DAS and at harvest.

Shivakumar *et al.* (2022a) stated that maximum plant population, plant height, leaf area and dry matter production plant^{-1} were recorded in sole chickpea over chickpea sown as sequential intercropping with pigeonpea (S3 pigeonpea + sweetcorn – chickpea and S5 paired row pigeonpea + sweetcorn – chickpea) at all the growth stages during both the years of study.

Debata and Das (2024) reported that the pigeon-pea as pure crop recorded significantly higher values for plant height (174.9 cm) and no. of branches/plant at harvest-(15.3), similarly, turmeric as pure crop recorded highest value for plant height (78.30cm), rooting depth (13.11cm), length of leaves (36.31cm).

2.3 Effect of intercropping on yield attributes and yield:

Singh *et al*. (1978) revealed that the reduction in the yield of pigeonpea was mainly due to competition by intercrops for nutrients, moisture and solar energy.

It was frequently stated that a major reason for the predominance of intercropping in poorly developed agriculture was that it could give greater stability of yield over different season. The basis for this was that if one crop failed or grew poorly, the other component crop or crop compensate; such compensation was not possible if the crop were grown separately (Willey, 1979a).

Sharma *et al*. (1988) reported that intercropping of mungbean, urdbean, groundnut or soyabean in pigeonpea rows sown 60 cm apart in 1:1 uniform row at Pant Nagar against pigeonpea sole. They observed that grain yield of pigeonpea reduced in intercropping than pigeonpea as sole but net return was higher in intercroppings due to additional yields of intercrops.

Subramanian and Rao (1988) reported that the intercropping of sorghum with pigeonpea in 2:1 row proportion decreased the seed yields of both the crops (284 and 82 g m^{-2} respectively) when compared to pure stands (354 and 123 g m^{-2} respectively). Further, they attributed in the reduction of pigeonpea yield in intercropping system to reduced number of pods m^{-2}.

Singh *et al.* (1990) examined rice based intercropping system for rainfed upland conditions of chhotonagar plateau with ragi (2:2 row ratio), pigeonpea (3:1 and 4:1 row ratio) and greengram, cowpea and blackgram (2:1 row ratio). They found that rice as a sole crop gave the grain yield of 2.2 t ha^{-1}. Rice + pigeonpea in 4:1 row ratio gave the highest grain yields of the intercropped treatments (1.6 and 0.4 t ha^{-1} for rice and pigeonpea, respectively). Rice intercropped with cowpea gave the lowest grain seed^{-1} of 0.9 and 0.3 t ha^{-1} for rice and cowpea respectively.

Padhi *et al*. (1992) noticed that intercropping reduced the grain yield of both the component crops in pigeonpea + rice, pigeonpea + finger millet, pigeonpea + green gram, pigeonpea + blackgram and pigeonpea + groundnut intercropping systems.

When pigeonpea was intercropped with blackgram and rice, the reduction in yield of pigeonpea ranged from 2.7 percent to 28.74 percent. Seed yield of pigeonpea decreased due to intercropping with rice irrespective of planting pattern (Bajpai and Singh, 1992).

Behera *et al*. (1998) reported that the highest pigeonpea yield was found in sole pigeonpea planting (0.732 and 0.765 t ha^{-1}) and pigeonpea yield gets reduced when it was intercropped with okra, radish and rice.

Singh and Rahman (1999) obtained significantly higher seed yield of sole pigeonpea (1710 kg ha^{-1}) followed by intercropping of pigeonpea and groundnut 1:2 row ratio (1320 kg ha^{-1}).

Halvankar *et al*. (2000) obtained the highest pigeonpea yield in sole pigeonpea planting (1821 kg ha^{-1}) and pigeonpea yield gets reduced when it was intercropped with soybean.

Omprakash and Bhushan (2000) revealed that intercropping of pigeon pea + green gram and castor + green gram proved superior to pigeon pea + sesame/ pearlmillet and castor + sesame pearlmillet^{-1} intercropping system in respect of productivity and economics. Castor + green gram and pigeon pea + green gram being on par recorded higher LER than other intercropping treatments. Pigeon pea + green gram intercropping showed the highest B: C ratio. The grain yield of pigeon pea and soybean intercropping system significantly decreased as compared to their sole crop yields.

Velayutham *et al.* (2000) in their findings found the sole crop of pigeonpea to record significantly higher seed yield (1101 kg ha^{-1}) but pigeonpea grown at 120 × 120 cm spacing performed better in enhancing the grain yield of the intercrops.

Rana *et al.* (2002) reported that in rice based intercropping system with green gram, groundnut, black gram and pigeon pea, the intercropping in general increased the yield attributing character i.e., LAI, number of tillers and number of panicles of rice. The total productivity on rice + pigeon pea was the highest among the cropping system.

Jat and Ahlawat (2003) found that in pigeonpea + groundnut intercropping system the groundnut in all intercropping treatment being at par recorded significantly lower yield attributes (except 1000- seed weight) and yield compared with sole groundnut.

Rathod *et al.* (2004) showed that the grain yield (1495 kg ha^{-1}), stalk yield (3530 kg ha^{-1}) and harvest index (29.51 %) was found highest in pigeonpea grown as a sole crop over in intercropping systems.

Chaudhary and Thakur (2005) reported that the mean seed yield of pigeonpea was higher in sole stand which was significantly superior to all other systems. The highest values of yield attributes of pigeonpea viz. pods plant^{-1}, grains pod^{-1} and 1000- grain weight was recorded under sole stand and the lowest when intercropped with maize and sesame owing to their canopy effect.

Jabbar *et al.* (2005) conducted a field experiment on the performance of different upland rice based intercropping system (rice + forage maize, rice + sesbania, rice + mungbean, rice + rice bean, rice + cowpea, rice + pigeonpea and rice alone), revealed that all the intercropping system gave 16.42 to 37.67% higher total rice grain yield equivalent than monocropped rice.

Sharma and Singh (2008) reported that the seed yields of sesame intercropped with soybean and black gram were substantially more than that intercropped with maize. The values of sesame equivalent yield, land equivalent ratio, net monetary returns and benefit: Cost ratios were higher with sesame + black gram at 2:2, which was closely followed by sesame + soybean at 2:2 intercropping.

According to Darshan *et al.* (2009) significantly higher seed yield (1919 kg ha^{-1}) was recorded with sole pigeonpea grown with wider planting geometry of 120 x 15 cm compared to other planting geometries (60 x 30 cm and 90 x 20 cm) either in sole or intercropping system. Among the intercropping situations, higher seed yield (1476 kg ha^{-1}) was recorded with wider planting geometry (120 x 15 cm) pigeonpea with sesame in 1:3 row ratio over other treatments. Sesame seed yield followed the same trend as that of pigeonpea.

Dass and Sudhishri (2010) studied that finger millet + pigeonpea (3:2) caused the highest reduction (41.1%) in finger millet yield and loss in finger millet yield due to finger millet + pigeonpea (6:2) and finger millet + blackgram (6:2) was only 14.7 and 4.5%, respectively as compared to sole contour sown finger millet (2.24 t ha^{-1}).

Patra and Patra (2010) observed that intercropping between sesame and soybean increased the number of filled pods due to intercropping as compared to respective sole cropping. Number of seeds/pod of sesame cv Rama increased in intercropping with soybean cv Pb-1 over sole cropping. Test weight of sesame did not vary remarkably in mixed stand with respect to their pure stands. Intercropping combinations always recorded higher yield advantages in both the seasons (15 to 27% in summer and 17 to 32% in rainy season). Considering soybean equivalent yields (2.12-2.20) and land equivalence (1.27-1.30) it can be concluded that soybean cv PK-327 can be grown in association with sesame cv Kanke-1 either in 1:1 or 2:2 proportions in both summer and rainy seasons. Other intercropping was also advantageous over sole cropping to some extent.

Kumawat *et al*. (2012) revealed that pigeonpea sole gave higher grain yield (1848.5 kg ha^{-1}) than pigeonpea + blackgram in 1:1 row ratio (1779 kg ha^{-1}) and pigeonpea + blackgram in paired row (1743.5 kg ha^{-1}).

Dhandayuthapani *et al.* (2015) revealed that intercropping of pigeonpea (120 cm × 30 cm) + green gram with highest seed yield (1741 kg ha^{-1}) of pigeonpea over other treatments. Similarly, pigeonpea equivalent yield (2397 kg ha^{-1}), land equivalent ratio (1.52), area time equivalent ratio (1.15) and income equivalent ratio (1.29) were also higher with pigeonpea (120 cm × 30 cm) + greengram 1:3 row ratio over rest of the treatments.

Pal *et al.* (2016) recorded higher seed yield 1729 kg ha^{-1} with pigeonpea + urdbean intercropping system over pigeonpea + sorghum intercropping. They also reported that plant growth parameters such as plant height and dry matter accumulation as well as nitrogen uptake by grain and straw were also higher with pigeonpea + urdbean intercropping system.

Singh (2017) reported that with cropping systems and integrated nutrient management significantly higher yield attributes were recorded under sole crop in pigeonpea and blackgram intercropping system, however no of seeds pod^{-1} of blackgram was at par with pigeonpea + blackgram 1:1 and 100- seed weight of both crops significantly superior over others.

Yadav *et al.* (2017) observed sole planting of sesame to have recorded significantly higher seed yield (720 kg ha^{-1}) and stick yield (2450 kg ha^{-1}) as compared to other intercropping systems.

Sujatha and Babalad (2018) found that among the intercropping systems, transplanted pigeonpea intercropping with greengram recorded significantly higher growth parameters and pigeonpea grain yield (2,550 kg ha^{-1}) and transplanted pigeonpea intercropping with blackgram recorded significantly pigeonpea equivalent yield (3,987 kg ha^{-1}) as compared to other intercropping systems and sole pigeonpea.

Bhardwaj *et al*. (2023) on the basis of their experiment results showed that sole pigeon pea, sole green gram and sole sesame produced significantly higher seed and stover yield over intercropped mean. Under cropping system, yield attributes were at par but maximum grain yield was recorded under pigeon pea + black gram but strover yield in pigeon pea + sesame.

Debata and Das (2024) reported that the pigeon-pea as pure crop recorded significantly higher values for no. of pods /plant (12.3), no of seeds /pod (4.7), 1000 seed mass (82.11) g, and yield of 14.07 q ha^{-1}. The turmeric as pure crop recorded higher weight of mother rhizome - 34.40 g, weight of primary rhizome - 132.30 g, and weight of secondary and tertiary rhizome - 75.20 g, total weight clump - 241.80 g and fresh turmeric rhizome -106,04 q ha^{-1}.

2.4 Effect of intercropping on competitive indices

The LER values in different intercropping system were always greater than unity indicating yield advantage from intercropping systems. This resulted from both temporal and spatial complementarities between rice and the grain legumes. This corroborated the findings of several workers (Mandal and Mahapatra, 1990; Schultz *et al.,* 1982; Mandal *et al.,* 1986 and 1987).

With regard to monetary advantage, intercropping systems showed higher monetary advantage as compared to sole crops as the value of LER was always greater than unity. Mandal and Mahapatra (1990) also made similar observation. However, the monetary advantage value followed the same trend as LER. Patra *et al.* (1990) also opined alike.

Kumar *et al.* (2005) proved that pigeonpea was more competitive than green gram as reflected by higher competitive ratio of pigeonpea, which ranged from 1.94 and 3.25 in different intercropping systems. The negative aggressivity of greengram under all intercropping systems reflected the poor competitiveness of greengram than pigeonpea, which had positive aggressivity in all the intercropping systems. The Intercropping of greengram either one or two rows in between two rows of pigeon pea irrespective of row spacing were advantageous because the product of relative crowding coefficient was more than 1 due to their complementary relationship.

Pigeonpea was more competitive than finger millet at both the row ratios, having higher values of competitive ratio and positive aggressivity factor. In general, 'UPAS 120' sown at 2:4 row ratio recorded the highest land equivalent ratio (LER), area-time equivalent ratio (ATER), competitive ratio (CRa), aggressivity (Aa) and monetary advantage index (MAI). Among the intercropping systems, 'UPAS 120' + 'Bhairabi. This system recorded 42% more land use efficiency, 32% more per day yield and Rs 586 more monetary advantage than the respective sole component crops. (Padhi *et al.*, 2010).

Kumar *et al*. (2013) reported the highest land equivalent ratio (LER) of 1.55 was recorded in pigeonpea + maize intercropping system. There was significant superiority in growth and yield attributes as well as yield of pigeonpea under sole pigeonpea as compared to its intercropping with mungbean. However, pigeonpea equivalent yield (1.86 t ha^{-1}) was the highest under intercropping of pigeonpea with mungbean.

Pigeonpea + urdbean (*Vigna mungo* L.) intercropping system, recorded higher yield of pigeonpea (1.85 t ha^{-1}), pigeonpea equivalent yield (2.17 t ha^{-1}), LER (2.29), production efficiency (8.56 %), fruiting efficiency (17.16 %) net return (67.3 × 103 ha^{-1}) and net return per rupee investment (3.05) as compared to pigeonpea + maize (*Zea mays* L.) intercropping system and sole pigeonpea (Pandey *et al.*, 2013).

Kujur and Ahamad (2018) observed that land equivalent ratio (LER) was recorded maximum (1.46) under pigeonpea + fingermillet (short duration) 1:1 row ratio, relative crowding coefficient (K) of pigeonpea was more than one in all the intercropping system indicating more of non-competitive interference than the competitive one. The degree of non-competitive interference was more in pigeonpea + fingermillet (short duration) 1:2 row ratio. However, the other spatial arrangement produced less values of RCC which showed lower degree of non-competitive interference resulting in low yield advantages. It seemed that the crop species are partially competed for the different resources. The least competition was evaluated under pigeonpea + fingermillet (long duration) 1:1 (CR = 1.01).

Keerthanapriya *et al.* (2019) obtained that the highest little millet Grain Equivalent Yield of 2083 kg ha^{-1} was significantly recorded in little millet + small onion intercropping system. While the highest land equivalent ratio (LER) of 1.32, relative crowding coefficient (RCC) value of 2.35, aggressivity value of + 0.63 and CR value of 1.56 was recorded in little millet + blackgram.

Kumar *et al.* (2020) in their study concluded that among all intercropping systems, paired row planting of maize at 60:105 cm along with two rows of mungbean in between two pairs was recorded with significantly higher Maize Equivalent Yield (5647 kg ha^{-1}), Relative Crowding Coefficient for system (3.73), Land Equivalent Ratio (1.29), net return (61335), Benefit cost ratio (2.37) and per day return (Rs.515.4/ha/day). Maize was recorded with higher competitive ratio and aggressivity values compared to intercrops, which shows the more competitive nature of maize over intercrops. Among intercrops, mungbean and soybean showed higher competitive nature compared to urdbean and cluster bean against maize crop.

Experiment conducted on growth and yield performance of upland rice (*Oryza sativa* L. var. zambales) intercropped with mungbean (*Vigna radiata* L.) and peanut *(Arachis hypogaea* L.*)* revealed that upland rice with peanut var. CVRC Pn 2011–002 (T_4) had the highest LER value of 1.30 and ATER value of 1.93. (Papong and Cagasan, 2020).

According to Maini and Sandhu (2022) among the different intercropping systems, pigeonpea + pearlmillet [*Pennisetum glaucum* (L.) R. Br.] fodder gave the maximum pigeonpea-equivalent yield of 1.85 tonnes ha^{-1}, being superior to 1.31 tonnes ha^{-1} in sole pigeonpea and 1.38 tonnes ha^{-1} of pigeonpea + fingermillet, while it was at par with pigeonpea + greengram [*Vigna radiata* (L.) R. Wilczek] (1.80 tonnes ha^{-1}).

Sharmili *et al.* (2023) in their experiment recorded higher relative crowding coefficient (RCC) value of 1.14 in little millet at 6:1 ratio, the results further showed that the aggressivity values in little millet were negative and those of legume intercrops were positive, indicating little millet a dominated species and legumes the dominant species. The values of competition ratio computed indicate that among the intercropping systems, competitive ratio was higher when little millet is intercropped with pigeonpea at 4:1 ratio (2.06 and 2.06).

Singh *et al*. (2024b) conducted an experiment on productivity and economic feasibility of pigeonpea base companion cropping under additive series planting system. Over two consecutive *Kharif* seasons in 2016-2017 and 2017-18, a study was conducted at the Soil Conservation and Water Management Farm of C.S. Azad University of Agriculture and Technology in Kanpur. Results indicated that higher performance of yield in sole pigeonpea (17.34 q ha^{-1}), sole blackgram (9.44 q ha^{-1}) and sole sesame (6.32 q ha^{-1}) in compare to other intercropping system.

2.5 Effect of intercropping on economic return

Sharma *et al*. (1988) reported that inter cropping of urdbean with pigeonpea gave the highest net returns of ₹ 5105 ha^{-1} with an additional increase of ₹ 529 ha^{-1} over pure pigeonpea followed by mungbean (₹ 333 ha^{-1}) and soybean (₹ 103 ha^{-1}). Maize and sorghum gave lower net returns than that of pure pigeonpea.

Shinde (1990) found the seed yield of both component crops reduced in intercropping than their sole stands. The margin of total yield reduction in pigeonpea was maximum under 1:3 row ratio and that in groundnut was maximum under 2:2 row ratio of intercropping. However, LER, gross return, net return and B:C ratio were recorded highest under 1:3 row ratio of pigeonpea + groundnut among all treatments of inter and sole cropping.

Jha *et al.* (1991) assessed the yield and net returns for various rice based cropping systems and found that the higher net return to the tune of Rs. 4402 ha^{-1} was obtained when four rows of short duration rice was raised between two pigeonpea rows under experimental stations, but the highest net return of Rs. 6529 ha^{-1} was obtained when groundnut was intercropped with pigeonpea in 4:1 row ratio in farmer's field. They further reported that four rows of short duration rice between pigeon pea rows was the most productive cropping system with respect to land equivalent ratio of 2.10 and net returns of Rs. 4,402 ha^{-1} under rainfed upland condition. For evaluating production potential of pigeonpea based cropping system under different planting patterns of pure pigeon pea, pigeon pea + maize pigeon pea + rice.

Shivran and Ahlawat (2000) observed that pigeonpea and black gram intercropping fetched the highest net return (₹ 23867 ha^{-1}) as compared to sole pigeonpea (₹ 20621 ha^{-1})

Bhagat (2002) indicated that sole crop of pigeonpea with 60×30 cm at $N_{20}P_{40}K_{20}$ + maize with 100% fertilizer i.e., $N_{100}P_{60}K_0$ gave highest net returns (₹10,379 ha^{-1}) as compared to rest of the treatments.

Experiment conducted at ICAR Research Complex, Kolasib, on the productivity and economics of different rice and maize based cropping system revealed that the highest maize equivalent yield (60.64 q ha^{-1}) was obtained with maize + groundnut intercropping. Intercropping legumes with cereals was found to be highly productive and profitable inclusion of groundnut as an intercrop with rice with maize not only enhanced crop yield and highest net return but also has positive effect on soil fertility build up (Laxminarayana and Munda, 2004).

Pigeonpea (UPAS 120) + finger millet (Bhairabi) 2:4 showed significantly higher net return of (8566 Rs. ha^{-1}), monetary advantage (5868 Rs. ha^{-1}), which was comparable with pigeonpea (UPAS 120) + finger millet (PR 202) 2: 4 and significantly superior than sole pigeonpea (Padhi *et al.*, 2010).

Sharma *et al.* (2010) observed that when intercropping of pigeonpea was done with green gram and pearl millet in different row ratio pigeonpea equivalent yield of (17.37 q ha^{-1}) and economics returns i.e., gross return and net return (31237 and 22546 Rs. ha^{-1}, respectively) as compared to pigeonpea + pearl millet intercropping system. But harvest index was highest under pigeonpea + rice intercropping system as compared to all other intercropping systems.

Sharma *et al.* (2012) observed that pigeonpea + greengram intercropping was superior over pigeonpea + pearl millet intercropping with higher PEY, gross return, net return, and BC ratio (14.43 and 13.23 q ha^{-1}, 17.13 and 14.78 q ha^{-1}, 40983 and 35483 Rs. ha^{-1}, 32499 and 27230 Rs. ha^{-1} and 3.81 and 2.29 respectively).

Intercropping system recorded higher net returns (21.91 × 103 ha^{-1}) and B: C ratio (2.1) over sole pigeonpea. (Kumar *et al.*, 2013)

Singh *et al.* (2013) conducted the research experiment for two years and observed that the pigeonpea equivalent yield of 1.45 t ha^{-1} and 1.75 t ha^{-1} was recorded in intercropping system over sole pigeonpea (1.24 and 1.48 t ha^{-1}). The intercropping of mungbean in pigeonpea gave an additional grain yield of mungbean 0.24 and 0.26 t ha^{-1}, whereas, pigeonpea also produced similar yield (1.19 and 1.44 t ha^{-1}) in combination, which resulted in higher pigeonpea equivalent yield over sole crops of both pigeonpea and mungbean. Pigeonpea + mungbean intercropping system fetched significantly higher net returns (19,034 and 23,249 Rs. ha^{-1}) and BC ratio (2.40 and 2.81) over sole pigeonpea and mungbean during the respective years.

Khargkharate *et al*. (2014) revealed that the reductions in boll weight, yield $plant^{-1}$ as well as seed cotton yield ha^{-1} were recorded due to all intercropping treatments over sole cotton. However, highest gross and net monetary returns were received from cotton + soybean (1:1) intercropping (81,419 and 40,878 ha^{-1}, respectively). Cotton + soybean and cotton + pigeonpea were most remunerative intercropping systems in terms of B:C ratio (1.97).

Pigeonpea + greengram 1:2 set furrow with 2.5 t ha^{-1} of vermicompost recorded comparatively higher nutrient uptake NPK (181.3, 14.8 and 75.4 kg ha^{-1} respectively), higher water use efficiency (2.99 kg $ha^{-1}mm^{-1}$), higher PEY (24.6 q ha^{-1}), LER (1.96) and ATER (1.55), and gave significantly higher net return (36916 Rs ha^{-1}) and B:C ratio (3.11) as compared to rest of the treatments. Pigeonpea + groundnut (1:3) was found superior as compared to other intercropping systems treatments (pigeonpea + sorghum 1:3, pigeonpea + cowpea 1:3, pigeonpea + kidneybean 1:3, pigeonpea + sunflower 1:3, pigeonpea + pearlmillet 1:3 and pigeonpea + pearl millet 1:2) with respect to higher PEY (1425 kg ha^{-1}), higher rain water use efficiency (3.19 kg $ha^{-1}mm^{-1}$) and also recorded higher net return (30703 Rs. ha^{-1}) and LER of 1.29. (Kathmale *et al.*, 2014).

Kumawat *et al.* (2015) revealed that among intercropping systems of pigeonpea + black gram (1:1), pigeonpea + black gram (2:2) paired row and sole cropping, pigeonpea + black gram (1:1) showed higher values of PEY (21.75 q ha^{-1}), gross return (120050 Rs ha^{-1}) and net return (99396 Rs ha^{-1}) and BC ratio (4.8) which was comparable with paired row intercropping system and superior to sole pigeonpea.

Ray *et al.* (2016) revealed that among the pigeonpea based intercropping systems, pigeonpea + blackgram (1:1) proved more remunerative and productive with significantly higher pigeonpea equivalent yield (2504 kg/ha) which might be due to higher main crop yield with fair production of intercrop. Significantly higher (and maximum) net return (INR 84115/ ha) and B:C ratio 3.39 was also recorded in pigeonpea + blackgram 1:1 over all other treatment.

Ahamad *et al.* (2017) conducted a field experiment during *kharif* seasons of 2013-14 and 2014-15 at Agronomy Research Farm, Narendra Deva University of Agricultural and Technology, Kumarganj, Faizabad, Uttar Pradesh on silty loam soils to study the response of integrated nutrient management on productivity and nutrient uptake of rainfed pigeonpea based intercropping systems. On the basis of two years results, pigeonpea + black gram intercropping system recorded significantly higher pigeonpea equivalent yield (25.35 and 23.47 q/ha), B:C ratio (2.18 and 2.20).

Kithan *et al*. (2020) showed that among the different intercropping as for economics paired row (2:2) ratios of Pigeonpea and Soybean proved superior to all other treatments in LER (1.89), Net return (Rs 86877 ha^{-1}), Gross return (Rs 133177.8 ha^{-1}) and Pigeonpea Equivalent yield (876.9 Kg ha^{-1}) which was at par with (1:2) row ratios of Pigeonpea and Soybean.

Babu and Padmalatha (2021) observed that among the various pigeonpea intercropping systems, Pigeonpea + cowpea (1:5) was found superior with mean maximum pigeonpea equivalent yield 2026 kg/ha and mean maximum rainwater use efficiency of 2.84 kg/ha-mm compared to other intercropping systems. Maximum net returns of Rs.75,555/ha and benefit cost ratio 2.57 was also recorded with Pigeonpea + cowpea (1:5) intercropping system. Further, this intercropping system also recorded relatively higher land equivalent ratio of 3.27 indicating yield advantage of 27% compared to sole crops.

Kushwaha and Mehta (2023) revealed that pigeon pea + green gram with

125% RDF maximized the pigeon pea grain equivalent yield of 1505 kg ha^{-1}, land equivalent ratio (1.65), net profit of Rs 84826 ha^{-1}and benefit cost ratio (4.68) followed by pigeon pea + green gram.

Manjunath *et al.* (2023) conducted a field experiment on productivity and nutrient uptake of soybean and millets in intercropping systems, results revealed significantly higher land equivalent ratio (1.50) and area time equivalent ratio (1.48) was recorded by 4:2 row ratio of soybean + foxtail millet and 2:1 row ratio of soybean + foxtail millet compared to any intercropping systems.

Singh *et al.* (2024a) the results of the experiment conducted indicated the highest gross return Rs. 134024 ha^{-1}, net return Rs. 76148 ha^{-1} and BCR 2.32 under pigeonpea + black gram (1:1) additive series

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The investigation entitled “Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland” was conducted during the *kharif* seasons of 2021 and 2022 in the Agronomy experimental farm of School of Agricultural Sciences (SAS), Nagaland University, Medziphema Campus, Nagaland. The details of the materials used and methods adopted during the course of investigation have been discussed in this chapter.

3.1 General information

3.1.1 Location

The experiment was conducted at the experimental farm located at Medziphema, in foot hill situation of Nagaland at an altitude of 310 meters above mean sea level (MSL) with the geographical location at $25^{0}45'43''$ North latitude and $95^{0}53'4''$ East longitude.

3.1.2 Climatic condition

Table 3.1a & 3.1b and Figure 3.1 & 3.2 showed the monthly average atmospheric temperature, rainfall, relative humidity and sunshine hour during the period of field experiments.

3.1.2.1 Rainfall

From the recorded meteorological data, it has been found that the crop received total rainfall of 829.9 mm and 1070.8 mm in the year of 2021 and 2022, respectively during the period of experimentation. However, the highest rainfall occurred in July (272.2 mm) during 2021 and 2022 (375.8 mm) respectively. No rainfall was received in the month of November during both 2021 and 2022 respectively.

Table 3.1(a) Meteorological data recorded during the cropping season (2021)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (˚C)	Min (˚C)			
22	33.11	22.94	91.29	61.00	17.40	1	4.4
23	33.56	23.63	91.71	63.14	39.1	1	2.8
24	33	24.79	93.29	75.29	19.5	3	3.8
25	33.01	24.51	93.29	67.43	43.4	4	4.3
26	33	25	92.57	69.14	37.6	1	1.9
27	33.17	24.73	88.86	73.43	19.2	2	2.5
28	32.41	24.69	92.71	70.43	105.7	5	3.9
29	33.69	24.66	94.57	69.57	53.3	2	3.9
30	34.49	24.89	89.57	70.43	74.9	2	6.6
31	32.27	25.1	91.57	78.43	34	3	3.9
32	33.2	24.53	92.86	67.86	25.2	3	3.4
33	32.47	24.93	95.57	77	41.8	2	1.6
34	32.37	24.29	91.86	67.71	7	0	3.2
35	32.31	24.29	92.86	72.86	52.9	4	3.0
36	33.19	24.01	94.57	68.43	49.1	3	6.5
37	33.79	23.94	93.57	67.71	42.2	1	5.8
38	32.11	23.31	94	67.71	13.1	2	5.0
39	33.7	23.77	93.14	66	8.1	2	7.1
40	32.29	23.06	94.29	71.14	5	1	5.0
41	33.89	23.57	91.86	62.86	53.8	2	7.8
42	33.3	23.6	95.43	70.14	69.1	3	5.4
43	29.99	18.97	96.86	71.86	2.1	0	7.2
44	30.03	19.07	95.14	57.86	0	0	7.5
45	29.46	15.24	96	49.14	0	0	8.4
46	28.64	16.39	94.86	54.71	0	0	7.5
47	27.76	13.33	96.43	49.29	0	0	8.0
48	26.90	11.40	95.86	45.71	0.00	0	7.9
49	26.43	15.24	95.14	57.71	8.50	1	5.0
50	25.33	11.60	94.86	51.71	0.00	0	6.7
51	24.91	8.93	95.43	46.71	4.70	1	6.7
52	23.35	9.66	96.50	50.00	3.20	1	6.2

Source: ICAR Research Centre for NEH Region, Nagaland Centre, Medziphema

Table 3.1(b) Meteorological data recorded during the cropping season (2022)

Week No.	Temperature		Relative humidity		Rainfall (mm)	Rainy days	Sunshine hours
	Max (˚C)	Min (˚C)	Max (%)	Min (%)			
22	33.3	23.3	93	65	22.5	2	4.8
23	33.0	24.0	94	74	51.1	4	2.9
24	30.3	23.3	95	74	46.7	4	1.3
25	31.2	23.4	95	75	34.8	3	1.8
26	33.3	24.9	93	68	9.9	2	4.5
27	34.2	24.7	91	66	77.1	3	7.2
28	34.1	24.5	90	69	22.9	3	6.9
29	33.9	24.5	92	75	135.3	4	3.4
30	31.8	23.2	96	70	135.3	5	3.6
31	33.6	23.9	93	68	48.8	2	3.1
32	33.3	23.9	96	71	114.7	5	5.1
33	33.6	24.2	91	72	27.5	2	6.1
34	34.1	24.5	94	68	64.2	1	4.1
35	32.7	24.3	93	68	9.0	1	4.6
36	33.4	24.4	89	67	21.7	2	4.9
37	31.9	23.5	91	72	42.8	3	4.1
38	33.5	24.0	91	65	15.3	2	5.6
39	32.8	23.2	91	70	81.2	2	6.3
40	31.9	23.5	95	74	31.0	3	4.4
41	31.8	22.7	91	71	2.9	1	5.0
42	30.9	20.6	94	65	19.7	3	5.9
43	28.1	19.9	95	71	41.0	2	4.7
44	29.8	17.1	96	60	0.0	0	8.0
45	29.3	16.7	96	57	0.0	0	8.2
46	27.9	14.6	98	56	0.0	0	8.2
47	27.7	12.8	96	52	0.0	0	8.0
48	27.8	14.3	96	67	0.0	0	7.4
49	27.6	12.0	95	49	0.0	0	8.0
50	26.4	11.3	96	50	0.0	0	7.0
51	25.7	11.0	96	51	0.2	0	6.4
52	22.7	11.2	97	60	15.2	1	3.9

Source: ICAR Research Centre for NEH Region, Nagaland Centre, Medziphema

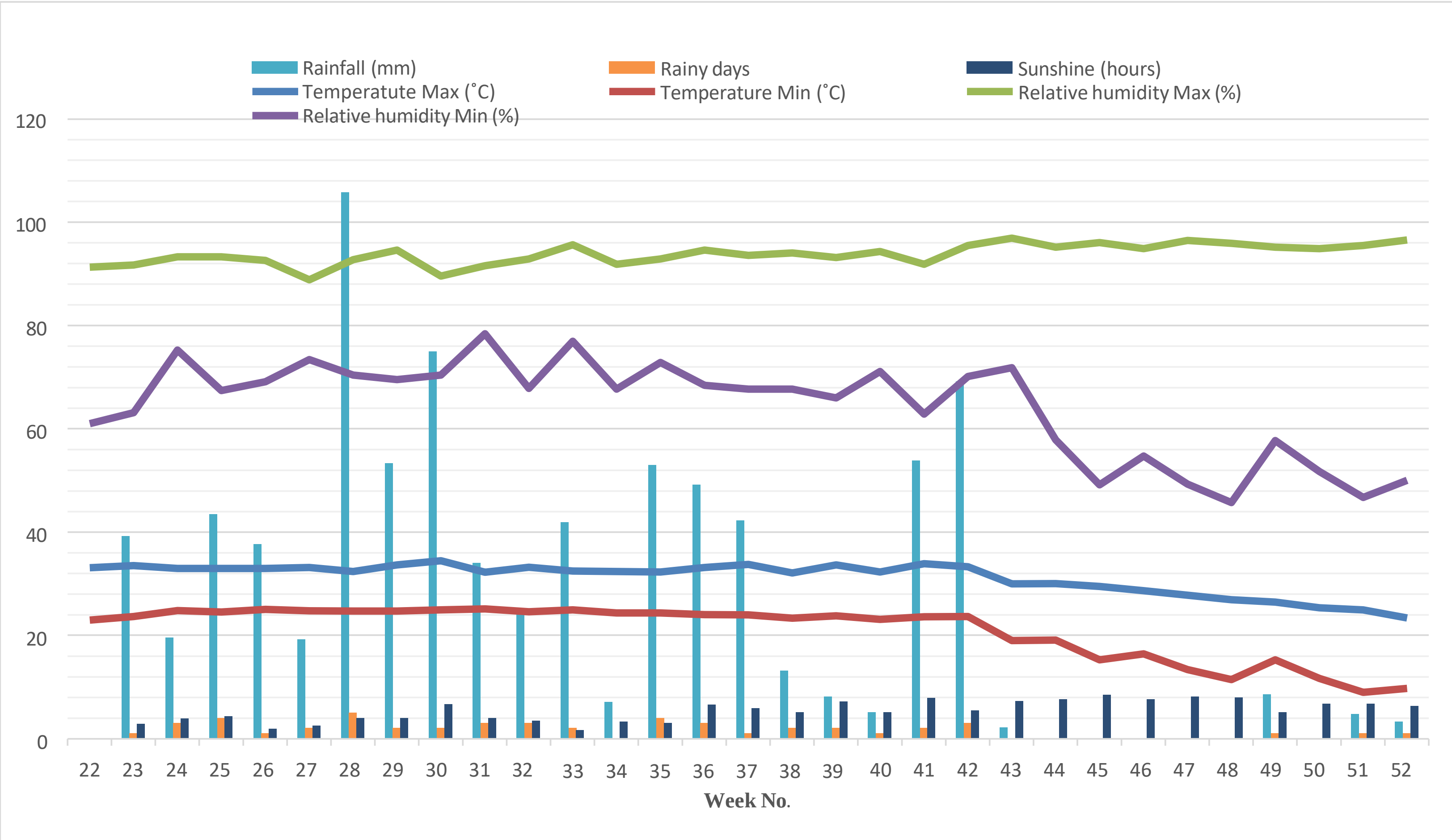

Fig 3.1(a): Meteorological data recorded during the cropping season June- December, 2021

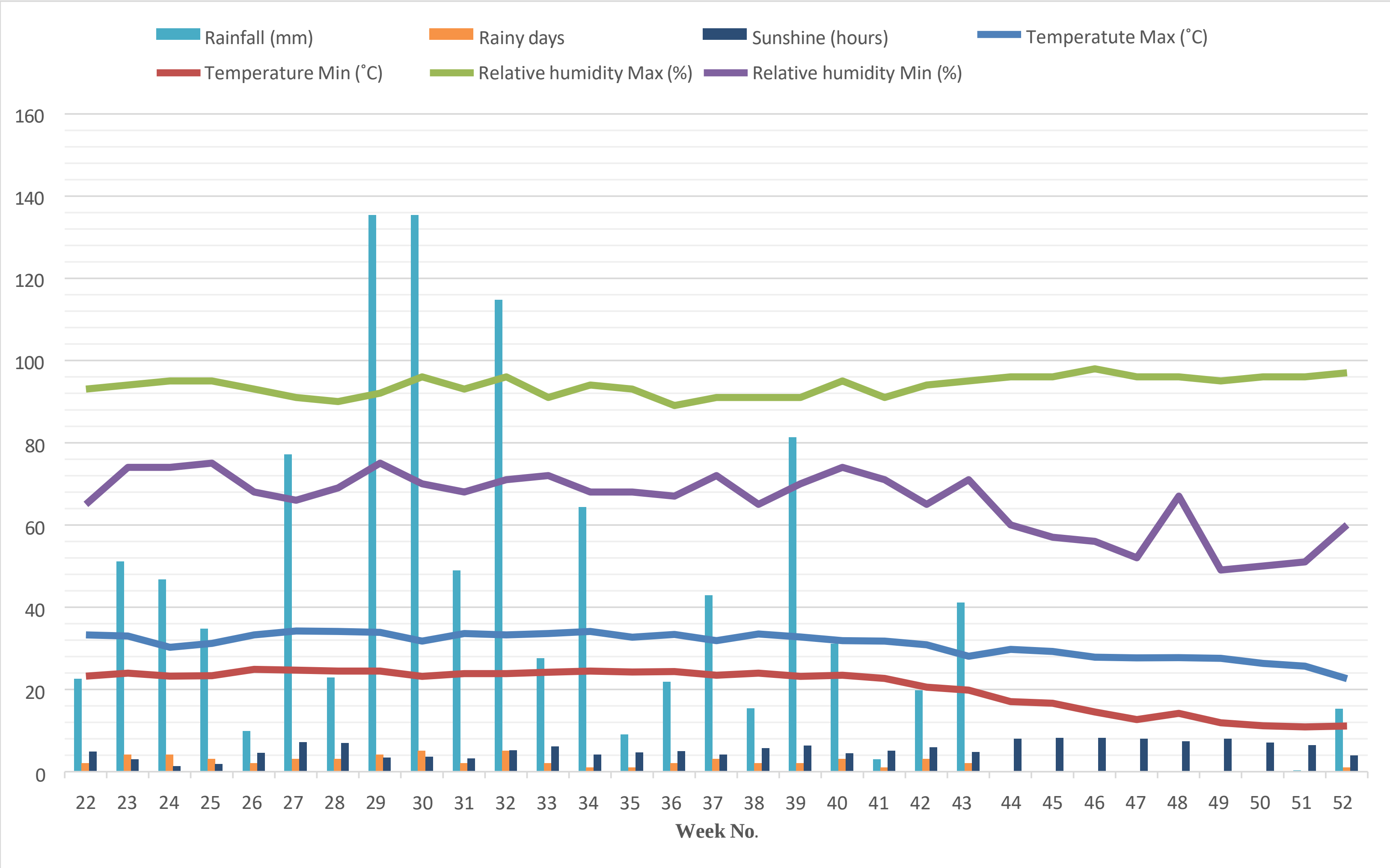

Fig 3.1(b): Meteorological data recorded during the cropping season June- December, 2022

3.1.2.2 Temperature

During the period of field experiment, the highest monthly average maximum temperature was recorded in the month of July (33.33˚C) and lowest maximum temperature (11.3˚C) was in August during the first experimentation year (2021). In 2022, highest average maximum temperature was recorded in the month of July (33.6˚C) and lowest monthly mean minimum temperature (11.7˚C) was observed in December. The maximum monthly average temperature ranged between 24.55˚C – 33.45˚C and minimum monthly average temperature ranged between 11.5˚C - 25.4˚C during study period.

3.1.2.3 Relative Humidity

Regarding relative humidity (RH) the highest monthly relative humidity was recorded in November, 2021 (96.86 %) while, the lowest monthly mean minimum relative humidity was in December, 2021 (45.71 %) during the first year of study. However, during second year, the highest monthly mean maximum relative humidity was recorded in November (98.00 %) and the lowest monthly mean minimum relative humidity was in December (49.00 %).

3.1.3 Previous cropping history of the experimental field

The details of cropping history of the experimental field for last three years experimentation were as given below:

Table 3.2 Previous cropping history of the experimental site

Year	Crops grown		
	Pre-kharif	***Kharif***	***Rabi***
2017-2018	-	Groundnut	-
2018-2019	-	Groundnut	-
2019-2020	Fallow	Fallow	Fallow

3.1.4 Soil condition

The soil of the experimental plot was categorized as clay loam and well drained. Soil samples were collected before sowing and after harvest of crop from each plot and were air dried, ground, and sieved through 2 mm diameter sieve and were used for estimation of available N, P, K, and organic carbon. The soil was acidic in nature with high organic carbon content. The details of physio-chemical status of the soil at the experimental site before sowing and after harvest of crop is presented in Table 3.3.

Table 3.3 Initial soil status of experimental field

Soil parameters	Method followed	2021		2022	
		Status	Remark	Status	Remark
Soil texture	International pipette method (Piper,1966)	Sand: 54.90% Silt:27% Clay:18.1%	Sandy loam	Sand: 55.80% Silt:27.2 % Clay: 17%	Sandy loam
Soil pH	Digital pH meter (Jackson,1973)	4.96	Strongly acidic	4.99	Strongly acidic
Organic carbon (%)	Titrimetric determination (Walkley and Black method,1934)	1.44	High	1.49	High
Available N (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	263.54	Low	270.15	Low
Available P (kg ha^{-1})	Bray's I method (Bray and Kurtz, 1945)	22.45	Low	23.65	Low
Available K (kg ha^{-1})	Neutral normal ammonium acetate method (Jakson,1973)	147.12	Medium	152.34	Medium

3.2. Experimental materials

3.2.1 Crops and varieties

The general descriptions of the crop varieties used in the present experiment are given below:

a. Pigeonpea variety PA-291

Pigeonpea variety PA-291 is a promising composite variety obtained from All India Coordinated Project (AICRP) on Pigeonpea, Medziphema, Nagaland Centre. This variety is early medium duration, semi dwarf and drought tolerant. It performed well in the region.

b. Rice variety CAU-R2

The rice variety CAU-R2 is a variety developed by Central Agricultural University, Imphal. It is a semi dwarf, extra early maturing type suitable for rainfed upland and jhum ecosystem condition with high organic matter content. The variety performed well in the region.

c. Sesame variety GT-10

The sesame variety GT-10 released from Gujarat, it is a high yielding variety, resistant to powdery mildew. The variety performed well in the region.

d. Greengram variety Pusa Vishal

The green gram variety Pusa Vishal developed by Indian Agricultural Research Institute (IARI). It is a high yielding variety tolerant to various diseases and pests. This variety produces up to 15-20% higher yield than local variety and has a shorter maturity period of around sixty days.

e. Soybean variety JS-9752

The soybean variety JS-9752 released from DSR Indore and NJKVV, Jabalpur is recommended for the north eastern zone. The plant had white flowers, tawny pubescence, large number of pods per plants. Tolerant to excessive soil moisture, good seed longevity and short crop duration.

3.2.2 Chemical fertilizers

Nitrogen as Urea, Phosphorus as Single Super Phosphate and Potash as Muriate of Potash were utilized in the present experiment.

3.2.3 Plant protection chemicals

Chlorpyriphos, malathion and neem oil were used for control insects in the crops. Saaf and redomil fungicides were used for seed treatment and control of seedling blight.

3.3 Experimental details

3.3.1 Experimental design

The experiment was laid in Randomized Block Design (RBD) with three replications. The experimental field was divided into three equal blocks, with each block subdivided into seventeen equal plots. The different treatments were than randomly allocated within the plots of each block. The layout of the experiment is given in Fig 3.2.

3.3.2 Details of the experimental techniques

Experimental design	: Randomised Block Design (RBD)
Number of treatment combinations	17
Number of replications	3
Total number of plots	51
Plot size	: 5 m x 4 m
Block border	: 1 m
Plot border	: 0.5 m

3.3.3 Treatment details

The different treatments and their combinations in the present experiment are given below:

C_1: Pigeonpea + Rice (1: 1)

C_2: Pigeonpea + Rice (1: 2)

C_3: Pigeonpea + Rice (1: 3)

C_4: Pigeonpea + Sesame (1: 1)

C_5: Pigeonpea + Sesame (1: 2)

C_6: Pigeonpea + Sesame (1: 3)

C_7: Pigeonpea + Greengram (1:1)

C_8: Pigeonpea + Greengram (1:2)

C_9: Pigeonpea + Greengram (1:3)

C_{10}: Pigeonpea + Soybean (1:1)

C_{11}: Pigeonpea + Soybean (1:2)

C_{12}: Pigeonpea + Soybean (1:3)

C_{13}: Pigeonpea sole

C_{14}: Rice sole

C_{15}: Sesame sole

C_{16}: Greengram sole

C_{17}: Soybean sole

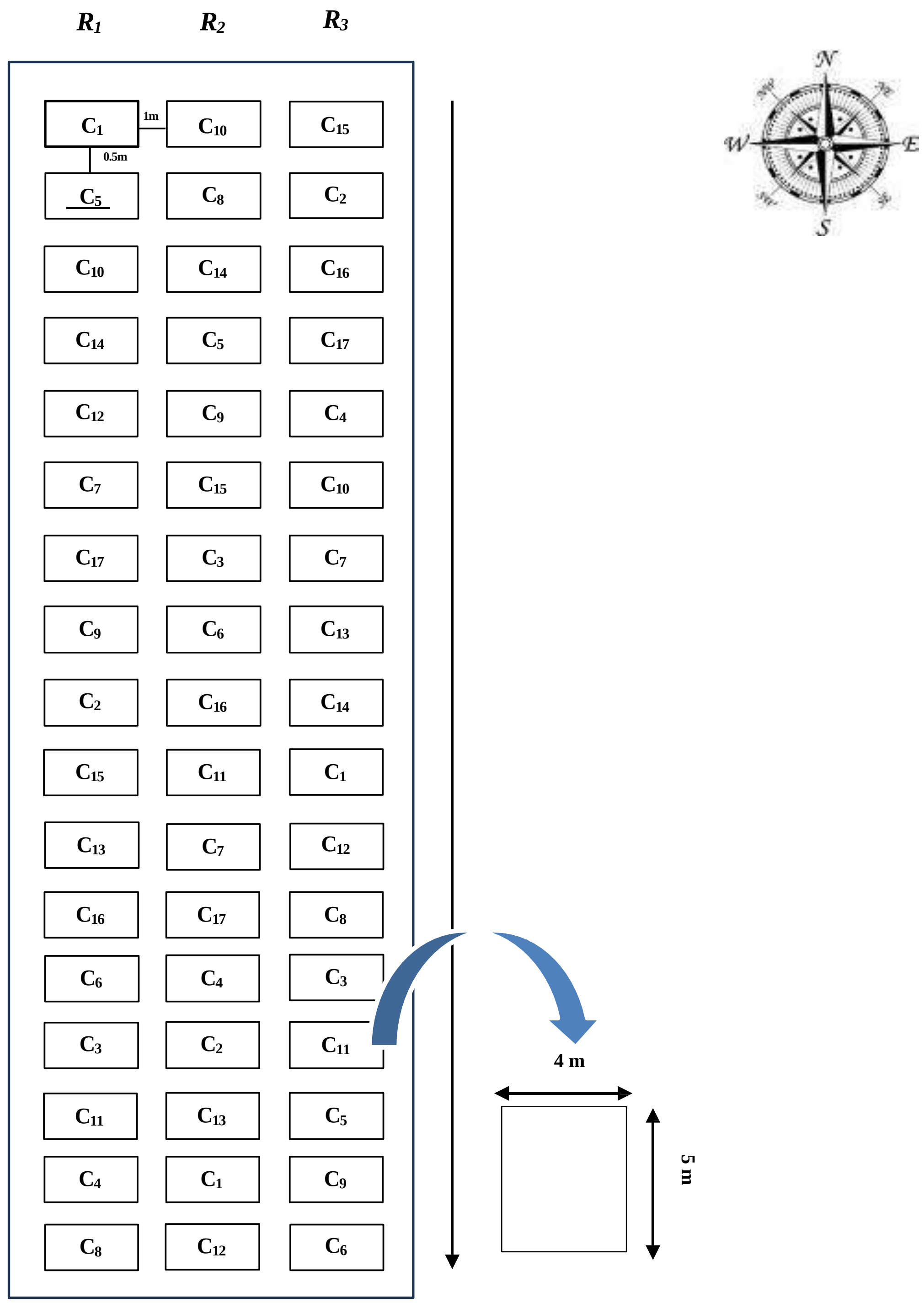

Fig. 3.2: Field layout of the experiment in Randomized Block Design (RBD)

3.3.4 Cultivation details

The agronomic practices carried out during the course of the experiment are given below. The calendar of agronomic management practices followed during the investigation period are presented in Appendix-A

3.3.4.1 Field preparation

The field experiment was carried out in the experimental field at the Agronomy block at SAS farm, Medziphema. The field was thoroughly ploughed with tractor drawn disc plough in the last week of June followed by harrowing in the first week of July and leveled properly. All the stubbles and debris were removed and the layout was prepared according to the various cropping systems.

3.3.4.2 Application of manure

The recommended dose of FYM of the main crop pigeonpea was taken and calculated for each plot separately and applied four weeks before the sowing of the crops.

3.3.4.3 Application of fertilizers

Fertilizer requirements of the crops were met through Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O).

a) Pigeonpea intercrop and sole crop of pigeonpea

The recommended dose of NPK - 20: 40: 30 were applied for the sole and intercrop of pigeonpea. Full dose of nitrogen, phosphorus and potassium was applied as basal dose at the time of sowing.

b) Rice, sesame, greengram and soybean as intercrop.

No additional dose of fertilizer was given to intercrops when intercropped with pigeonpea.

c) Rice, sesame, greengram and soybean as sole crop.

The sole crops were applied with the recommended dose of their fertilizer. Sole crop of rice received NPK - 60: 40: 30 which was applied as full dose of P and K and one-third (1/3) of N as basal dose and remaining two-third (2/3) of N in split doses at tillering and panicle initiation stage.

Recommended fertilizer dose NPK- 30: 40: 30 of sole crop sesame which was applied as whole dose of P and K and half of N as basal and the remaining nitrogen at first hoeing and weeding.

In case of greengram and soybean the full recommended dose NPK- 20: 60: 40 and NPK- 20: 60: 40 respectively were applied as basal dose at the time of sowing.

3.3.4.4 Seed treatment

Seeds were treated with fungicide saaf @ 2 g kg^{-1} seed. The fungicide was made into paste with the help of water and spread evenly into the seeds and kept for shade dry before sowing of the seeds.

3.3.4.5 Seed rate

Healthy and clean seeds were selected as per their recommended seed rate. The seed rate of sole pigeonpea and pigeonpea (1:1) was 12 kg ha^{-1} while 9.6 kg ha^{-1} and 7.2 kg ha^{-1} for pigeonpea (1:2) and pigeonpea (1:3) respectively.

Similarly, the seed rate of the intercrops was calculated and sown accordingly.

3.3.4.6 Planting geometry

a) Sole crop

Each crop was sown at their own specific spacing. Sowing of pigeon pea was done at 60 cm row to row and 30 cm plant to plant, while rice was sown at

20 cm row to row and 10 cm plant to plant. In case of sesame, greengram and soybean, sowing was done at 30 cm row to row and 10 cm plant to plant.

b) 1:1 ratio

The main crop pigeonpea was sown by line sowing at the same spacing as that of the sole crop while a single row of intercrops (i.e. rice, sesame, greengram and soybean) were sown in between in the rows of pigeonpea.

c) 1:2 ratio

Sowing of main crop pigeonpea was done in pigeonpea rows at a spacing of 90 cm row to row and 30 cm plant to plant. In case of the intercrops two rows of each crop were sown in between the main crop in the respective treatments.

d) 1:3 ratio

Pigeonpea sowing as main crop was done by line sowing at the spacing 120 cm row to row and 30 cm plant to plant and three rows of intercrops were sown in between the main crop.

3.3.4.7 Sowing of seeds

Both the base crop and component crops were sown on the 1st week of July during 2021 and 2nd week of July during 2022. Seeds were sown in the open furrows in lines by dibbling two or three seeds per hill. Sowing of pigeonpea was done in pigeonpea rows and the intercrops i.e rice, sesame, greengram and soybean were dibbled in their respective lines as per row proportion of the treatments.

3.3.4.8 Intercultural operations

Gap filling was done after 10 DAS to maintain the optimum plant population in the field. Similarly, thinning was carried out at 15 DAS keeping one plant with a view to obtain optimum plant population. Hand weeding followed by earthing up was done at 30 DAS for all the crops. All the plants were given uniform intercultural operations during the entire growth period in both the years.

3.3.4.9 Harvesting

a) Pigeonpea

The crop was harvested manually when most of the pods (80%) turned. The plants were cut at the base close to ground level. Harvested crop was left as such for respective plots for sun drying for a period of ten days. After sun drying, the bundles were made and weighed. Threshing was done by beating the plant material with a wooden stick. After threshing the produce was winnowed, cleaned and weighed. Grain yield as well as stalk yield was recorded.

b) Rice

The crop was harvested manually with the help of a sickle and bundled separately for each plot. The harvested crop was sun dried, threshed and winnowed manually. The grains were packed separately for each plot and marked according to the plot number.

c) Sesame

The produce after harvesting was left in the field for sun drying, and the bundles of each net plot were tied. The straw yield of each plot was obtained in kg/plot by subtracting the seed yield of the respective plot from the weight of these bundles and then converted into kg ha^{-1} by multiplying with the conversion factor. The straw of the plant *i.e.* leaves and pod covers of the crop were weighed after threshing in each plot.

d) Greengram

The Green gram was harvested from 28th August to 15th Sept 2021 first year and on 25 August to 15th September 2022 during the second year, respectively. The crops were threshed manually plot wise.

e) Soybean

The harvesting was done manually with the help of sickle when the crop was harvested when it reached at its maturity. Soybean maturity was judged when plants started drying to pale yellowish colour, leaflets started shedding and pods turned to yellow colour. The produce of each plot was tied into bundles, duly labeled and allowed to sun dry in respective plots. The harvested bundles were weighed with the help of weighing balance. Threshing of the produce of each plot was done separately by beating with wooden sticks after which seeds were cleaned by winnowing manually for each plot and were weighed.

3.4 Experimental observation

I. Crop observation

A) Pigeonpea

1. Growth attributes

For recording the growth attributes, five number of plants were randomly tagged from each plot. The readings were recorded at different crop growth stages.

1.1 Plant height (cm)

Five plants were randomly selected to take the height of plants for pigeonpea from the middle rows in the plots. The measurements were recorded at 30, 60, 90 and 120 DAS. The height of the plants was measured by the use of a linear scale from the ground level to the terminal apex. The mean height from the selected plants were taken as the score for each plot.

1.2 Plant population (m^{-2})

The plant population of the crop pigeonpea was recorded before harvest from three randomly selected areas in all the treatments per square meter. The results thus obtained were recorded as plants per m^{-2}.

1.3 Number of primary branches plant^{-1}

Randomly five plants from each plot were selected and the tagged plants were counted at 30, 60, 90 and 120 days after sowing (DAS) for the number of primary branches. The average number of branches of five plants was worked out.

1.4 Crop growth rate (g m^{-2} day^{-1})

It is the rate of growth in an interval of time. It is defined as the rate of dry matter production per unit ground area per unit time (Watson, 1952). CGR is expressed as g m^{-2} day^{-1} and calculated using the formula.

$$CGR = \frac{W_2 - W_1}{(t_2 - t_1)\ S}$$

Where, CGR= Crop growth rate, W_1 and W_2 = dry matter accumulation plant in g at time t_1 and t_2 respectively. S is the land area (m^2) over which dry matter was recorded.

1.5 Absolute growth rate (g day^{-1})

AGR expresses the increase in dry matter per unit time. It is generally expressed as (g day^{-1}) in case of dry matter accumulation plant^{-1} and it is calculated by using the formula (Radford, 1967)

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_2 and W_1 refer to the total dry matter accumulation plant^{-1} at times of t_2 and t_1, respectively.

1.6 Relative growth rate (g g^{-1} day^{-1})

It is the rate of increase of plant material per unit weight per unit time. The unit of relative growth rate is g g^{-1} day^{-1}.

$$RGR = \frac{\ln W_2 - \ln W_1}{(t_2 - t_1)}$$

Where, $\log_e W_1$ and $\log_e W_2$ are natural log of initial and final dry matter of plant at initial and final time interval.

1.7 Net Assimilation rate (g m^{-1}day^{-1})

NAR is the rate of increase in dry weight per unit leaf area per unit time.

It was estimated by using the formula given by Gregory (1926)

$$\text{NAR} = \frac{(W_2 - W_1)(\ln W_2 - \ln W_1)}{(t_2 - t_1)\ (L_2 - L_1)}$$

Where, W_1 and W_2 are plant dry weight at time t_1 and t_2 respectively L_1 and L_2 are leaf area at time t_1 and t_2 respectively.

1.8 Leaf Area Index (LAI)

Leaf area index of the five tagged plants were recorded at 30, 60 and 90 DAS. The LAI was worked out using the formula (Watson, 1947)

$$LAI = \frac{Total\ leaf\ area\ (\text{cm}^2)}{\text{Ground area (cm}^2)}$$

2. Yield attributes

2.1 Plant stand at harvest (m^{-2})

The plant stand at harvest was recorded by actually counting the number of plants in the net plot during harvest of the crop. For the final plant stands of pigeonpea per row meter, plant count was done by actually counting the number of plants in one meter of three rows in net plot.

2.2 Number of pods plant^{-1}

The number of pods per plant was counted from the tagged plants in each plot and the average was recorded as the numbers of pods plant^{-1}.

2.3 Number of seeds pod^{-1}

The number of seeds per pod was counted from five tagged plants from each plot and the mean was calculated for statistical analysis.

2.4 Length of pod (cm)

The number of seeds per pod was counted from five tagged plants from each plot using a scale and mean was calculated for statistical analysis.

2.5 Weight of pod plant^{-1} (g)

The number of seeds per pod was counted from five tagged plants from each plot and mean was calculated for statistical analysis.

2.6 Seed index (g)

The hundred seeds were randomly taken from the finally cleaned produce of each plot for recording test weight. Then weight of 100-seeds of each plot was recorded separately on an electrical balance.

3. Yield

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

The seed yield per sq. meter area was recorded after winnowing the seed with the help of digital balance. Finally, seed yield of each plot was converted into seed yield per hectare by multiplying it with appropriate conversion factor.

3.2 Stover yield (kg ha^{-1})

The stover yield per sq. meter area was determined by subtracting seed yield of each plot from biological yield (Bundle weight) of the same plot. This was later on converted into stover yield per hectare by multiplying with the same conversion factor which was used in case of seed yield per hectare.

3.3 Biological yield (kg ha^{-1})

Biological yield is the sum of grain yield and straw or stover yield. It is calculated as: Biological yield = Grain yield + straw or stover yield.

3.4 Harvest index (%)

It is the ratio of economic yield to the biological yield. It was determined with the help of following formula and expressed in percentage as follows:

$$Harvest\ index\ (\%) = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw yield)}} \times 100$$

B) Rice

1. Growth attributes

1.1 Plant height (cm)

Five plants were selected randomly and tagged the plants. The longest tiller length was measured from the base of plant to longest terminal point by measuring tape. The height of the plants was measured at 30 DAS, 60 DAS and 90 DAS. The mean of five plants were taken to calculate average plant height at different intervals in rice.

1.2 Plant population (m^{-2})

The plant population was estimated from each plot with the help of quadrate of one square meter. The total number plants per m^{-2} were counted from rice at different time intervals.

1.3 Crop growth rate ($g\ m^{-2}\ day^{-1}$)

Crop growth rate estimated the increment in dry weight of plant material. Data was calculated by formulae of CGR given by Watson (1952):

$$CGR = \frac{W_2 - W_1}{(t_2 - t_1)S}$$

Where W_2 = Dry weight (g) of plant at time t_2, W_1 = Dry weight (g) of plant at time t_1. S is the land area over which dry matter was recorded.

1.4 Absolute growth rate ($g\ day^{-1}$)

AGR expresses the increase in dry matter per unit time. It is generally expressed as (g day^{-1}) in case of dry matter accumulation plant^{-1} and it is calculated by using the formula (Radford, 1967)

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_2 and W_1 refer to the total dry matter accumulation plant^{-1} at times of t_2 and t_1, respectively.

1.5 Relative growth rate (g g^{-1}day^{-1})

It is the rate of increase of plant material per unit weight per unit time. The unit of Relative growth rate (RGR) is g g^{-1} day^{-1}

$$RGR = \frac{\ln W_2 - \ln W_1}{(t_2 - t_1)}$$

Where, $Log_e W_1$ and $Log_e W_2$ are natural log of initial and final dry matter of plant at initial and final time interval.

1.6 Net Assimilation rate (g m^{-1}day^{-1})

The dry matter of the plants measured at different intervals which were used to count NAR.

$$NAR = \frac{(W_2 - W_1)(\ln W_2 - \ln W_1)}{(t_2 - t_1)\ (L_2 - L_1)}$$

Where,

W_2 and W_1 = Dry weight (g) of plants at time t_2 and t_1 and L_2 and L_1 = Leaf area at time t_2 and t_1 respectively.

1.7 Leaf Area Index (LAI)

Leaf area index of the five tagged plants were recorded at 30, 60 and 90 DAS. The LAI was worked out using the formula (Watson, 1947)

$$LAI = \frac{\text{Total leaf area (cm}^2)}{\text{Ground area (cm}^2)}$$

2. Yield attributes

2.1 Plant stand at harvest (m^{-2})

Plant stand at harvest was recorded by counting the number of plants in the plot at harvest of the crop. Per meter plant, count was done by counting the number of plants in one meter of three rows in a net plot.

2.2 Number of panicles m^{-2}

Randomly five plants were selected and the plants were tagged. The number of panicles on each tagged panicles were counted and mean was taken from each plot.

2.3 Panicle length (cm)

From each plot randomly five plants were selected and length of panicles was measured with the help of a scale, the measurements were taken from neck to tip of apical grain, mean value of 5 plants were observed as the panicle length.

2.4 Weight of panicle (g)

Panicles from the five tagged plants which were randomly selected from each plot was weighed with the use of digital weighing balance and the mean value was recorded.

2.5 Filled grains (%)

The number of filled and unfilled grains per panicle were counted from randomly selected five plants from each plot and were worked out per plot, thereafter, calculated using the formula.

$$\text{Filled grain \%} = \frac{\text{Number of filled grain per panicle}}{\text{Total number of grains per panicle}} \times 100$$

2.6 Test weight (g)

The samples of grains were collected from each treatment and weight of 1000 grains were weighed for recording the test weight.

3. Yield

3.1 Grain yield (kg ha^{-1})

The plants were harvested net plot wise and then threshed after sun drying. The grain yield of each net plot was recorded and then converted into kg ha^{-1} by multiplying with the conversion factor.

3.2 Straw yield (kg ha^{-1})

The produce after harvesting was left in the field for sun drying. The straw yield of each plot was obtained in kg/plot by subtracting the seed yield of the respective plot from the weight of these bundles and then converted into kg ha^{-1} by multiplying with the conversion factor (multiplies yield per plot by 10,000 m^2/ha and divide by the area of the plot (m^2/plot). The straw of the plant *i.e.* leaves and pod covers of the crop were weighed after threshing in each plot.

3.3 Biological yield (kg ha^{-1})

Biological yield is the sum of grain yield and straw or stover yield. It is calculated as:

Biological yield = Grain yield + straw or stover yield.

3.4 Harvest index (%)

The harvest index (HI) was calculated by the following formula:

$$Harvest\ idex\ (\%) = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw yield)}} \times 100$$

Where, biological yield = seed yield + straw yield

C) Sesame

1. Growth attributes

1.1 Plant height (cm)

In each plot five plants were selected randomly and tagged for the study. The plant height of main shoot of selected plant was measured from ground level to the tip of the plant and averaged at 30 DAS, 60 DAS and 90 DAS days of sowing.

1.2 Plant population (m^{-2})

Plant population of the sesame were recorded at 30 DAS, 60 DAS and 90 DAS in all the treatments per square meter. The results thus obtained were recorded as plants per m^{-2}.

1.3 Crop growth rate (g m^{-2} day^{-1})

Crop growth rate estimated the increment in dry weight of plant material. Data was calculated by formulae of CGR given by Watson (1952):

$$CGR = \frac{w_2 - w_1}{(t_2 - t_1\ )s}$$

Where W_2 = Dry weight (g) of the plant at time t_2, W_1 = Dry weight (g) of plant at time t_1. S is the land area over which dry matter was recorded.

1.4 Absolute growth rate (g day^{-1})

AGR expresses the increase in dry matter per unit time. It is generally expressed as (g day^{-1}) in case of dry matter accumulation $plant^{-1}$ and it is calculated by using the formula (Radford, 1967)

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_2 and W_1 refer to the total dry matter accumulation $plant^{-1}$ at times of t_2 and t_1, respectively.

1.5 Relative growth rate (g g^{-1} day^{-1})

It is the rate of increase of plant material per unit weight per unit time. The unit of relative growth rate (RGR) is g g^{-1} day^{-1}.

$$RGR = \frac{\ln W_2 - \ln W_1}{(t_2 - t_1)}$$

Where, $Log_e W_1$ and $Log_e W_2$ are natural log of initial and final dry matter of plant at initial and final time interval.

1.6 Net Assimilation rate (g m^{-1} day^{-1})

The dry matter of the plants was measured at different intervals which was used to count NAR.

$$NAR = \frac{(W_2 - W_1)(\ln W_2 - \ln W_1)}{(t_2 - t_1)\ (L_2 - L_1)}$$

Where,

W_2 and W_1 = Dry weight (g) of plants at time t_2 and t_1 and L_2 and L_1 = Leaf area at time t_2 and t_1 respectively.

1.7 Leaf Area Index (LAI)

Leaf area index of the five tagged plants were recorded at 30, 60 and 90 DAS. The LAI was worked out using the formula (Watson, 1947).

$$LAI = \frac{\text{Total leaf area } (cm^2)}{\text{Ground area } (cm2)}$$

2. Yield attributes

Yield attributes and yields of sesame were recorded from five selected tag plants at the time of harvesting.

2.1 Plant stand at harvest (m^{-2})

The plant stand at harvest was recorded by counting the number of plants in the net plot at harvest of the crop. Per meter plant count was done by actually counting number of plants in one meter of three rows in net plot.

2.2 Number of capsules plant^{-1}

The total number of capsules from five randomly selected tag plants were counted and averaged out to record.

2.3 Number of seeds capsule^{-1}

Total number of seeds removed from 20 selected pods and total grain numbers were counted and averaged.

2.4 Weight of capsule plant^{-1} (g)

The capsules from each plant randomly selected and tagged were weighed (g) and the mean was recorded.

2.5 Test weight (g)

The grain sample from the produce of each plot were taken and 1000 seeds were counted and then its weight was recorded.

3. Yield

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

The plants were harvested net plot wise and then threshed after sun drying. The seed yield of each net plot was recorded and then converted into kg ha^{-1} by multiplying with the conversion factor (multiplies yield per plot by 10,000 m^2/ha and divide by the area of the plot (m^2/plot).

3.2 Stover yield (kg ha^{-1})

The produce after harvesting were left in the field for sun drying. The stover yield of each plot was obtained in kg/plot by subtracting the seed yield of the respective plot from the weight of these bundles and then converted into kg ha^{-1} by multiplying with the conversion factor (multiplies yield per plot by

10,000 m^2/ha and divide by the area of the plot (m^2/plot). The stover of the plant *i.e.* leaves and pod covers of the crop were weighed after threshing in each plot.

3.3 Biological yield (kg ha^{-1})

Biological yield is the sum of grain yield and straw or stover yield. It is calculated as:

Biological yield = Grain yield + straw or stover yield.

3.4 Harvest index (%)

The harvest index (HI) was calculated by the following formula:

$$Harvest\ idex\ (\%) = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw yield)}} \times 100$$

Where, Biological yield = Seed yield + Straw yield

D) Greengram and soybean

1. Growth attributes

1.1 Plant height (cm)

The plant height (cm) of the randomly tagged five plants of the field crops was measured in cm from ground level up to the terminal bud of the main shoot.

1.2 Plant population (m^{-2})

The plant-population was recorded by actually counting the number of plants in the net plot after complete emergence and thinning and at various interval. For initial and final plant stands of greengram and soybean per meter plant count was done by actually counting number of plants in one meter of three rows in net plot.

1.3 Crop growth rate (g m^{-2} day^{-1})

Crop growth rate estimated the increment in dry weight of plant material.

Data was calculated by formulae of CGR given by Watson (1952):

$$CGR = \frac{W_2 - W_1}{(t_2 - t_1)S}$$

Where W_2 = Dry weight (g) of plant at time t_2, W_1 = Dry weight (g) of plant at time t_1. S is the land area over which dry matter was recorded.

1.4 Absolute growth rate (g day^{-1})

AGR expresses the increase in dry matter per unit time. It is generally expressed as (g day^{-1}) in case of dry matter accumulation plant^{-1} and it is calculated by using the formula (Radford, 1967)

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where, W_2 and W_1 refer to the total dry matter accumulation plant^{-1} at times of t_2 and t_1, respectively.

1.5 Relative growth rate (g g^{-1}day^{-1})

It is the rate of increase of plant material per unit weight per unit time. The unit of relative growth rate (RGR) is g g^{-1} day^{-1}.

$$RGR = \frac{\ln W_2 - \ln W_1}{(t_2 - t_1)}$$

Where, $Log_e W_1$ and $Log_e W_2$ are natural log of initial and final dry matter of plant at initial and final time interval.

1.6 Net Assimilation rate (g m^{-1}day^{-1})

The dry matter of the plants was measured at different intervals which were used to count NAR.

$$NAR = \frac{(W_2 - W_1)(\ln W_2 - \ln W_1)}{(t_2 - t_1)\,(L_2 - L_1)}$$

Where, W_2 and W_1 = Dry weight (g) of plants at time t_2 and t_1 and L_2 and L_1 = Leaf area at time t_2 and t_1 respectively.

1.7 Leaf area index (LAI)

Since the crop yield is assessed from per unit of ground area, instead of plant^{-1}, the determination of leaf area per unit of ground area is a must. This measure is known as leaf area index. It was calculated from the data on leaf area plant^{-1} at various stages of crop growth according to the formula proposed by Watson (1947).

$$\text{LAI} = \frac{\text{Total leaf area } (\text{cm}^2)}{\text{Ground area } (\text{cm}^2)}$$

2. Yield attributes

2.1 Plant stand at harvest (m^{-2})

The plant stand at harvest was recorded by counting the number of plants in the net plot at harvest of the crop. Per meter plant count was done by actually counting number of plants in one meter of three rows in net plot.

2.2 Number of pods plant^{-1}

The pods from the selected observation plants were plucked and their number was counted. The average number of pods plant^{-1} was then worked out.

2.3 Number of seeds pod^{-1}

The separated seeds from pods of five randomly selected plants were actually counted and average number of seeds pod^{-1} was worked out.

2.5 Weight of pod plant^{-1} (g)

The pods from each plant randomly selected and tagged were weighed (g) and the mean was recorded.

2.5 Seed weight (g)

1000 seeds from the produce of each plot were taken and their weight (g) was recorded for greengram, similarly 100 seeds of soybean from each plot were taken and weighed (g) and the test weights were recorded.

3. Yield

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

After the threshing of plants from the net plot, seeds were collected and the weight of seeds per plot (g) was recorded. This yield obtained from the net plot is converted into grain yield per hectare.

3.2 Stover yield (kg ha^{-1})

After threshing and plucking, the plants were collected from net plot and tied in bundles and allowed to dry in the field and their weight (kg) was recorded after complete drying and this yield was converted into stover yield per hectare (kg).

3.3 Biological yield (kg ha^{-1})

Biological yield is the sum of grain yield and straw or stover yield. It is calculated as: Biological yield = Grain yield + straw or stover yield.

3.4 Harvest index (%)

The harvest index (HI) was calculated by the following formula:

$$Harvest\ idex\ (\%) = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw yield)}} \times 100$$

Where, Biological yield = Seed yield + Straw yield

II Plant analysis

1. N, P and K content (%) and nutrient uptake (kg ha^{-1})

Randomly selected plant samples from the base crop and component crops were collected treatment wise for chemical estimation. Straw and grains were separated, air dried and finally oven dried at a temperature of 65^0C and grounded in a grinding machine to pass through a 30 mess sieve. Grain and straw samples were analyzed for nitrogen by modified Kjeldahl's method (Jackson, 1973) and potassium by flame photometric method (Jackson,1973). The uptake was further

Calculated by using the formula nutrient uptake (kg ha^{-1})

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) in grain or straw x grain or straw yield } kg\ ha^{-1}}{100}$$

III Intercropping competitive indices

1. Pigeonpea equivalent yield (PEY)

According to Lal and Ray (1976) and Verma and Mogdal (1983), pigeonpea equivalent yield (PEY) was calculated based on seed yield of the pigeonpea and intercropped pulses and prevailing market prices of both pigeonpea and intercrop as given below:

$$PEY = Y_p X \ \frac{PP}{P_P} + Y_i X \ \frac{Pi}{P_P}$$

Where,

PEY= Pigeonpea equivalent yield Y_p = Yield of pigeonpea

Y_i = Yield of intercrop P_p

= Price of pigeonpea P_i =

Price of intercrop

2. Land equivalent ratio (LER)

The concept of LER is described in detail by Willey (1979b). LER is defined as the relative land area under sole crops that is required to produce the yields achieved in intercropping. It is calculated as the sum total of the ratios of yield of each component crop in an intercropping system to its corresponding yield when grown as a sole crop.

Land Equivalent Ratio (LER) was calculated following Willey (1979b) as under:

$$LER= \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}}$$

Where, Y_{ab} and Y_{ba} =Yield of species a and b in intercrop Y_{aa}

and Y_{bb}= are the yield of a and b in sole crop

3 Area time equivalent ratio (ATER)

In the present studies, the method used by Hiebsch (1980) was followed for calculation of ATER.

$$ATER= (LER_a \times LER_b \times DC)\ Dt$$

Where,

LER is land equivalent ratio of crop, DC

is duration (days) taken by crop,

Dt is days to intercropping system from planting to harvest Hiebsch (1980) interpreted ATER as under:

When,

ATER > 1, it implies yield advantage of intercropping

ATER = 1, it implies no effect of intercropping

ATER< 1, it implies yield disadvantage of intercropping

4 Relative crowding coefficient

This was proposed by De Wit (1960). It assumes that mixture treatments form a replacement series. Each species has its own coefficient (k) which gives a measure of whether that species has produced more, or less, yield than expected. It also measures the relative dominance of one component crop over the other in an intercropping system. For species 'a' in combination with 'b' it can be written as

$K = (K_{cereal} \times K_{legume})$

Where,

K = RCC of the intercropping system

K_{cereal} = RCC of intercropped cereal

K_{legume} = RCC of intercropped legume

$$K_{pigeonpea} = \frac{Y_{ab} \ X \ Z_{ab}}{(Y_{aa} - Y_{ab}) X \ Z_{ab}}$$

$$K_{intercrop} = \frac{Y_{ab} \ X \ Z_{ab}}{(Y_{aa} - Y_{ab}) X \ Z_{ab}}$$

Where,

Y_{ab} =yield of species 'a' in intercropping

Z_{ba} = sown proportion of legume ‘b’ in intercropping

Y_{aa} = yield of cereal 'a' in sole crop

Z_{ab} = sown proportion of cereal 'a' in intercropping Y_{ba}

= yield of legume 'b' in intercropping

Y_{bb} = yield of legume ‘b’ in sole crop

If a species has a coefficient less than, equal to, or greater than one, it means it has produced less yield, the same yield, or more yield than 'expected', respectively. The component crop with the higher coefficient is the dominant one. To determine if there is a yield advantage of mixing, the product of coefficients is formed. This is usually designated as K. If K > 1 there is a yield advantage, if K= 1 there is no difference, and if K < 1 there is a yield disadvantage.

5 Aggressivity (A)

The index of aggressivity was proposed by Mc Gilchrist (1965). It assumes that mixtures form a replacement series and it gives a simple measure of how much the relative yield increase in species 'a' is greater than that for species 'b' in an intercropping system and can be expressed as Aab·

$$A_{cereal} = \frac{Y_{ab}}{Y_{aa} \times Z_{ab}} - \frac{Y_{ba}}{Y_{bb} \times Z_{ba}}$$

$$A_{legume} = \frac{Y_{ba}}{Y_{ba} \times Z_{ba}} - \frac{Y_{ab}}{Y_{aa} \times Z_{ab}}$$

Where,

Y_{ab} =Mixture yield of species 'a', in combination with 'b',

Y_{ba} =Mixture yield of species 'b', in combination with 'a',

Y_{aa} = Pure stand yield of species 'a',

Y_{bb} =Pure stand yield of with species 'b',

Z_{ab}= Sown proportion of species 'a' in mixture with 'b'

Z_{ba}= Sown proportion of species 'b' in mixture with 'a'.

An aggressivity value of zero indicates that the component species are equally competitive. For any other situation, both species will have the same numerical value but the sign of the dominant species will be positive and that of the dominated negative, the greater the numerical value the bigger the difference in competitive abilities and the bigger the difference between 'actual' and 'expected' yield.

6 Competitive ratio (CR)

Competitive ratio (CR) was calculated by the following formula as given by Willey and Rao (1980).

$$CR_a = \frac{LER_a}{LER_b} \times \frac{Z_{ba}}{Z_{ab}}$$

$$CR_b = \frac{LER_b}{LER_a} \times \frac{Z_{ab}}{Z_{ba}}$$

Where,

CR = Competition Ratio of ‘a’ in the mixture over ‘b’

LER_a = LER of component ‘a’

LER_b = LER of component ‘b’

Z_{ba} = sown proportion of component ‘b’in combination with ‘a’

Z_{ab} = sown proportion of component ‘a’ in combination with ‘b’

If the values of CR<1, there is a positive benefit. It means there is limited competition between component crops and they can be grown as intercrops (Ghosh, 2004). However, if the value is higher than one (CR>1), there is a negative impact. In this condition, the competition between intercrops in the association is too high, and they are not recommended to grow as intercrops. The competition ratio (CR) of legume and intercrop cereal has an inverse relationship.

IV Soil analysis

1. Soil pH

The pH of the soil in 1:2.5 soil water suspensions was determined by digital pH meter (Jackson, 1973).

2. Organic carbon (%)

The organic carbon content of the soil was determined by the rapid titration method (Walkley and Black, 1934) and the results were expressed in percentage.

3. Available Nitrogen (kg ha^{-1})

The available nitrogen in the soil was determined by the alkaline permanganate method as given by Subbaiah and Asija (1956) with the help of a Kelpus nitrogen analyzer and the results were expressed in kg ha^{-1}.

4. Available Phosphorus (kg ha^{-1})

The available phosphorus content was determined by extracting with 0.03N NH_4F + 0.025 N HCl (Bray and Kurtz, 1945) and the phosphorus content was estimated colorimetrically using the ascorbic acid method.

5. Available Potassium (kg ha^{-1})

Using a flame photometer, the available potassium content was determined in neutral normal ammonium acetate extract (Jackson, 1973).

V Economic analysis

The cost of cultivation, gross return, net returns, return per rupee investment and benefit cost ratio of different treatments were determined based on prevailing market prices.

1. Cost of cultivation

The cost of cultivation was calculated based on existing local charges for different inputs used in the experimental plot.

3. Gross return

Economic yield was calculated by subtracting the total cost of cultivation from the gross return.

4. Net return

The net return was calculated by subtracting the total cost of cultivation from the gross return.

Net return = Gross return – Cost of cultivation

5. Benefit cost ratio (BCR)

Benefit cost ratio was calculated by using the formula:

$$B\!:\!C\ Ratio = \frac{Net\ return}{Cost\ of\ cultivation} \times 100$$

VI Statistical analysis

All the experimental data were subjected to statistical analysis by adopting an appropriate method of Analysis of Variance as described by Gomez and Gomez (1984). Pooled analyses of data were also carried out to establish the trend of treatments applied. Wherever, the F values were found significant at 5 percent levels of probability, the critical difference (CD) values were computed for making comparison among the treatment mean.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results obtained during the course of present investigation on "Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland" conducted in the experimental research farm of the School of Agricultural Sciences (SAS), Medziphema campus, Nagaland University during two consecutive *kharif* seasons of 2021 and 2022. The data recorded during the course of the experiment were analysed statistically and the results obtained are being interpreted and further illustrated in this chapter.

I Crop observation

4.1 PIGEONPEA

4.1.1 Growth attributes

4.1.1.1 Plant height (cm)

Data pertaining to plant height at different crop stages as influenced by different intercropping systems at 30, 60, 90 and 120 DAS are presented in Table 4.1.(a) and Table 4.1.(b). The study revealed that there was significant effect on plant height of pigeonpea during the crop growth stages under different intercropping system in both the years as well as in pooled data.

It was observed from the data that during 2021, maximum plant height (23.42, 54.73,112.01 and 202.88 cm at 30, 60, 90 and 120 DAS respectively) of pigeonpea in sole pigeonpea T_{13} was recorded and it was statistically at par with pigeonpea + soybean (1:1) T_{10} (23.24, 53.54, 107.38 and 194.67 cm at 30, 60, 90 and 120 DAS respectively), pigeonpea + sesame (1:1) T_4 (23.28, 52.40, 106.61 and 193.48 cm at 30, 60, 90 and 120 DAS respectively), pigeonpea + greengram (1:1) T_7 (23.05, 52.32, 106.31 and 193.23 cm at 30, 60, 90 and 120 DAS respectively), and pigeonpea + rice (1:1) T_1 (22.50, 52.13, and 191.54 cm at 30, 60 and 120 DAS respectively) at all the crop growth stage. Pigeonpea intercropped with rice in the ratio 1:3 recorded the minimum plant height (18.79, 42.13, 85.89 and177.64 cm at 30, 60, 90 and 120 DAS respectively).

Similarly, during 2022 maximum plant height (26.99, 54.87, 123.58 and 222.26 cm at 30, 60, 90 and 120 DAS respectively) of pigeonpea in Sole pigeonpea T_{13} was recorded and was statistically at par with pigeonpea + soybean (1:1) T_{10} (26.56, 54.74, 120.83 and 215.17 cm at 30, 60, 90 and 120 DAS respectively), pigeonpea + sesame (1:1) T_4 (26.42, 53.60, 120.59 and 213.24 cm at 30, 60, 90 and 120 DAS respectively), pigeonpea + greengram (1:1) T_7 (26.33, 53.30, 120 and 212.13 cm at 30, 60, 90 and 120 DAS respectively), and pigeonpea + rice (1:1) T_1 (53.01, and 119.71 cm at 60 and 90 respectively). Minimum value was recorded in pigeonpea + rice (1:3) T_3 with 23.67, 50.31, 107.58 and 185.03 cm at 30, 60, 90 and 120 DAS, respectively.

From the pooled data of years 2021 and 2022, it was evident that maximum plant height was recorded in sole pigeonpea T_{13} (25.21, 54.80, 117.80 and 212.57 at 30, 60, 90 and 120 DAS respectively) and remained statistically at par with pigeonpea + soybean (1:1) T_{10} (24.90, 54.14 and 114.11 cm at 30, 60 and 90 DAS respectively), pigeonpea + sesame (1:1) T_4 (24.85 cm at 30 DAS respectively) and pigeonpea + greengram (1:1) T_7 (24.69 cm at 30 DAS respectively). Meanwhile pigeonpea + rice (1:3) T_3 (21.23, 46.22, 96.74 and 181.33 at 30, 60, 90 and 120 DAS respectively) recorded the minimum plant value.

The height of pigeonpea in sole crop is more as compared to intercropping systems. These findings were also in conformity with Kumar *et al.* (2012): Yadav and Maurya (2012) who reported that closely spaced pigeonpea plants grow rapidly. Planting of pigeonpea in narrow spacing of 60 cm x 30 cm in sole pigeonpea, recorded remarkably taller plants as compared to plants grown in intercropping systems, while plant height was reduced as the row spacing was increased at all growth stages. Plant height in sole cropping might increase due to the growth of pigeonpea under competition free habitat. In intercropping systems irrespective of planting pattern, pigeonpea height has decreased considerably compared with sole pigeonpea due to more inter-specific competition than the intra-specific competition of sole stand. Such growth habit of pigeonpea has also been reported by Yadav *et al.* (2021)

4.1.1.2 Plant population (m^{-2})

Plant population data regarding pigeonpea recorded at 30, 60, 90 and 120 DAS as influenced by different intercropping systems for the years 2021, 2022 and in pooled are presented in Tables 4.2(a) and 4.2(b). Results revealed that different treatments of the intercropping system showed significant influence on plant stand recorded at crop growth stages during individual years and in pooled analysis. The maximum plant population m^{-2} among the treatments was recorded in sole pigeonpea T_{13} in both the experiment years.

In 2021, sole pigeonpea T_{13} recorded the maximum plant population m^{-2} (6, 6, 5.67 and 5.67 at 30, 60, 90 and 120 DAS respectively) with the rest of the treatments with the ratio (1:1) and (1:2). Pigeonpea + rice (1:3) T_3 recorded the minimum plant population (3, 3, 2.67 and 2.33 at 30, 60, 90 and 120 DAS respectively). Similarly, in 2022 sole pigeonpea T_{13} recorded the maximum plant population m^{-2} (6, 6, 5.67 and 5.67 at 30, 60, 90 and 120 DAS respectively), along with the rest of the treatments with the ratio (1:1) and (1:2). The minimum plant population m^{-2} (2.67, 2.33, 2.33 and 2.33 at 30, 60, 90 and 120 DAS respectively) was observed in the treatment pigeonpea + rice (1:3) T_3. Pooled data of both years also revealed that sole pigeonpea recorded the maximum plant population m^{-2} (6, 6, 5.83 and 5.83 at 30, 60, 90 and 120 DAS respectively) and similarly pigeonpea + rice (1:3) T_3 recorded the minimum plant population m^{-2} (3, 2.67, 2.33 and 2.33 at 30, 60, 90 and 120 DAS respectively).

Table 4.1(a): Plant height (cm) of pigeonpea under different intercropping system at 30 and 60 DAS

Treatments	Plant height					
	30 DAS			60 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	23.05	26.00	24.52	52.13	53.01	52.57
T_2 - Pigeonpea +Rice (1:2)	21.56	26.01	23.79	49.52	52.48	51.00
T_3 - Pigeonpea +Rice (1:3)	18.79	23.67	21.23	42.13	50.31	46.22
T_4 - Pigeonpea +Sesame (1:1)	23.28	26.08	24.68	52.40	53.60	53.00
T_5 - Pigeonpea +Sesame (1:2)	21.19	25.90	23.55	50.70	52.33	51.52
T_6- Pigeonpea +Sesame (1:3)	19.60	23.74	21.67	43.65	52.08	47.87
T_7 - Pigeonpea +Greengram (1:1)	22.50	26.28	24.39	52.32	53.30	52.81
T_8 - Pigeonpea +Greengram (1:2)	21.73	25.74	23.74	51.54	52.12	51.83
T_9 - Pigeonpea +Greengram (1:3)	21.62	23.76	22.69	46.87	51.27	49.07
T_{10} - Pigeonpea +Soybean (1:1)	23.24	26.20	24.72	52.54	53.75	53.14
T_{11} - Pigeonpea +Soybean (1:2)	22.08	25.94	24.01	51.30	52.62	51.96
T_{12} - Pigeonpea +Soybean (1:3)	21.57	24.11	22.84	49.34	52.07	50.71
T_{13} - Sole Pigeonpea	23.42	26.99	25.21	52.73	54.01	53.37
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.44	0.26	0.26	0.95	0.61	0.56
CD (P=0.05)	1.29	0.76	0.73	2.77	1.78	1.60

Table 4.1(b): Plant height (cm) of pigeonpea under different intercropping system at 90 and 120 DAS

Treatments	Plant height					
	90 DAS			120 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	100.96	119.71	110.33	191.54	210.74	201.14
T_2 - Pigeonpea +Rice (1:2)	97.88	118.09	107.99	188.55	201.80	195.17
T_3 - Pigeonpea +Rice (1:3)	85.89	107.58	96.74	177.64	185.03	181.33
T_4 - Pigeonpea +Sesame (1:1)	106.61	120.59	113.60	193.48	213.24	203.36
T_5 - Pigeonpea +Sesame (1:2)	98.01	118.40	108.21	191.44	197.73	194.59
T_6- Pigeonpea +Sesame (1:3)	87.44	110.48	98.96	181.06	187.37	184.21
T_7 - Pigeonpea +Greengram (1:1)	106.31	120.00	113.16	193.23	212.13	202.68
T_8 - Pigeonpea +Greengram (1:2)	99.23	116.70	107.97	190.78	201.68	196.23
T_9 - Pigeonpea +Greengram (1:3)	87.46	111.80	99.63	184.61	193.79	189.20
T_{10} - Pigeonpea +Soybean (1:1)	107.38	120.83	114.11	194.67	215.17	204.92
T_{11} - Pigeonpea +Soybean (1:2)	99.34	118.03	108.69	187.19	203.93	195.56
T_{12} - Pigeonpea +Soybean (1:3)	88.52	114.88	101.70	184.66	199.58	192.12
T_{13} - Sole Pigeonpea	112.01	121.84	116.93	202.88	222.26	212.57
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	2.28	1.69	1.42	3.93	3.57	2.66
CD (P=0.05)	6.66	4.92	4.03	11.48	10.43	7.56

Table 4.2(a): Plant population (m^{-2}) of pigeonpea under different intercropping system at 30 and 60 DAS

Treatments	Plant population					
	30 DAS			60 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	6.00	6.00	6.00	6.00	5.67	5.83
T_2 - Pigeonpea +Rice (1:2)	5.67	6.00	5.83	5.67	5.67	5.67
T_3 - Pigeonpea +Rice (1:3)	3.00	2.67	2.83	3.00	2.33	2.67
T_4 - Pigeonpea +Sesame (1:1)	6.00	6.00	6.00	6.00	6.00	6.00
T_5 - Pigeonpea +Sesame (1:2)	6.00	5.67	5.83	6.00	5.00	5.50
T_6- Pigeonpea +Sesame (1:3)	3.00	3.00	3.00	3.00	3.00	3.00
T_7 - Pigeonpea +Greengram (1:1)	6.00	6.00	6.00	6.00	6.00	6.00
T_8 - Pigeonpea +Greengram (1:2)	6.00	6.00	6.00	6.00	5.67	5.83
T_9 - Pigeonpea +Greengram (1:3)	3.00	3.00	3.00	3.00	2.67	2.83
T_{10} - Pigeonpea +Soybean (1:1)	6.00	6.00	6.00	6.00	6.00	6.00
T_{11} - Pigeonpea +Soybean (1:2)	6.00	5.67	5.83	6.00	5.67	5.83
T_{12} - Pigeonpea +Soybean (1:3)	3.00	3.00	3.00	3.00	3.00	3.00
T_{13} - Sole Pigeonpea	6.00	6.00	6.00	6.00	6.00	6.00
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.09	0.16	0.09	0.09	0.24	0.13
CD (P=0.05)	0.27	0.47	0.26	0.27	0.70	0.36

Table 4.2(b): Plant population (m^{-2}) of pigeonpea under different intercropping system at 90 and 120 DAS

Treatments	Plant population					
	90 DAS			120 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	6.00	5.33	5.67	6.00	5.33	5.67
T_2 - Pigeonpea +Rice (1:2)	5.67	5.67	5.67	5.67	5.67	5.67
T_3 - Pigeonpea +Rice (1:3)	2.67	2.33	2.50	2.33	2.33	2.33
T_4 - Pigeonpea +Sesame (1:1)	6.00	6.00	6.00	5.67	5.67	5.67
T_5 - Pigeonpea +Sesame (1:2)	6.00	5.00	5.50	6.00	5.00	5.50
T_6- Pigeonpea +Sesame (1:3)	3.00	3.00	3.00	3.00	3.00	3.00
T_7 - Pigeonpea +Greengram (1:1)	5.67	6.00	5.83	5.67	6.00	5.83
T_8 - Pigeonpea +Greengram (1:2)	6.00	5.67	5.83	5.67	5.67	5.67
T_9 - Pigeonpea +Greengram (1:3)	3.00	2.67	2.83	3.00	2.67	2.83
T_{10} - Pigeonpea +Soybean (1:1)	6.00	6.00	6.00	6.00	5.67	5.83
T_{11} - Pigeonpea +Soybean (1:2)	6.00	5.67	5.83	5.67	5.33	5.50
T_{12} - Pigeonpea +Soybean (1:3)	3.00	3.00	3.00	3.00	3.00	3.00
T_{13} - Sole Pigeonpea	5.67	6.00	5.83	5.67	6.00	5.83
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.18	0.24	0.15	0.23	0.24	0.17
CD (P=0.05)	0.54	0.70	0.43	0.66	0.71	0.47

Maximum plant population m^{-2} in the sole pigeonpea cropping system at all crop growth stages might be due to uniform plant population under the sole cropping system; however, under the intercropping system main crop was intercropped in 1:1, 1:2 and 1:3 row ratio, which had plant population maintained according to the row ratio. Slight variation in the plant population also may be due to uprooting of plants for recording dry matter for CGR, RGR and LAI, incident of pests and diseases etc. Lingaraju *et al.* (2008) conducted a study on intercropping of maize + pigeonpea and reported that sole maize and sole pigeonpea recorded higher plant population. Egbe and Kalu (2009) and Nndwambi *et al.* (2016) also reported that the pigeonpea plant population was significantly higher under sole than under intercrop plots.

4.1.1.3 Number of primary branches plant^{-1}

The data pertaining to the number of primary branches plant^{-1} under different intercropping systems are exhibited in the Table 4.3(a) and Table 4.3(b). The number of primary branches plant^{-1} of pigeonpea varied significantly among different intercropping systems. In general, maximum number of primary branches were observed in sole pigeonpea at all crop growth stages.

The maximum number of primary branches plant^{-1} of pigeonpea in the initial year of experiment 2021 was obtained in sole pigeonpea T_{13} (3.63, 7.53, 13.27 and 19.20 at 30, 60, 90 and 120 DAS respectively). Pigeonpea + soybean (1:1) T_{10} (3.60, 7.40, 12.87 and 19.07 at 30, 60, 90 and 120 DAS respectively), pigeonpea + sesame (1:1) T_4 (3.53, 7.33, 12.27 and 18.53 at 30, 60, 90 and 120 DAS respectively), pigeonpea + greengram (1:1) T_7 (3.37, 7.30, 12 and 17.80 at 30, 60, 90 and 120 DAS respectively), and pigeonpea + rice (1:1) T_1 (3.27, 7.27 and 11.80 at 30, 60 and 90 DAS respectively) remained statistically at par with the highest value of sole pigeonpea. The minimum number of primary branches plant $^{-1}$ (1.90, 5.67, 9.40, and 15.87 at 30, 60, 90

Table 4.3(a): Number of primary branches of pigeonpea under different intercropping system at 30 and 60 DAS

Treatments	Number of primary branches^{-1}					
	30 DAS			60 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	3.27	3.40	3.33	7.27	8.37	7.82
T_2 - Pigeonpea +Rice (1:2)	2.93	3.20	3.07	6.93	7.87	7.40
T_3 - Pigeonpea +Rice (1:3)	1.90	2.40	2.15	5.67	7.07	6.37
T_4 - Pigeonpea +Sesame (1:1)	3.53	3.60	3.57	7.33	8.67	8.00
T_5 - Pigeonpea +Sesame (1:2)	3.03	3.23	3.13	6.87	7.93	7.40
T_6- Pigeonpea +Sesame (1:3)	2.27	2.93	2.60	5.70	7.27	6.48
T_7 - Pigeonpea +Greengram (1:1)	3.37	3.47	3.42	7.30	8.40	7.85
T_8 - Pigeonpea +Greengram (1:2)	2.87	3.20	3.03	6.93	8.07	7.50
T_9 - Pigeonpea +Greengram (1:3)	2.40	3.00	2.70	6.07	7.33	6.70
T_{10} - Pigeonpea +Soybean (1:1)	3.60	3.73	3.67	7.40	8.73	8.07
T_{11} - Pigeonpea +Soybean (1:2)	3.10	3.30	3.20	7.00	8.20	7.60
T_{12} - Pigeonpea +Soybean (1:3)	2.60	2.93	2.77	5.80	7.27	6.53
T_{13} - Sole Pigeonpea	3.63	3.80	3.72	7.53	8.80	8.17
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.19	0.18	0.13	0.17	0.22	0.14
CD (P=0.05)	0.55	0.53	0.37	0.48	0.65	0.39

Table 4.3(b): Number of primary branches of pigeonpea under different intercropping system at 90 and 120 DAS

Treatments	Number of primary branches^{-1}					
	90 DAS			120 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	11.80	14.47	13.13	17.47	19.40	18.43
T_2 - Pigeonpea +Rice (1:2)	11.40	13.93	12.67	16.80	18.30	17.55
T_3 - Pigeonpea +Rice (1:3)	9.40	10.20	9.80	15.87	16.93	16.40
T_4 - Pigeonpea +Sesame (1:1)	12.27	14.53	13.40	18.53	19.70	19.12
T_5 - Pigeonpea +Sesame (1:2)	10.80	14.37	12.58	17.00	18.33	17.67
T_6- Pigeonpea +Sesame (1:3)	10.33	12.87	11.60	16.40	17.93	17.17
T_7 - Pigeonpea +Greengram (1:1)	12.00	14.50	13.25	17.80	19.50	18.65
T_8 - Pigeonpea +Greengram (1:2)	10.40	13.73	12.07	17.20	18.47	17.83
T_9 - Pigeonpea +Greengram (1:3)	10.20	13.53	11.87	16.73	18.07	17.40
T_{10} - Pigeonpea +Soybean (1:1)	12.87	14.93	13.90	19.07	19.73	19.40
T_{11} - Pigeonpea +Soybean (1:2)	10.67	14.33	12.50	17.40	18.67	18.03
T_{12} - Pigeonpea +Soybean (1:3)	10.33	13.60	11.97	16.87	18.27	17.57
T_{13} - Sole Pigeonpea	13.27	16.13	14.70	19.20	20.87	20.04
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.69	0.61	0.46	0.56	0.58	0.41
CD (P=0.05)	2.01	1.78	1.31	1.64	1.71	1.15

and 120 DAS respectively) was obtained in pigeonpea + rice (1:3) T_3.

In the year 2022, the maximum number of primary branches plant^{-1} was obtained in sole pigeonpea T_{13} (3.80, 8.80, 16.13. and 20.21 at 30, 60, 90 and 120 DAS respectively) which was at par with pigeonpea + soybean (1:1) T_{10} (3.73, 8.73, 14.93 and 19.73 at 30, 60, 90 and 120 DAS respectively), pigeonpea + sesame (1:1) T_4 (3.60, 8.67, 14.53 and 19.70 at 30, 60, 90 and 120 DAS respectively), pigeonpea + greengram (1:1) T_7 (3.47, 8.40, 14.50 and 19.50 at 30, 60, 90 and 120 DAS respectively), and pigeonpea + rice (1:1) T_1 (3.40 and 8.37 at 30 and 60 respectively). Pigeonpea + rice (1:3) T_3 recorded the minimum number of primary branches plant^{-1} value (2.40, 7.07, 10.20 and 16.93 at 30, 60, 90 and 120 DAS respectively)

The pooled data followed a similar trend as that of year one and two (2021 and 2022). Sole pigeonpea recorded the maximum number of primary branches plant^{-1} of 3.72, 8.17, 14.70 and 20.04 at 30, 60, 90 and 120 DAS respectively and was also at par with the similar treatments as that of the experimental years. Pigeonpea + soybean (1:1) T_{10} (3.67, 8.07, 13.90 and 19.40 at 30, 60, 90 and 120 DAS respectively), pigeonpea + sesame (1:1) T_4 (3.57, 8, 13.40 and 19.12 at 30, 60, 90 and 120 DAS respectively), pigeonpea + greengram (1:1) T_7 (3.42, 7.85 at 30 and 60 DAS respectively), and pigeonpea + rice (1:1) T_1 (3.33 and 7.82 at 30 and 60 respectively). Pigeonpea + rice (1:3) T_3 recorded the minimum number of primary branches plant^{-1} value (2.15, 6.37, 9.80 and 16.40 at 30, 60, 90 and 120 DAS respectively).

From the above finding, it can be concluded that the number of primary branches plant^{-1} were more in sole pigeonpea. Meanwhile, the intercropping system of pigeonpea showed lesser number of primary branches plant^{-1} than sole pigeonpea, absence of aggressivity behavior in pigeonpea intercropping system and adequate availability of space, nutrients and moisture in the soil may be the factor contributing to the higher number of primary branches plant^{-1}. These results are in conformity with the research findings concluded by

Kumar (2004): Oad *et al.* (2007) and Rani and Reddy (2010) who reported sole pigeonpea recorded a significantly higher number of branches than that intercropped with soybean. The results of the experiment are also in conformity with the findings of Sarojani (2018), where in, sole pigeonpea recorded a higher number of primary branches than pigeonpea intercropped with field bean.

4.1.1.4 Crop growth rate (g m^{-2} day^{-1})

CGR indicates the dry matter production capacity per unit area and also indicates net primary productivity. The data related to CGR recorded at 30-60, 60-90, 90-120 DAS of pigeonpea as influenced by different intercropping system are depicted in Table 4.4(a) and 4.4(b). In the first year of experiment 2021, the results revealed that the highest crop growth rate was observed in sole pigeonpea T_{13} (2.40, 4.31 and 7.22 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively) and was found to be at par with pigeonpea + soybean (1:1) T_{10} (2.39, 4.30 and 7.12 g m^{-2} day^{-1} at 30-60, 60- 90 and 90- 120 DAS respectively), pigeonpea + sesame (1:1) T_4 (2.38 and 4.27 g m^{-2} day^{-1} at 30-60 and 60-90 DAS respectively), pigeonpea + greengram (1:1) T_7 (2.36 and 4.19 g m^{-2} day^{-1} at 30 - 60 and 60-90 DAS respectively), pigeonpea + rice (1:1) T_1 with 2.31 g m^{-2} day^{-1} at 30-60 DAS. The lowest CGR value (1.08, 2.05 and 3.47 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively) was observed in pigeonpea + rice (1:3) T_3.

Similarly, in the experimental year 2022 the highest CGR value (2.47, 4.32 and 7.49 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively) was observed in sole pigeonpea T_{13} which was significantly at par with pigeonpea + soybean (1:1) T_{10} (2.42, 4.26 and 7.41 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively), pigeonpea + sesame (1:1) T_4 (2.40, 4.24 and 7.36 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively), pigeonpea + greengram (1:1) T_7 (2.39 and 4.23 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively), and pigeonpea + rice (1:1) T_1 (4.21 g m^{-2} day^{-1} at 60-90 DAS).

Table 4.4(a): Crop growth rate (g m^{-2} day^{-1}) of pigeonpea under different intercropping system at 30-60 and 60-90 DAS

Treatments	CGR (30 -60 DAS)					
	30-60 DAS			60-90 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	2.31	2.36	2.33	4.14	4.21	4.18
T_2 - Pigeonpea +Rice (1:2)	1.53	1.62	1.58	2.72	2.79	2.76
T_3 - Pigeonpea +Rice (1:3)	1.08	1.10	1.09	2.05	2.07	2.06
T_4 - Pigeonpea +Sesame (1:1)	2.38	2.40	2.39	4.26	4.24	4.25
T_5 - Pigeonpea +Sesame (1:2)	1.47	1.58	1.52	2.78	2.79	2.78
T_6- Pigeonpea +Sesame (1:3)	1.13	1.16	1.14	2.07	2.03	2.05
T_7 - Pigeonpea +Greengram (1:1)	2.37	2.39	2.38	4.18	4.23	4.20
T_8 - Pigeonpea +Greengram (1:2)	1.50	1.61	1.56	2.82	2.79	2.81
T_9 - Pigeonpea +Greengram (1:3)	1.14	1.15	1.14	2.06	2.09	2.08
T_{10} - Pigeonpea +Soybean (1:1)	2.39	2.42	2.40	4.30	4.26	4.28
T_{11} - Pigeonpea +Soybean (1:2)	1.52	1.64	1.58	2.78	2.78	2.78
T_{12} - Pigeonpea +Soybean (1:3)	1.14	1.56	1.35	2.06	2.08	2.07
T_{13} - Sole Pigeonpea	2.40	2.47	2.43	4.31	4.32	4.31
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.04	0.03	0.02	0.04	0.04	0.03
CD (P=0.05)	0.10	0.08	0.06	0.12	0.11	0.08

Table 4.4(b): Crop growth rate (g m^{-2} day^{-1}) of pigeonpea under different intercropping system at 90-120 DAS

Treatments	CGR (90 -120 DAS)		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	7.09	7.11	7.10
T_2 - Pigeonpea +Rice (1:2)	4.80	4.65	4.72
T_3 - Pigeonpea +Rice (1:3)	3.47	3.53	3.50
T_4 - Pigeonpea +Sesame (1:1)	7.10	7.36	7.23
T_5 - Pigeonpea +Sesame (1:2)	4.77	4.65	4.71
T_6- Pigeonpea +Sesame (1:3)	3.57	3.55	3.56
T_7 - Pigeonpea +Greengram (1:1)	7.09	7.27	7.18
T_8 - Pigeonpea +Greengram (1:2)	4.73	4.62	4.68
T_9 - Pigeonpea +Greengram (1:3)	3.58	3.53	3.56
T_{10} - Pigeonpea +Soybean (1:1)	7.12	7.41	7.27
T_{11} - Pigeonpea +Soybean (1:2)	4.78	4.67	4.73
T_{12} - Pigeonpea +Soybean (1:3)	3.52	3.54	3.53
T_{13} - Sole Pigeonpea	7.22	7.49	7.35
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	0.03	0.06	0.03
CD (P=0.05)	0.10	0.18	0.10

CGR value was recorded the lowest in pigeonpea + rice (1:3) T_3 with values being 1.10, 2.07 and 3.53 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively.

Pooled data of year 2021 and 2022 revealed that the highest CGR value was recorded in sole pigeonpea T_{13} (2.43, 4.31 and 7.35 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively) and remained statistically at par with pigeonpea + soybean (1:1) T_{10} (2.40, 4.28 and 7.27 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively), pigeonpea + sesame (1:1) T_4 (2.39 and 4.25 g m^{-2} day^{-1} at 30-60 and 60-90 DAS respectively) and pigeonpea + greengram (1:1) T_7 (2.37 g m^{-2} day^{-1} at 30-60 DAS). Meanwhile, pigeonpea + rice (1:3) T_3 (1.09, 2.06 and 3.50 g m^{-2} day^{-1} at 30-60, 60-90 and 90-120 DAS respectively) recorded the minimum CGR value. Yang *et al.* (2018) also reported that the CGR of sole maize was always greater than intercropped maize, and it increased by 3.2% to 93.6% during the period of 15 to 95 days after pea emergence. Amanullah *et al*. (2021) recorded higher CGR value in sole crops (*i.e*. pigeonpea, mungbean, fababean, wheat and barley) in cereal-legume intercropping.

4.1.1.5 Absolute growth rate (g day^{-1})

An inquisition of data presented in Table 4.5(a) and 4.5(b) revealed that the absolute growth rate varied significantly among the treatments under intercropping with pigeonpea at 30 - 60 DAS during 2022 and pooled data, 60 - 90 DAS during pooled data and 90 – 120 DAS during 2022 and pooled data. It was evident from the data given in the table that sole pigeonpea T_{13} recorded the maximum value 0.445 and 0.438 g day^{-1} in 2022 and pooled data respectively at 30 – 60 DAS, 0.777 g day^{-1} for pooled data at 60-90 DAS, 1.35 and 1.32 for 2022 and pooled data at 90 - 120 DAS. The values were at par with pigeonpea + soybean (1:1) T_{10} 0.442 and 0.427 g day^{-1} in 2022 and pooled data respectively at 30 – 60 DAS, 0.770 g day^{-1} for pooled data at 60-90 DAS. The minimum value was recorded in pigeonpea + rice (1:3) T_3 with value 0.396 and 0.393 during 2022 and pooled data respectively at 30-60 DAS, 0.742 at 60-90 DAS and 1.26 for pooled data at 90-120 DAS.

4.1.1.6 Relative growth rate (g g^{-1} day^{-1})

Observations recorded on relative growth rate for both the years as well as pooled data are presented in Table 4.6(a) and 4.6(b). The data revealed that the relative growth rate of rice was found to be non-significant when intercropped with pigeonpea in almost all crop growth stages expect 30-60 DAS in year 2022 and pooled data. RGR value was found to be superior over rest of the treatments at pigeonpea + sesame (1:2) $T_{5,}$ pigeonpea + sesame (1:3) T_6 and pigeonpea + greengram (1:2) T_8 (0.065, 0.665 and 0.665 g g^{-1} day^{-1} at 30-60 DAS) in 2022. Pigeonpea + sesame (1:2) T_5, pigeonpea + sesame (1:3) T_6, pigeonpea + greengram (1:2) T_8, pigeonpea +soybean (1:2) T_{11} and pigeonpea + soybean (1:3) T_{12} (0.063, 0.063, 0.063 and 0.063 g g^{-1} day^{-1}at 30-60 DAS pooled data. The minimum value for RGR at 30-60 DAS was recorded in pigeonpea +Soybean (1:2) T_{10} (0.060 and 0.061 g g^{-1} day^{-1}in 2021 and pooled data), pigeonpea + sesame (1:1) T_4 and sole rice T_{14} (0.061 and 0.061 g g^{-1} day^{-1} in pooled data) The results corroborate with findings of Kour *et al*. (2016) in sole chickpea.

4.1.1.7 Net assimilation rate (g day^{-1} m^{-2})

The result presented in Table 4.7(a) and table 4.7(b) shows the effect of net assimilation rate as influence by intercropping system with pigeonpea at 30 - 60, 60 - 90 and 90 - 120 DAS. The NAR value showed significant influence at 30-60 DAS for the pooled data only, the highest NAR value was recorded in sole pigeonpea T_{13} with value 0.773 g day^{-1} m^{-2} at 30 - 60 DAS which was found to be stastically significantly at par with pigeonpea + soybean (1:1) T_{10} (0.769 g day^{-1} m^{-2} at 30 - 60 DAS), pigeonpea + sesame (1:1) T_4 (761 g day^{-1} m^{-2} at 30 - 60 DAS), pigeonpea + greengram (1:1) T_7 (0.755 g day^{-1} m^{-2} at 30 - 60 DAS)

Table 4.5(a): Absolute growth rate (g day^{-1}) of pigeonpea under different intercropping system at 30-60 and 60-90 DAS

Treatments	AGR (30 -60 DAS)					
	30-60 DAS			60-90 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.415	0.426	0.420	0.745	0.758	0.752
T_2 - Pigeonpea +Rice (1:2)	0.400	0.438	0.419	0.750	0.753	0.751
T_3 - Pigeonpea +Rice (1:3)	0.390	0.396	0.393	0.737	0.746	0.742
T_4 - Pigeonpea +Sesame (1:1)	0.428	0.432	0.430	0.769	0.763	0.766
T_5 - Pigeonpea +Sesame (1:2)	0.409	0.426	0.417	0.741	0.752	0.747
T_6- Pigeonpea +Sesame (1:3)	0.404	0.417	0.411	0.746	0.730	0.738
T_7 - Pigeonpea +Greengram (1:1)	0.425	0.430	0.427	0.755	0.761	0.758
T_8 - Pigeonpea +Greengram (1:2)	0.405	0.436	0.420	0.760	0.755	0.757
T_9 - Pigeonpea +Greengram (1:3)	0.401	0.412	0.407	0.754	0.752	0.753
T_{10} - Pigeonpea +Soybean (1:1)	0.430	0.435	0.433	0.775	0.766	0.770
T_{11} - Pigeonpea +Soybean (1:2)	0.412	0.442	0.427	0.752	0.751	0.751
T_{12} - Pigeonpea +Soybean (1:3)	0.411	0.421	0.416	0.742	0.748	0.745
T_{13} - Sole Pigeonpea	0.432	0.445	0.438	0.775	0.778	0.777
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.009	0.008	0.006	0.011	0.010	0.007
CD (P=0.05)	NS	0.022	0.017	NS	NS	0.021

Table 4.5(b): Absolute growth rate (g day^{-1}) of pigeonpea under different intercropping system at 90-120 DAS

Treatments	AGR (90 -120 DAS)		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	1.28	1.28	1.28
T_2 - Pigeonpea +Rice (1:2)	1.30	1.25	1.28
T_3 - Pigeonpea +Rice (1:3)	1.25	1.27	1.26
T_4 - Pigeonpea +Sesame (1:1)	1.28	1.32	1.30
T_5 - Pigeonpea +Sesame (1:2)	1.29	1.26	1.27
T_6- Pigeonpea +Sesame (1:3)	1.28	1.28	1.28
T_7 - Pigeonpea +Greengram (1:1)	1.28	1.31	1.29
T_8 - Pigeonpea +Greengram (1:2)	1.28	1.25	1.26
T_9 - Pigeonpea +Greengram (1:3)	1.29	1.27	1.28
T_{10} - Pigeonpea +Soybean (1:1)	1.28	1.33	1.31
T_{11} - Pigeonpea +Soybean (1:2)	1.29	1.26	1.28
T_{12} - Pigeonpea +Soybean (1:3)	1.27	1.27	1.27
T_{13} - Sole Pigeonpea	1.30	1.35	1.32
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	0.01	0.01	0.01
CD (P=0.05)	NS	0.04	0.02

Table 4.6(a): Relative growth rate (g g^{-1} day^{-1}) of pigeonpea under different intercropping system at 30-60 and 60-90 DAS

Treatments	RGR (30 - 60 DAS)					
	30-60 DAS			60-90 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.061	0.063	0.062	0.031	0.031	0.031
T_2 - Pigeonpea +Rice (1:2)	0.061	0.064	0.062	0.031	0.030	0.031
T_3 - Pigeonpea +Rice (1:3)	0.061	0.063	0.062	0.032	0.032	0.032
T_4 - Pigeonpea +Sesame (1:1)	0.061	0.061	0.061	0.031	0.030	0.030
T_5 - Pigeonpea +Sesame (1:2)	0.061	0.065	0.063	0.031	0.031	0.031
T_6- Pigeonpea +Sesame (1:3)	0.061	0.065	0.063	0.031	0.031	0.031
T_7 - Pigeonpea +Greengram (1:1)	0.061	0.062	0.062	0.030	0.030	0.030
T_8 - Pigeonpea +Greengram (1:2)	0.061	0.065	0.063	0.032	0.030	0.031
T_9 - Pigeonpea +Greengram (1:3)	0.062	0.063	0.062	0.032	0.031	0.031
T_{10} - Pigeonpea +Soybean (1:1)	0.061	0.060	0.061	0.031	0.030	0.030
T_{11} - Pigeonpea +Soybean (1:2)	0.061	0.064	0.063	0.031	0.030	0.030
T_{12} - Pigeonpea +Soybean (1:3)	0.062	0.064	0.063	0.031	0.031	0.031
T_{13} - Sole Pigeonpea	0.061	0.061	0.061	0.031	0.030	0.030
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.001	0.001	0.001	0.001	0.000	0.000
CD (P=0.05)	NS	0.002	0.001	NS	NS	NS

Table 4.6(b): Relative growth rate (g m^{-2} day^{-1}) of pigeonpea under different intercropping system at 90-120 DAS

Treatments	RGR (90 -120 DAS)		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.024	0.023	0.023
T_2 - Pigeonpea +Rice (1:2)	0.024	0.023	0.023
T_3 - Pigeonpea +Rice (1:3)	0.024	0.024	0.024
T_4 - Pigeonpea +Sesame (1:1)	0.023	0.024	0.023
T_5 - Pigeonpea +Sesame (1:2)	0.024	0.023	0.024
T_6- Pigeonpea +Sesame (1:3)	0.024	0.024	0.024
T_7 - Pigeonpea +Greengram (1:1)	0.023	0.024	0.023
T_8 - Pigeonpea +Greengram (1:2)	0.024	0.023	0.023
T_9 - Pigeonpea +Greengram (1:3)	0.024	0.024	0.024
T_{10} - Pigeonpea +Soybean (1:1)	0.023	0.024	0.023
T_{11} - Pigeonpea +Soybean (1:2)	0.024	0.023	0.023
T_{12} - Pigeonpea +Soybean (1:3)	0.024	0.024	0.024
T_{13} - Sole Pigeonpea	0.023	0.024	0.023
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	0.000	0.000	0.000
CD (P=0.05)	NS	NS	NS

Table 4.7(a): Net assimilation rate (g m^{-2} day^{-1}) of pigeonpea under different intercropping system at 30-60 and 60-90 DAS

Treatments	NAR (30 – 60 DAS)					
	30-60 DAS			60-90 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.731	0.747	0.739	1.44	1.50	1.47
T_2 - Pigeonpea +Rice (1:2)	0.643	0.653	0.648	1.39	1.45	1.42
T_3 - Pigeonpea +Rice (1:3)	0.549	0.563	0.556	1.52	1.41	1.46
T_4 - Pigeonpea +Sesame (1:1)	0.758	0.763	0.761	1.43	1.60	1.51
T_5 - Pigeonpea +Sesame (1:2)	0.666	0.663	0.664	1.63	1.41	1.52
T_6- Pigeonpea +Sesame (1:3)	0.617	0.593	0.605	1.36	1.54	1.45
T_7 - Pigeonpea +Greengram (1:1)	0.758	0.751	0.755	1.66	1.40	1.53
T_8 - Pigeonpea +Greengram (1:2)	0.650	0.673	0.662	1.37	1.36	1.37
T_9 - Pigeonpea +Greengram (1:3)	0.622	0.644	0.633	1.63	1.38	1.50
T_{10} - Pigeonpea +Soybean (1:1)	0.757	0.780	0.769	1.42	1.26	1.34
T_{11} - Pigeonpea +Soybean (1:2)	0.654	0.682	0.668	1.61	1.61	1.61
T_{12} - Pigeonpea +Soybean (1:3)	0.630	0.652	0.641	1.70	1.46	1.58
T_{13} - Sole Pigeonpea	0.766	0.781	0.773	1.50	1.27	1.39
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.052	0.049	0.036	0.12	0.14	0.09
CD (P=0.05)	NS	NS	0.101	NS	NS	NS

Table 4.7(b): Net assimilation rate (g m^{-2} day^{-1}) of pigeonpea under different intercropping system at 90 DAS

Treatments	NAR (60- 90 DAS)		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	2.91	3.30	3.10
T_2 - Pigeonpea +Rice (1:2)	3.34	3.46	3.40
T_3 - Pigeonpea +Rice (1:3)	3.15	3.80	3.47
T_4 - Pigeonpea +Sesame (1:1)	3.27	3.34	3.31
T_5 - Pigeonpea +Sesame (1:2)	2.72	2.95	2.84
T_6- Pigeonpea +Sesame (1:3)	2.82	2.78	2.80
T_7 - Pigeonpea +Greengram (1:1)	3.45	3.44	3.45
T_8 - Pigeonpea +Greengram (1:2)	3.37	3.29	3.33
T_9 - Pigeonpea +Greengram (1:3)	3.87	3.28	3.58
T_{10} - Pigeonpea +Soybean (1:1)	3.20	3.47	3.34
T_{11} - Pigeonpea +Soybean (1:2)	3.86	3.52	3.69
T_{12} - Pigeonpea +Soybean (1:3)	3.94	3.36	3.65
T_{13} - Sole Pigeonpea	3.64	3.60	3.62
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	0.36	0.39	0.26
CD (P=0.05)	NS	NS	NS

and pigeonpea + rice (1:1) T_1 (0.739 g day^{-1} m^{-2} at 30 - 60 DAS). The minimum NAR at 30 – 60 DAS was recorded in pigeonpea + rice (1:3) T_3 with value 0.556 g day^{-1} m^{-2} for the pooled data. Heggenstaller *et al.* (2009) reported higher NAR value in maize. These findings are in harmony with the findings of Addo-Quaye *et al*. (2011) in maize-soybean intercropping system. Similarly, Sujatha and Babalad (2018) in their experiment revealed significantly higher NAR (21.23 g/day/m^2) in sole direct sown pigeonpea.

4.1.1.8 Leaf area index

The data of leaf area index of pigeonpea under intercropping system at 30, 60 and 90 DAS are depicted in Table 4.8(a) and 4.8(b). Persual of data showed that the leaf area index was affected significantly in both the years of experiment. During 2021 the highest value was recorded in sole pigeonpea T_{13} (0.873, 2.63 and 3.73 at 30, 60 and 90 DAS respectively). Pigeonpea + soybean (1:1) T_{10} (0.870, 2.56 and 3.70 at 30, 60 and 90 DAS respectively), pigeonpea + sesame (1:1) T_4 (0.867, 2.52 and 3.68 at 30, 60 and 90 DAS respectively), pigeonpea + greengram (1:1) T_7 (0.853, 2.48 and 3.67 at 30, 60 and 90 DAS respectively), and pigeonpea + rice (1:1) T_1 (0.843, 2.46 and 3.63 at 30, 60 and 90 DAS respectively) remained statistically at par with the highest value of sole pigeonpea. The lowest LAI (0.650, 1.37 and 2.89 at 30, 60 and 90 DAS respectively) was obtained at pigeonpea + rice (1:3) T_3.

Similarly, during the second year 2022 sole pigeonpea T_{13} recorded the highest LAI (0.937, 2.87 and 3.80 at 30, 60 and 90 DAS respectively) and was significantly at par with pigeonpea + soybean (1:1) T_{10} (0.913, 2.72 and 3.77 at 30, 60 and 90 DAS respectively), pigeonpea + sesame (1:1) T_4 (0.883, 2.63 and 3.76 at 30, 60 and 90 DAS respectively), pigeonpea + greengram (1:1) T_7 (0.873, 2.56 and 3.71 at 30, 60 and 90 DAS respectively), and pigeonpea + rice (1:1) T_1 (0.860, 2.49 and 3.70 at 30, 60 and 90 DAS respectively). While pigeonpea + rice (1:3) T_3 (0.640, 2.12 and 2.90 at 30, 60 and 90 DAS respectively) recorded the lowest LAI value.

Table 4.8(a): Leaf area index of pigeonpea under different intercropping system at different growth stages.

Treatments	LAI					
	30 DAS			60 DAS		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.843	0.860	0.852	2.46	2.49	2.47
T_2 - Pigeonpea +Rice (1:2)	0.737	0.740	0.738	2.10	2.27	2.19
T_3 - Pigeonpea +Rice (1:3)	0.650	0.640	0.645	1.37	2.12	1.74
T_4 - Pigeonpea +Sesame (1:1)	0.867	0.883	0.875	2.52	2.63	2.58
T_5 - Pigeonpea +Sesame (1:2)	0.757	0.787	0.772	2.17	2.28	2.22
T_6- Pigeonpea +Sesame (1:3)	0.663	0.653	0.658	1.49	2.15	1.82
T_7 - Pigeonpea +Greengram (1:1)	0.853	0.873	0.863	2.48	2.56	2.52
T_8 - Pigeonpea +Greengram (1:2)	0.753	0.783	0.768	2.15	2.28	2.21
T_9 - Pigeonpea +Greengram (1:3)	0.683	0.657	0.670	1.60	2.16	1.88
T_{10} - Pigeonpea +Soybean (1:1)	0.870	0.913	0.892	2.56	2.72	2.64
T_{11} - Pigeonpea +Soybean (1:2)	0.760	0.793	0.777	2.18	2.30	2.24
T_{12} - Pigeonpea +Soybean (1:3)	0.697	0.663	0.680	1.63	2.14	1.89
T_{13} - Sole Pigeonpea	0.873	0.937	0.905	2.63	2.87	2.75
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.036	0.047	0.030	0.15	0.16	0.11
CD (P=0.05)	0.104	0.139	0.084	0.43	0.48	0.31

Table 4.8(b): Leaf area index of pigeonpea under different intercropping system at 90 DAS

Treatments	LAI (90 DAS)		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	3.63	3.70	3.66
T_2 - Pigeonpea +Rice (1:2)	3.22	3.25	3.23
T_3 - Pigeonpea +Rice (1:3)	2.89	2.90	2.89
T_4 - Pigeonpea +Sesame (1:1)	3.68	3.76	3.72
T_5 - Pigeonpea +Sesame (1:2)	3.24	3.30	3.27
T_6- Pigeonpea +Sesame (1:3)	2.95	2.97	2.96
T_7 - Pigeonpea +Greengram (1:1)	3.67	3.71	3.69
T_8 - Pigeonpea +Greengram (1:2)	3.27	3.26	3.27
T_9 - Pigeonpea +Greengram (1:3)	3.05	3.09	3.07
T_{10} - Pigeonpea +Soybean (1:1)	3.70	3.77	3.73
T_{11} - Pigeonpea +Soybean (1:2)	3.36	3.32	3.34
T_{12} - Pigeonpea +Soybean (1:3)	3.06	3.19	3.12
T_{13} - Sole Pigeonpea	3.73	3.80	3.77
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	0.10	0.16	0.09
CD (P=0.05)	0.28	0.47	0.26

Sole pigeonpea T_{13} in pool data also recorded the highest value (0.905, 2.75 and 3.77 at 30, 60 and 90 DAS respectively) meanwhile remained statistically at par with pigeonpea + soybean (1:1) T_{10} (0.892, 2.64 and 3.73 at 30, 60 and 90 DAS respectively), pigeonpea + sesame (1:1) T_4 (0.875, 2.58 and 3.72 at 30, 60 and 90 DAS respectively) and pigeonpea + greengram (1:1) T_7 (0.863, 2.52 and 3.69 at 30, 60 and 90 DAS). Pigeonpea + rice (1:3) T_3 (0.645, 1.74 and 2.89 at 30, 60 and 90 DAS respectively) recorded the lowest LAI.

The significant effect of CGR, AGR, RGR NAR and LAI could be mainly due to the production of more dry matter which inturn indicates higher leaf area production in sole pigeonpea. Reddy *et al.* (2015) also reported higher leaf area index of pigeonpea in sole pigeonpea than the pigeonpea intercropped with sesame. Yang *et al.* (2018) also reported higher LAI 6.7% to 10.2% in 2012 to 2013 sole maize and 21.0% to 24.1% higher for sole pea in 2012 and 2013. Rajashree *et al.* (2022) revealed that leaf area index of pigeonpea in sole cropping was superior to the intercropped pigeonpea.

4.1.2 Yield attributes

4.1.2.1 Plant stand at harvest (m^{-2})

Data of plant stand at harvest or final plant population presented at Table 4.9 revealed that the intercropping system with pigeonpea had significantly influenced among the treatments. In both the years and their pool data recorded maximum value (4.33, 4.33 and 4.33) for sole pigeonpea T_{13} while pigeonpea intercropped with rice at 1:3 ratio (T_3) value 1.33, 1.67 and 1.50 recorded the minimum plant stand at harvest in the year 2021, 2022 and pooled data respectively. As the treatments had different row ratio the plant stands at harvest differed significantly. The results were in conformity with Shivakumar *et al.* (2022a).

Table 4.9: Final plant population (m^{-2}) and no. of pods plant^{-1} of pigeonpea under different intercropping system

Treatments	Final plant population			No. of pods plant^{-1}		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	3.33	3.67	3.50	209.00	253.37	231.19
T_2 - Pigeonpea +Rice (1:2)	2.67	2.33	2.50	181.33	237.86	209.60
T_3 - Pigeonpea +Rice (1:3)	1.33	1.67	1.50	161.37	205.22	183.29
T_4 - Pigeonpea +Sesame (1:1)	3.33	3.67	3.50	221.30	268.86	245.08
T_5 - Pigeonpea +Sesame (1:2)	2.67	3.00	2.83	187.37	241.85	214.61
T_6- Pigeonpea +Sesame (1:3)	2.00	2.00	2.00	172.67	205.67	189.17
T_7 - Pigeonpea +Greengram (1:1)	3.67	4.00	3.83	220.04	263.82	241.93
T_8 - Pigeonpea +Greengram (1:2)	2.67	2.67	2.67	185.77	238.27	212.02
T_9 - Pigeonpea +Greengram (1:3)	2.00	2.00	2.00	170.75	208.20	189.48
T_{10} - Pigeonpea +Soybean (1:1)	4.00	4.00	4.00	227.50	277.94	252.72
T_{11} - Pigeonpea +Soybean (1:2)	2.67	3.00	2.83	194.29	245.16	219.73
T_{12} - Pigeonpea +Soybean (1:3)	2.00	2.00	2.00	171.00	216.42	193.71
T_{13} - Sole Pigeonpea	4.33	4.33	4.33	229.20	280.24	254.72
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.23	0.20	0.15	6.37	11.61	6.62
CD (P=0.05)	0.67	0.60	0.44	18.59	33.90	18.83

4.1.2.2 Number of pods plant^{-1}

An examination of data on number of pods plant^{-1} of pigeonpea under intercropping system with pigeonpea during both the years of crop growth period are presented in Table 4.9. Variation on number of pods plant^{-1} due to intercropping system was found to be significant during the period of experimentation. During both the years the highest number of pods plant^{-1} was recorded for sole pigeonpea (229.20 and 280.24 during 2021 and 2022 respectively) which was at par with pigeonpea + soybean (1:1) T_{10} (227.50 and 277.94 in 2021 and 2022 respectively), pigeonpea + sesame (1:1) T_4 (221.30 and 268.86 in 2021 and 2022 respectively), pigeonpea + greengram (1:1) T_7 (220.04 and 263.82 in 2021 and 2022 respectively) and pigeonpea + rice T_1 (253.37 at 2022). Pooled result thus obtained also recorded the highest number of pods plant^{-1} of 254.72 which was at par with the values of pigeonpea + soybean (1:1) T_{10} (252.72), pigeonpea + sesame (1:1) T_4 (245.08), pigeonpea + greengram (1:1) T_7 (241.93) as well. Significantly the lowest number of pods plant^{-1} was found in pigeonpea + rice (1:3) T_3 recording 161.37, 205.22 and 183.29 in 2021, 2022 and pooled data respectively. Similar results of higher number of pod plant^{-1} were observed in sole pigeonpea by Mallikarjun (2018) and Yadav *et al.* (2021).

4.1.2.3 Number of seeds per pod^{-1}

Data pertaining to the effect of intercropping system on number of seeds pod^{-1} in pigeonpea is tabulated in Table 4.10 which indicates that, the intercropping system did not influence the number of seeds pod^{-1} during the individual years as well as in pooled analysis.

4.1.2.4 Length of pod (cm)

Data depicted in Table 4.10 showed that length of pod of pigeonpea did not show any significant variation under intercropping system during individual year of study (2021 and 2022) and on pooled basis.

4.1.2.5 Pod weight plant^{-1} (g)

The perusal of data on the pod weight plant^{-1} is presented in Table

4.111. Pigeonpea did not display any significant results for the pod weight plant^{-1} under intercropping system.

4.1.2.6 Seed index (g)

The results in Table 4.11 elucidated that intercropping system during both the years did not reveal any significant variability in the seed index of pigeonpea.

4.1.3 Yield

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

Adaption of different pigeonpea intercropping system practices influenced the seed yield of pigeonpea in both the years, the mean data and the pooled data for both the years during the kharif of 2021 and 2022 are presented in Table 4.12 and figure 4.1. Sole pigeonpea T_{13} significantly recorded superior crop yield of 1377.78, 1387.03 and 1382.41 kg ha^{-1} during both the years of experiment 2021, 2022 and pool data respectively and was statistically at par with pigeonpea + soybean (1:1) T_{10} (1299.63, 1361.11 and 1330.37 kg ha^{-1} in the year 2021, 2022 and pooled data respectively). While the minimum value was recorded in pigeonpea + rice (1:3) T_3 (825.52, 832.96 and

830.74 kg ha^{-1} in both the years of experiment 2021, 2022 and their pooled data respectively). Higher yield in sole crop might be due to higher values of yield attributing characters as there was lower competition for resources *viz.* space, moisture and nutrients in sole cropping as compared to intercropping. Mahto *et al.* (2007) reported that intercropping with decreased plant density of finger millet in association with pigeon pea resulted in higher seed yield of pigeon pea. Results were in conformity with findings of Biradar *et al*. (2020) who also reported sole pigeonpea (1115 kg ha^{-1} and 1090 kg ha^{-1} in 2017 and 2018) to produce the highest seed yield. Similar findings were also reported by Kithan *et al*. (2020). In intercropping systems with row ratio 1:2 and 1:3 seed yield of pigeon pea was significantly reduced due to increased plant population of intercrops.

Table 4.10: No. of seeds pod^{-1} and pod length (cm) of pigeonpea under different intercropping system

Treatments	No. of seeds pod^{-1}			Pod length		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	4.17	4.28	4.23	5.30	5.56	5.43
T_2 - Pigeonpea +Rice (1:2)	3.85	4.08	3.97	5.27	5.43	5.35
T_3 - Pigeonpea +Rice (1:3)	3.57	3.44	3.50	4.87	5.15	5.01
T_4 - Pigeonpea +Sesame (1:1)	3.88	4.34	4.11	5.37	5.58	5.47
T_5 - Pigeonpea +Sesame (1:2)	4.36	4.09	4.23	5.23	5.46	5.35
T_6- Pigeonpea +Sesame (1:3)	3.78	3.61	3.69	4.93	5.21	5.07
T_7 - Pigeonpea +Greengram (1:1)	4.21	4.34	4.28	5.33	5.57	5.45
T_8 - Pigeonpea +Greengram (1:2)	3.94	4.20	4.07	5.13	5.53	5.33
T_9 - Pigeonpea +Greengram (1:3)	3.79	3.93	3.86	4.97	5.39	5.18
T_{10} - Pigeonpea +Soybean (1:1)	4.36	4.36	4.36	5.43	5.60	5.52
T_{11} - Pigeonpea +Soybean (1:2)	4.08	4.24	4.16	5.27	5.54	5.40
T_{12} - Pigeonpea +Soybean (1:3)	3.85	3.96	3.90	5.00	5.42	5.21
T_{13} - Sole Pigeonpea	4.47	4.36	4.41	5.53	5.65	5.59
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.30	0.25	0.20	0.23	0.13	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.11: Weight of pods plant^{-1} (g) and seed index (g) of pigeonpea under different intercropping system

Treatments	Weight of pods plant^{-1}			Seed index		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	78.10	83.76	80.93	9.03	9.43	9.23
T_2 - Pigeonpea +Rice (1:2)	72.90	80.44	76.67	9.02	9.31	9.17
T_3 - Pigeonpea +Rice (1:3)	70.90	72.84	71.87	8.06	9.19	8.63
T_4 - Pigeonpea +Sesame (1:1)	80.70	85.69	83.20	9.12	9.53	9.33
T_5 - Pigeonpea +Sesame (1:2)	73.33	81.55	77.44	8.98	9.17	9.07
T_6- Pigeonpea +Sesame (1:3)	71.56	75.43	73.50	8.57	9.00	8.79
T_7 - Pigeonpea +Greengram (1:1)	80.41	84.91	82.66	9.05	9.52	9.28
T_8 - Pigeonpea +Greengram (1:2)	75.96	82.09	79.03	8.87	9.46	9.16
T_9 - Pigeonpea +Greengram (1:3)	71.54	78.83	75.19	8.76	9.13	8.95
T_{10} - Pigeonpea +Soybean (1:1)	81.02	86.24	83.63	9.25	9.54	9.39
T_{11} - Pigeonpea +Soybean (1:2)	77.95	83.32	80.64	9.19	9.47	9.33
T_{12} - Pigeonpea +Soybean (1:3)	72.14	78.96	75.55	9.00	9.10	9.05
T_{13} - Sole Pigeonpea	82.62	86.81	84.72	9.39	9.57	9.48
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	4.69	4.44	3.23	0.24	0.26	0.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS

4.1.3.2 Stover yield (kg ha^{-1})

Data related to stover yield due to intercropping system with pigeonpea are presented in Table 4.13 and figure 4.2. Sole pigeonpea T_{13} recorded the highest value over rest of the treatments during both the years and even in pooled data (3250.37, 3188.48 and 3219.42 kg ha^{-1} in 2021, 2022 and pooled respectively), which was statistically at par with pigeonpea + soybean (1:1) T_{10} (3083.81, 3160.00 and 3121.91 kg ha^{-1}) in 2021, 2022 and pooled data respectively. The lowest stover yield was recorded in pigeonpea + rice (1:3) T_3 (2198.15, 2140.74 and 2169.45 kg ha^{-1} in 2021, 2022 and pooled respectively). Similar trends were obtained with straw yields of pigeonpea (Singh and Rai 2004): Tripathi *et al*. (2005). These results are in agreement with the research findings of Sonawane *et al.* (2011) who observed that sole pigeonpea produced higher grain yield (18.07 q ha^{-1}) and stover yield (40.38 q ha^{-1}), Sangtam *et al.* (2019) and Bhardwaj *et al*. (2023) also reported that sole crop produced more stover yield over intercropping system.

4.1.3.3 Biological yield (kg ha^{-1})

Data pertaining to biological yield of pigeonpea under intercropping system are presented in Table 4.14. The biological yield of pigeonpea varied significantly among treatments in both the years of study. The highest biological yield was recorded in sole pigeonpea T_{13} (4628.15, 4575.51 and 4601.83 kg ha^{-1} in 2021, 2022 and pooled data respectively) and was significantly at par with pigeonpea + soybean T_{10} (4517.11, 4537.88 and 4427.49 kg ha^{-1} in 2021, 2022 and pooled data), while lowest value was observed in pigeonpea + rice (1:3) T_3 in both the years and in the pooled data (3033.34, 2973.70 and 3003.52 kg ha^{-1} respectively). The higher value of seed yield and stover yield in sole pigeonpea T_{13} cumulatively enhanced the biological yield. These results were in close proximity with Merkeb (2016) and Pandit *et al.* (2020) who also reported that sole pigeonpoea performed better with production of higher grain yield and straw yield which led to higher biological yield compared to other intercrop system.

Table 4.12: Seed yield (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	Seed yield		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	1130.74	1207.41	1169.08
T_2 - Pigeonpea +Rice (1:2)	962.96	1015.92	989.44
T_3 - Pigeonpea +Rice (1:3)	828.52	832.96	830.74
T_4 - Pigeonpea +Sesame (1:1)	1211.11	1226.67	1218.89
T_5 - Pigeonpea +Sesame (1:2)	1002.22	1020.37	1011.30
T_6- Pigeonpea +Sesame (1:3)	897.04	898.15	897.59
T_7 - Pigeonpea +Greengram (1:1)	1168.52	1211.11	1189.81
T_8 - Pigeonpea +Greengram (1:2)	1076.67	1087.78	1082.22
T_9 - Pigeonpea +Greengram (1:3)	849.63	865.19	857.41
T_{10} - Pigeonpea +Soybean (1:1)	1299.63	1361.11	1330.37
T_{11} - Pigeonpea +Soybean (1:2)	1003.70	1029.63	1016.67
T_{12} - Pigeonpea +Soybean (1:3)	929.63	931.85	930.74
T_{13} - Sole Pigeonpea	1377.78	1387.03	1382.41
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	32.00	35.38	23.85
CD (P=0.05)	93.40	103.28	67.83

Table 4.13: Stover yield (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	Stover yield		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	2714.81	2915.00	2814.91
T_2 - Pigeonpea +Rice (1:2)	2416.74	2492.17	2454.46
T_3 - Pigeonpea +Rice (1:3)	2198.15	2140.74	2169.45
T_4 - Pigeonpea +Sesame (1:1)	2880.63	2926.04	2903.33
T_5 - Pigeonpea +Sesame (1:2)	2485.86	2550.86	2518.36
T_6- Pigeonpea +Sesame (1:3)	2285.19	2260.53	2272.86
T_7 - Pigeonpea +Greengram (1:1)	2789.92	2911.11	2850.52
T_8 - Pigeonpea +Greengram (1:2)	2637.04	2633.70	2635.37
T_9 - Pigeonpea +Greengram (1:3)	2074.08	2193.78	2133.93
T_{10} - Pigeonpea +Soybean (1:1)	3083.81	3160.00	3121.91
T_{11} - Pigeonpea +Soybean (1:2)	2501.49	2571.11	2536.30
T_{12} - Pigeonpea +Soybean (1:3)	2315.93	2318.77	2317.35
T_{13} - Sole Pigeonpea	3250.37	3188.48	3219.42
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	63.67	87.28	54.02
CD (P=0.05)	185.83	254.75	153.59

Table 4.14: Biological yield (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	Biological yield		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	3845.56	4122.41	3983.98
T_2 - Pigeonpea +Rice (1:2)	3379.70	3508.10	3443.90
T_3 - Pigeonpea +Rice (1:3)	3026.67	2973.70	3000.19
T_4 - Pigeonpea +Sesame (1:1)	4091.74	4152.71	4122.22
T_5 - Pigeonpea +Sesame (1:2)	3488.08	3571.23	3529.65
T_6- Pigeonpea +Sesame (1:3)	3182.22	3158.68	3170.45
T_7 - Pigeonpea +Greengram (1:1)	3958.44	4122.22	4040.33
T_8 - Pigeonpea +Greengram (1:2)	3713.70	3721.48	3717.59
T_9 - Pigeonpea +Greengram (1:3)	2923.71	3058.96	2991.34
T_{10} - Pigeonpea +Soybean (1:1)	4383.44	4521.11	4452.28
T_{11} - Pigeonpea +Soybean (1:2)	3505.19	3600.74	3552.96
T_{12} - Pigeonpea +Soybean (1:3)	3245.56	3250.62	3248.09
T_{13} - Sole Pigeonpea	4628.15	4575.51	4601.83
T_{14} - Sole Rice		-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	92.86	119.17	75.54
CD (P=0.05)	271.04	347.85	214.80

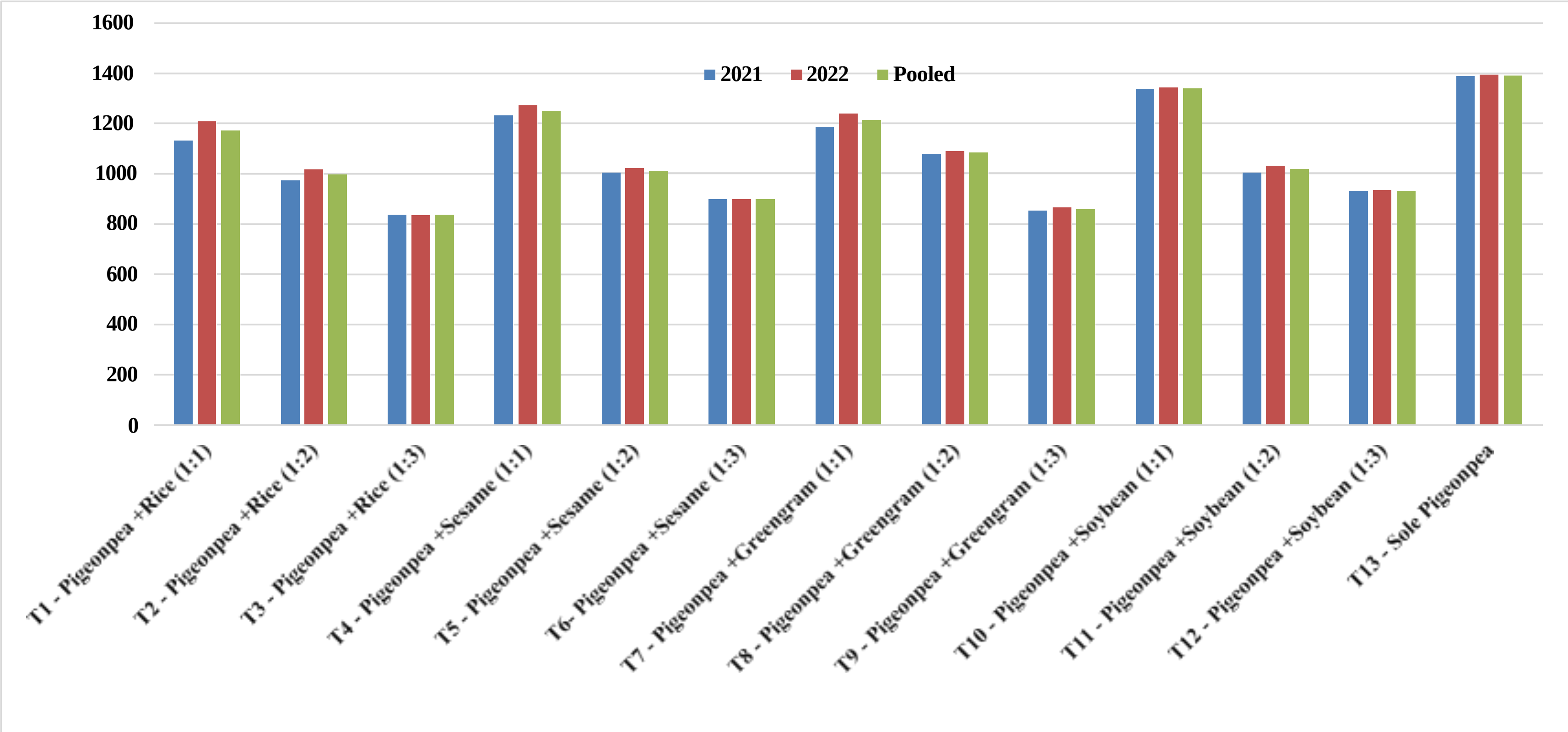

Fig. 4.1 Effect of different intercropping system on seed yield (kg ha^{-1}) of pigeonpea

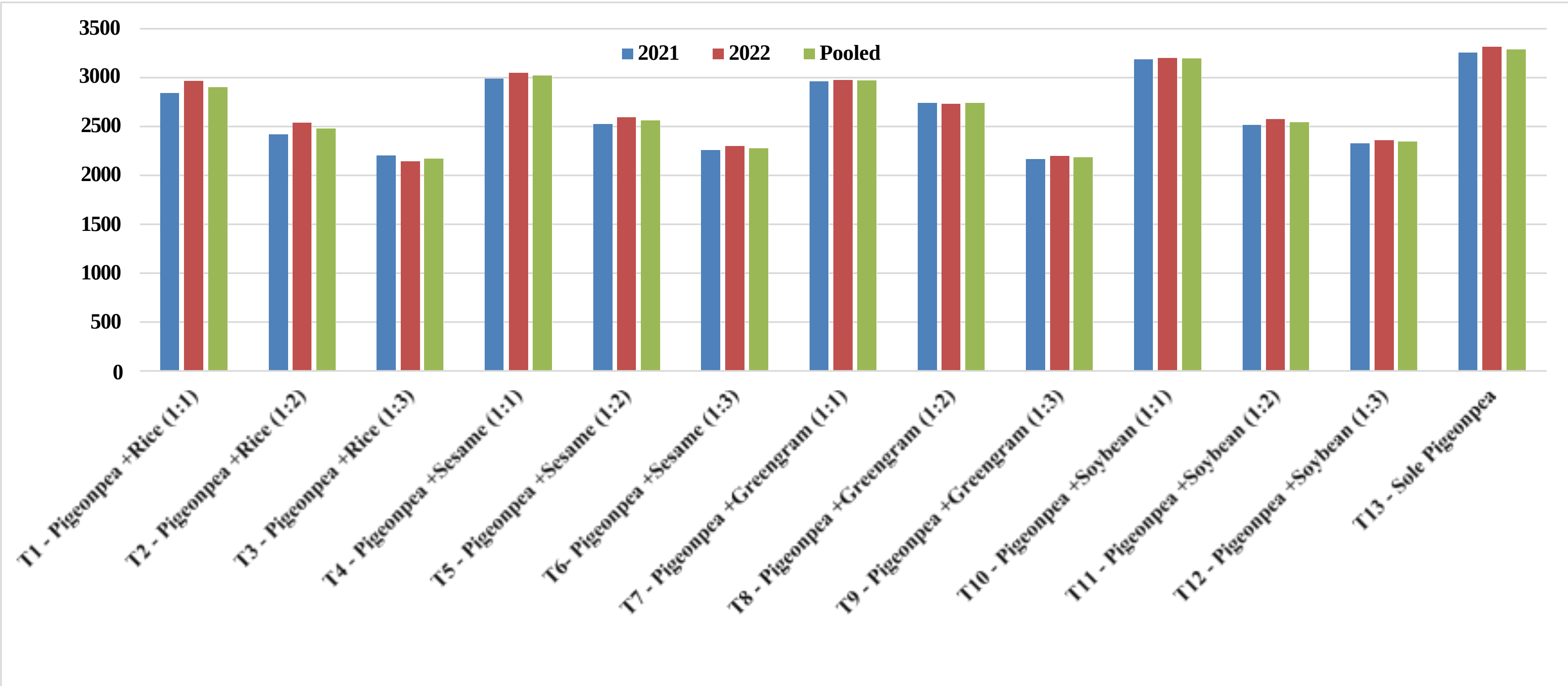

Fig. 4.2 Effect of different intercropping system on stover yield (kg ha^{-1}) of pigeonpea

4.1.3.4 Harvest index (%)

The result on harvest index of pigeonpea under intercropping system are presented in Table 4.15 and significant response was observed during both the years of experimentations. The harvest index (29.76, 30.31 and 30.04 % in 2021, 2022 and pooled data respectively) was recorded higher under sole pigeonpea T_{13} and was found at par with pigeonpea + soybean (1:1) T_{10} (29.64, 30.08 and 29.86 % in 2021, 2022 and pooled data respectively), pigeonpea + sesame (1:1) T_4 (29.60, 29.54 and 29.57 % in 2021, 2022 and pooled data respectively), pigeonpea + greengram (1:1) T_7 with value 29.40 % in 2022 and pigeonpea + rice T_1 (28.96 % in 2022). The least harvest index value was found in pigeonpea + rice (1:3) T_3 (27.37, 28.01 and 27.69 % in 2021, 2022 and pooled data respectively). The results were supported by Kumar and Khuswaha (2018).

4.1.4 Plant analysis

4.1.4.1 Nitrogen content seed (%)

An inquisition of data depicted to nitrogen content in seed of pigeonpea statistically analyzed and presented in Table 4.16 revealed that the highest nitrogen content in sole pigeonpea T_{13} (2.85, 2.98 and 2.91 % in 2021, 2022 and pooled data respectively) which was significantly at par with Pigeonpea + Soybean (1:1) T_{10} (2.84, 2.97 and 2.91% during 2021, 2022 and pooled data respectively) and Pigeonpea + Sesame (1:1) T_4 (2.83, 2.96 and 2.89% in 2021, 2022 and pooled data respectively). While, Pigeonpea + Rice (1:3) T_3 recorded the least nitrogen content in seed *viz*. 2.71, 2.82 and 2.77% for the year 2021, 2022 as well as mean data respectively.

4.1.4.2 Nitrogen content stover (%)

Analysis of data on nitrogen content in stover of pigeonpea is presented in Table 4.16, the data indicated that it was significantly influenced under different intercropping system. Sole pigeonpea T_{13} recorded the highest nitrogen content in stover (0.599, 0.629 and 0.614% in 2021, 2022 and pooled data respectively) and was found to be at par with pigeonpea + soybean (1:1) T_{10} (0.598, 0.625 and 0.612 % in the year 2021, 2022 and pooled data respectively). pigeonpea + rice (1:3) T_3 recorded the lowest nitrogen content in stover (0.581, 0.605 and 0.593% in 2021, 2022 and pool respectively). Das (2012) reported that cropping system had significant effect on the N and P content of seed and stover in sole pigeonpea.

4.1.4.3 Nitrogen uptake seed (kg ha^{-1})

A critical examination of the data presented in the Table 4.17, indicated that the nitrogen uptake in seed was highest in sole pigeonpea T_{13} (39.22, 41.94 and 40.58 kg ha^{-1} in 2021, 2022 and pooled data respectively) and found at par with pigeonpea + soybean (1:1) T_{10} (36.91 kg ha^{-1} during 2021). While the lowest nitrogen uptake in seed was recorded from pigeonpea + rice (1:3) T_3 with 22.48, 23.52 and 23.00 kg ha^{-1} in 2021, 2022 and pool respectively. Nutrient uptake in crop is the function of dry matter production and concentration of that nutrient (Singh, 2017). Likewise, higher nitrogen seed uptake may be due to higher dry matter production and concentration of nitrogen of pigeonpea sown as sole.

4.1.4.4 Nitrogen uptake stover (kg ha^{-1})

It is apparent from the Table 4.17 that the highest nitrogen uptake in stover was recorded in sole pigeonpea T_{13} (19.46, 20.82 and 20.14 kg ha^{-1} in 2021, 2022 and pooled data) and found to be at par with pigeonpea + soybean (1:1) T_{10} (18.83 kg ha^{-1} during 2021). While the lowest nitrogen uptake in stover was recorded in pigeonpea + greengram (1:3) T_9 with 12.61, 13.32 and 12.96 kg ha^{-1} in 2021, 2022 and pooled data respectively. The results were in accordance with Zhao *et al*. (2022).

Table 4.15. Harvest index (%) of pigeonpea under different intercropping system

Treatments	Harvest Index		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	29.40	29.28	29.34
T_2 - Pigeonpea +Rice (1:2)	28.49	28.96	28.73
T_3 - Pigeonpea +Rice (1:3)	27.37	28.01	27.69
T_4 - Pigeonpea +Sesame (1:1)	29.60	29.54	29.57
T_5 - Pigeonpea +Sesame (1:2)	28.73	28.62	28.68
T_6- Pigeonpea +Sesame (1:3)	28.17	28.41	28.29
T_7 - Pigeonpea +Greengram (1:1)	29.51	29.40	29.46
T_8 - Pigeonpea +Greengram (1:2)	28.99	29.26	29.12
T_9 - Pigeonpea +Greengram (1:3)	29.05	28.28	28.67
T_{10} - Pigeonpea +Soybean (1:1)	29.64	30.08	29.86
T_{11} - Pigeonpea +Soybean (1:2)	28.62	28.59	28.61
T_{12} - Pigeonpea +Soybean (1:3)	28.64	28.68	28.66
T_{13} - Sole Pigeonpea	29.76	30.31	30.04
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	0.34	0.36	0.25
CD (P=0.05)	1.01	1.05	0.71

Table 4.16: Nitrogen content (%) of pigeonpea under different intercropping system

Treatments	N content seed			N content stover		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	2.79	2.94	2.87	0.591	0.619	0.605
T_2 - Pigeonpea +Rice (1:2)	2.75	2.86	2.80	0.585	0.612	0.599
T_3 - Pigeonpea +Rice (1:3)	2.71	2.82	2.77	0.581	0.605	0.593
T_4 - Pigeonpea +Sesame (1:1)	2.83	2.96	2.89	0.595	0.623	0.609
T_5 - Pigeonpea +Sesame (1:2)	2.76	2.87	2.81	0.586	0.614	0.600
T_6- Pigeonpea +Sesame (1:3)	2.72	2.83	2.78	0.582	0.606	0.594
T_7 - Pigeonpea +Greengram (1:1)	2.81	2.95	2.88	0.592	0.620	0.606
T_8 - Pigeonpea +Greengram (1:2)	2.76	2.92	2.84	0.587	0.615	0.601
T_9 - Pigeonpea +Greengram (1:3)	2.73	2.84	2.79	0.583	0.607	0.595
T_{10} - Pigeonpea +Soybean (1:1)	2.84	2.97	2.91	0.598	0.625	0.612
T_{11} - Pigeonpea +Soybean (1:2)	2.77	2.93	2.85	0.588	0.618	0.603
T_{12} - Pigeonpea +Soybean (1:3)	2.74	2.85	2.80	0.584	0.611	0.598
T_{13} - Sole Pigeonpea	2.85	2.98	2.91	0.599	0.629	0.614
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.01	0.01	0.01	0.001	0.002	0.001
CD (P=0.05)	0.03	0.02	0.02	0.002	0.004	0.002

Table 4.17: Nitrogen uptake (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	N uptake seed			N uptake stover		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	31.51	35.53	33.52	16.75	18.34	17.54
T_2 - Pigeonpea +Rice (1:2)	26.76	29.02	27.89	14.14	15.52	14.83
T_3 - Pigeonpea +Rice (1:3)	22.66	23.52	23.09	12.78	12.95	12.87
T_4 - Pigeonpea +Sesame (1:1)	34.79	37.59	36.19	17.74	18.98	18.36
T_5 - Pigeonpea +Sesame (1:2)	27.66	29.25	28.45	14.78	15.87	15.32
T_6- Pigeonpea +Sesame (1:3)	24.40	25.44	24.92	13.11	13.89	13.50
T_7 - Pigeonpea +Greengram (1:1)	33.34	36.47	34.91	17.52	18.41	17.97
T_8 - Pigeonpea +Greengram (1:2)	29.72	31.80	30.76	16.07	16.79	16.43
T_9 - Pigeonpea +Greengram (1:3)	23.22	24.57	23.90	12.61	13.32	12.96
T_{10} - Pigeonpea +Soybean (1:1)	37.87	39.88	38.87	19.03	19.99	19.51
T_{11} - Pigeonpea +Soybean (1:2)	27.77	30.13	28.95	14.75	15.89	15.32
T_{12} - Pigeonpea +Soybean (1:3)	25.44	26.60	26.02	13.59	14.36	13.98
T_{13} - Sole Pigeonpea	39.51	41.50	40.51	19.46	20.82	20.14
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.69	0.80	0.53	0.34	0.41	0.27
CD (P=0.05)	2.02	2.34	1.50	1.00	1.21	0.76

4.1.4.5 Phosphorus content seed (%)

From the perusal of the result, it was evident from the data presented in Table 4.18 that P content in seed of pigeonpea showed significant effect under different intercropping system. Sole pigeonpea T_{13} recorded highest phosphorus content in seed (2.22, 2.26 and 2.24% in the year 2021, 2022 and pooled data respectively) and was at par with pigeonpea + soybean (1:1) T_{10} (2.21, 2.25 and 2.23% in the year 2021, 2022 and pooled data respectively), pigeonpea + sesame (1:1) T_4 (2.20, 2.24 and 2.22% during 2021, 2022 and pooled data respectively), pigeonpea + greengram (1:1) T_7 (2.19, 2.23 and 2.21% in 2021, 2022 and pool data), pigeonpea + rice (1:1) T_1 with 2.18, 2.22 and 2.20% in the year 2021, 2022 and pooled data respectively. However, the lowest phosphorus content in seed was recorded from pigeonpea + rice (1:3) T_3 with 2.10, 2.14 and 2.12% for the year 2021, 2022 as well as pooled data respectively.

4.1.4.6 Phosphorus content stover (%)

A close examination of the data given in Table 4.18 revealed that the phosphorus content in stover of pigeonpea was highest in sole pigeonpea T_{13} with 0.299, 0.319 and 0.309 % during the years 2021, 2022 and pooled data respectively with was significantly at par with pigeonpea + soybean (1:1) T_{10} (0.298 and 0.315 % during the year 2021 and 2022, respectively) and pigeonpea + greengram (1:1) T_7 with 0.314 % during the year 2022. Whereas, the least phosphorus content in stover was recorded from pigeonpea + rice (1:3) T_3 with 0.281, 0.289 and 0.285 % for the year 2021, 2022 and pooled data respectively. Higher uptake of N by pigeonpea was due to its larger share of contribution from atmospheric N fixation (to growth, biomass and protein yield) as legumes are known to be poor competitors for P and K especially when they are intercropped with fast growing short duration cereals (Ramesh and Reddy 2004).

4.1.4.7 Phosphorus uptake seed (kg ha^{-1})

An inference of the data presented in Table 4.19 revealed that the data on phosphorus uptake in seed of pigeonpea under different intercropping system was found to be significant. Sole pigeonpea T_{13} recorded the highest phosphorus uptake in seed (30.58, 31.80 and 31.19 kg ha^{-1} in the year 2021, 2022 and pooled data respectively) and was at par with pigeonpea + soybean (1:1) T_{10} with value 28.76 kg ha^{-1} in 2021. While pigeonpea + rice (1:3) T_3 recorded the lowest phosphorus uptake in seed (17.43, 17.80 and 17.61 kg ha^{-1} in the year 2021, 2022 and their mean respectively). The higher seed, stalk and total phosphorous uptake of sole pigeonpea than pigeonpea inter cropping systems may be due to higher dry matter production and concentration of phosphorus in grain and whole plant. Similar findings were also reported by Chhetri and Sinha (2020) in sole maize.

4.1.4.8 Phosphorus uptake stover (kg ha^{-1})

The results of phosphorus uptake of stover in pigeonpea are presented in Table 4.19. The data revealed that phosphorus uptake in stover of pigeonpea differed significantly under different intercropping system. Significantly the highest phosphorus uptake in stover was observed in sole pigeonpea T_{13} with 9.71, 10.55 and 10.13 kg ha^{-1} in 2021, 2022 and pooled data respectively and the data was significantly at par with pigeonpea + soybean (1:1) T_{10} with 9.38 kg ha^{-1} in the year 2021. Meanwhile the significantly lowest phosphorus uptake in stover was observed in pigeonpea + rice (1:3) T_3 with 6.18, 6.19 and 6.19 kg ha $^{-1}$ in 2021, 2022 and pool respectively. Tripathi *et al*. (2019) observed higher NPK uptake by pigeonpea which was significantly higher under pigeonpea sole with RDF over those by both intercropping (pigeonpea + sorghum/pearl millet) systems.

Table 4.18: Phosphorus content (%) pigeonpea under different intercropping system

Treatments	P content seed			P content stover		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	2.18	2.22	2.20	0.291	0.311	0.301
T_2 - Pigeonpea +Rice (1:2)	2.14	2.18	2.16	0.285	0.306	0.295
T_3 - Pigeonpea +Rice (1:3)	2.10	2.14	2.12	0.281	0.289	0.285
T_4 - Pigeonpea +Sesame (1:1)	2.20	2.24	2.22	0.295	0.313	0.304
T_5 - Pigeonpea +Sesame (1:2)	2.15	2.19	2.17	0.286	0.307	0.297
T_6- Pigeonpea +Sesame (1:3)	2.11	2.15	2.13	0.282	0.293	0.288
T_7 - Pigeonpea +Greengram (1:1)	2.19	2.23	2.21	0.292	0.314	0.303
T_8 - Pigeonpea +Greengram (1:2)	2.16	2.20	2.18	0.287	0.308	0.298
T_9 - Pigeonpea +Greengram (1:3)	2.12	2.16	2.14	0.283	0.303	0.293
T_{10} - Pigeonpea +Soybean (1:1)	2.21	2.25	2.23	0.298	0.315	0.306
T_{11} - Pigeonpea +Soybean (1:2)	2.17	2.21	2.19	0.288	0.310	0.299
T_{12} - Pigeonpea +Soybean (1:3)	2.13	2.17	2.15	0.284	0.305	0.295
T_{13} - Sole Pigeonpea	2.22	2.26	2.24	0.299	0.319	0.309
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.02	0.02	0.01	0.001	0.002	0.001
CD (P=0.05)	0.07	0.05	0.04	0.002	0.005	0.002

Table 4.19: Phosphorus uptake (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	P uptake seed			P uptake stover		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	24.64	26.80	25.72	8.24	9.22	8.73
T_2 - Pigeonpea +Rice (1:2)	20.79	22.18	21.48	6.89	7.75	7.32
T_3 - Pigeonpea +Rice (1:3)	17.57	17.80	17.68	6.18	6.19	6.19
T_4 - Pigeonpea +Sesame (1:1)	27.04	28.40	27.72	8.79	9.53	9.16
T_5 - Pigeonpea +Sesame (1:2)	21.55	22.31	21.93	7.21	7.93	7.57
T_6- Pigeonpea +Sesame (1:3)	18.96	19.31	19.13	6.36	6.72	6.54
T_7 - Pigeonpea +Greengram (1:1)	25.92	27.60	26.76	8.65	9.33	8.99
T_8 - Pigeonpea +Greengram (1:2)	23.25	23.93	23.59	7.86	8.41	8.13
T_9 - Pigeonpea +Greengram (1:3)	18.01	18.69	18.35	6.12	6.65	6.39
T_{10} - Pigeonpea +Soybean (1:1)	29.51	30.17	29.84	9.48	10.07	9.77
T_{11} - Pigeonpea +Soybean (1:2)	21.75	22.79	22.27	7.22	7.98	7.60
T_{12} - Pigeonpea +Soybean (1:3)	19.83	20.19	20.01	6.61	7.18	6.89
T_{13} - Sole Pigeonpea	30.81	31.48	31.14	9.71	10.55	10.13
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.60	0.61	0.43	0.17	0.21	0.14
CD (P=0.05)	1.75	1.78	1.22	0.49	0.62	0.38

4.1.4.9 Potassium content seed (%)

Data of potassium content in seed of pigeonpea are indicated in Table 4.20, which revealed that a significant difference was observed under different intercropping systems. Sole pigeonpea T_{13} recorded the maximum potassium content in seed (0.237, 0.259 and 0.248 % in the year 2021, 2022 and pooled data respectively) that was at par with pigeonpea + soybean (1:1) T_4 (0.235 and 0.258 % during the year 2021 and 2022 respectively) and pigeonpea + sesame (1:1) T_4 with 0.257 % during the year 2022. Pigeonpea + rice (1:3) T_3 recorded the minimum potassium content in seed (0.216, 0.238 and 0.227 in 2021, 2022 and pooled data respectively).

4.1.4.10 Potassium content stover (%)

Data tabulated in Table 4.20 indicated that under different intercropping systems significantly influenced the potassium content in stover of pigeonpea in both the years of experiment. In 2021, 2022 and for pooled data of both the years, it was observed that the highest potassium content in stover (0.994, 1.013 and 1.003% respectively) was recorded in sole pigeonpea T_{13} and was at par with pigeonpea + soybean (1:1) T_{10} (0.993, 1.006 and 1.000% during 2021, 2022 and pooled data respectively), pigeonpea + sesame (1:1) T_4 (0.992 and 1.005% for the year 2021 and 2022 respectively) and pigeonpea + greengram (1:1) T_7 with 0.991% during the year 2021. Whereas, the least potassium content in stover with 0.983, 0.992 and 0.988 % was recorded in pigeonpea + rice (1:3) T_3 for the respective years.

4.1.4.11 Potassium uptake seed (kg ha^{-1})

Analysis of data presented on Table 4.21 showed a significant influence on potassium uptake in seed under different intercropping system during the years 2021, 2022 and the pooled data.

Table 4.20: Potassium content (%) of pigeonpea under different intercropping system

Treatments	K content seed			K content stover		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.227	0.248	0.237	0.991	1.001	0.996
T_2 - Pigeonpea +Rice (1:2)	0.223	0.244	0.234	0.987	0.996	0.992
T_3 - Pigeonpea +Rice (1:3)	0.216	0.238	0.227	0.983	0.992	0.988
T_4 - Pigeonpea +Sesame (1:1)	0.234	0.257	0.246	0.992	1.005	0.998
T_5 - Pigeonpea +Sesame (1:2)	0.224	0.245	0.234	0.988	0.997	0.993
T_6- Pigeonpea +Sesame (1:3)	0.217	0.239	0.228	0.984	0.993	0.989
T_7 - Pigeonpea +Greengram (1:1)	0.228	0.254	0.241	0.991	1.004	0.997
T_8 - Pigeonpea +Greengram (1:2)	0.225	0.246	0.236	0.989	0.998	0.994
T_9 - Pigeonpea +Greengram (1:3)	0.218	0.242	0.230	0.985	0.994	0.990
T_{10} - Pigeonpea +Soybean (1:1)	0.235	0.258	0.246	0.993	1.006	1.000
T_{11} - Pigeonpea +Soybean (1:2)	0.226	0.247	0.237	0.990	1.000	0.995
T_{12} - Pigeonpea +Soybean (1:3)	0.221	0.243	0.232	0.986	0.995	0.991
T_{13} - Sole Pigeonpea	0.237	0.259	0.248	0.994	1.013	1.003
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.001	0.001	0.000	0.001	0.003	0.001
CD (P=0.05)	0.002	0.002	0.001	0.003	0.008	0.004

Table 4.21: Potassium uptake (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	K uptake seed			K uptake stover		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_1 - Pigeonpea +Rice (1:1)	2.56	2.99	2.78	28.09	29.68	28.88
T_2 - Pigeonpea +Rice (1:2)	2.17	2.48	2.32	23.86	25.25	24.56
T_3 - Pigeonpea +Rice (1:3)	1.80	1.98	1.89	21.60	21.24	21.42
T_4 - Pigeonpea +Sesame (1:1)	2.88	3.26	3.07	29.56	30.60	30.08
T_5 - Pigeonpea +Sesame (1:2)	2.24	2.50	2.37	24.92	25.76	25.34
T_6- Pigeonpea +Sesame (1:3)	1.94	2.14	2.04	22.16	22.78	22.47
T_7 - Pigeonpea +Greengram (1:1)	2.71	3.14	2.92	29.31	29.82	29.56
T_8 - Pigeonpea +Greengram (1:2)	2.42	2.68	2.55	27.08	27.26	27.17
T_9 - Pigeonpea +Greengram (1:3)	1.85	2.09	1.97	21.32	21.81	21.56
T_{10} - Pigeonpea +Soybean (1:1)	3.13	3.46	3.29	31.60	32.17	31.89
T_{11} - Pigeonpea +Soybean (1:2)	2.27	2.54	2.41	24.82	25.70	25.26
T_{12} - Pigeonpea +Soybean (1:3)	2.05	2.26	2.16	22.94	23.41	23.18
T_{13} - Sole Pigeonpea	3.29	3.60	3.45	32.31	33.54	32.92
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.06	0.07	0.04	0.59	0.68	0.45
CD (P=0.05)	0.16	0.20	0.13	1.71	2.00	1.28

Highest potassium uptake in seed was recorded in sole pigeonpea T_{13} (3.29, 3.60 and 3.45 kg ha^{-1} in 2021, 2022 and pooled data respectively) and was significantly at par with pigeonpea + soybean (1:1) T_{10} obtaining values 3.13 and 3.46 kg ha^{-1} in 2021 and 2022 respectively. Kumawat *et al.* (2015) observed similar results in pigeonpea.

4.1.4.12 Potassium uptake stover (kg ha^{-1})

Data related to potassium uptake in stover of pigeonpea under different intercropping systems are presented in Table 4.21 and showed significant results. Sole pigeonpea T_{13} recorded the highest potassium uptake in stover (32.31, 33.54 and 32.92 kg ha^{-1} in 2021, 2022 and pooled respectively) during the experimentation year and was significantly at par with pigeonpea + soybean (1:1) T_{10} with 31.27 kg ha^{-1} during the year 2021. Pigeonpea + greengram (1:3) T_9 recorded the minimum potassium uptake in stover with 21.32, 21.81 and 21.56 kg ha^{-1} in 2021, 2022 and pooled respectively. These results were in line with the findings of Shivakumar *et al.* (2022b) who observed that sole pigeonpea recorded significantly higher mean grain, stalk and total potassium uptake (17.90, 29.44 and 47.34 kg ha^{-1}, respectively) as compared to all other sequential inter cropping systems.

4.2 RICE

4.2.1 Growth attributes

4.2.1.1 Plant height (cm)

The data pertaining to plant height presented in Table 4.22 revealed significant difference at 30 DAS under intercropping system with pigeonpea during both the years (2021 and 2022) and for the pooled data. No significant difference was observed as crop growth increased with time.

Sole rice T_{14} in the initial year at 30 DAS recorded the maximum plant height 40.55 cm and was superiorly higher than the rest of the treatments.

Similarly sole rice T_{14} at 30 DAS in the second year recorded the maximum plant height 46.17 cm and was significantly at par with T_3 Pigeonpea + Rice (1:3) 41.48 cm and T_1 Pigeonpea + Rice (1:1) 41.54 cm, respectively. In both the years at 30 DAS T_2 Pigeonpea + Rice (1:2) recorded the minimum plant height 33.73 cm and 38.86 cm in 2021 and 2022 respectively. In case of the pooled data at 30 DAS sole rice T_{14} also recorded the maximum plant height 43.36 cm and the value was superior than the rest of the treatments meanwhile the lowest treatment was recorded in T_2 Pigeonpea + Rice (1:2) 36.30 cm. This may be due to the availability of nutrients for sole crop without any competition. The results were in conformity with the findings of Lawrence and Gohain (2011).

4.2.1.2 Plant population (m^{-2})

Data regarding the plant population of rice recorded at 30 DAS, 60 DAS and 90 DAS as influenced by intercropping system with pigeonpea for the years 2021, 2022 and pooled are presented in Table 4.23, results revealed that different treatments of intercropping system showed significant influence on plant population.

Sole rice T_{14} recorded the maximum plant population 49.67 (m^{-2}) in 2021 at 30 DAS which was statistically superior over the rest of the treatments. Similarly in 2022 and the pooled data at 30 DAS for both the years where sole rice T_{14} recorded the maximum plant population 49.33 and 49.50 (m^{-2}) respectively. Whereas the minimum plant population 20, 20 and 20 (m^{-2}) was found in the treatment pigeonpea + rice (1:1) T_1 and pigeonpea + rice (1:2) T_2 at 30 DAS in 2021, 2022 and pooled data respectively for both the years.

In 2021, 2022 and for pooled data of both the years at 60 DAS, maximum plant population 49, 48.67 and 48.83 (m^{-2}) respectively was recorded in sole rice T_{14} which was superior to the rest of the treatments. The minimum value 19.67

(m^{-2}) at 60 DAS for the year 2021, 2022 and the pooled data was recorded for T_2 pigeonpea + rice (1:2).

At 90 DAS similar trend as that of 30 and 60 DAS was revealed, sole rice T_{14} recorded the maximum value of 48.67 (m^{-2}) in the year 2021, 2022 and for the pooled data of both the years. While minimum plant population was recorded at T_2 pigeonpea + rice (1:2) with the value of 19 (m^{-2}). Maximum plant population m^{-2} in sole rice was due to the fact that it had more row ratio and uniform plant population in compare to the rest of the treatments.

4.2.1.3 Crop growth rate (g m^{-2} day^{-1})

From the persual of the result it was evident from the data presented in Table 4.24 that crop growth rate at 30 DAS was found significant among the treatments for rice when intercropped with pigeonpea. And had no significant effect at later growth stage. From the data given in the table it was revealed that the highest value (25.69 and 28.64 g m^{-2} day^{-1}) was recorded in Sole rice T_{14} during 2021 and 2022 respectively and the value was found to be at par with pigeonpea + rice (1:3) and pigeonpea + rice (1:1) (25.22 and 25.16 g m^{-2} day^{-1} in 2021 and 28.14 and 28.11 in 2022 respectively). Similar trend was also found in the pooled data sole rice T_{14} which recorded the highest value 27.17 g m^{-2} day^{-1} and the value was at par with pigeonpea + rice (1:3) and pigeonpea + rice (1:1) (26.68 and 26.63 g m^{-2} day^{-1} respectively). The lowest value was found in pigeonpea + rice (1:3) during 2021, 2022 and pooled data with values 23.85, 27.36 and 25.60 g m^{-2} day^{-1} respectively. The result was in accordance with findings of Patra (2005) who reported that higher value of CGR was recorded in sole cropping, similar result was also found by Adeniyan *et al.* (2014).

4.2.1.4 Absolute growth rate (g day^{-1})

An inquisition of data presented in Table 4.24 revealed that the absolute growth rate varied significantly among the treatments under intercropping with pigeonpea at 30 DAS. It was evident from the data given in the table that sole

Table 4.22: Plant height (cm) of rice at different growth stages under intercropping system with pigeonpea

Treatments	Plant height 30 DAS			Plant height 60 DAS			Plant height 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	34.42	41.54	37.98	65.99	64.57	65.28	77.57	91.39	84.48
T_2 - Pigeonpea + Rice (1:2)	33.73	38.86	36.30	58.67	57.85	58.26	75.91	88.87	82.39
T_3 - Pigeonpea + Rice (1:3)	36.52	41.58	39.05	68.83	67.16	68.00	77.61	92.31	84.96
T_{14} - Sole Rice	40.55	46.17	43.36	71.78	71.55	71.66	81.76	92.80	87.28
SEm±	0.96	1.39	0.85	5.02	2.64	2.83	2.84	1.02	1.51
CD (P=0.05)	3.33	4.81	2.61	NS	NS	NS	NS	NS	NS

Table 4.23: Plant population (m^{-2}) of rice at different growth stages under intercropping system with pigeonpea

Treatments	Plant population 30 DAS			Plant population 60 DAS			Plant population 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	20.00	20.00	20.00	20.00	19.67	19.83	19.00	19.33	19.17
T_2 - Pigeonpea + Rice (1:2)	20.00	20.00	20.00	19.67	19.67	19.67	19.00	19.00	19.00
T_3 - Pigeonpea + Rice (1:3)	30.00	29.67	29.83	29.67	29.33	29.50	29.67	29.00	29.33
T_{14} - Sole Rice	49.67	49.33	49.50	49.00	48.67	48.83	48.67	48.67	48.67
SEm±	0.17	0.40	0.22	0.35	0.44	0.28	0.51	0.43	0.33
CD (P=0.05)	0.58	1.37	0.66	1.20	1.53	0.86	1.76	1.49	1.03

Table 4.24: Crop growth rate (g m^{-2} day^{-1}) and absolute growth rate (g day^{-1}) of rice at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	CGR (30-60 DAS)			CGR (60-90 DAS)			AGR (30-60 DAS)			AGR (60-90 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	25.16	28.11	26.63	28.74	29.16	28.95	0.503	0.562	0.533	0.530	0.583	0.557
T_2 - Pigeonpea + Rice (1:2)	23.85	27.36	25.60	28.57	28.83	28.70	0.477	0.547	0.512	0.538	0.577	0.557
T_3 - Pigeonpea + Rice (1:3)	25.22	28.14	26.68	29.10	29.55	29.33	0.504	0.563	0.534	0.538	0.591	0.564
T_{14} - Sole Rice	25.69	28.64	27.17	29.12	29.16	29.14	0.514	0.573	0.543	0.538	0.583	0.561
SEm±	0.32	0.23	0.20	0.58	0.64	0.43	0.006	0.005	0.004	0.006	0.013	0.007
CD (P=0.05)	1.09	0.80	0.60	NS	NS	NS	0.022	0.016	0.012	NS	NS	NS

Table 4.25: Relative growth rate (g g^{-1} day^{-1}) and net assimilation rate (g m^{-2} day^{-1}) of rice at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	RGR (30-60 DAS)			RGR (60-90 DAS)			NAR (30-60 DAS)			NAR (60-90 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	0.083	0.084	0.083	0.024	0.022	0.023	14.60	13.98	14.29	9.26	9.35	9.30
T_2 - Pigeonpea + Rice (1:2)	0.082	0.083	0.082	0.025	0.023	0.024	13.26	13.56	13.41	9.17	9.24	9.20
T_3 - Pigeonpea + Rice (1:3)	0.083	0.083	0.083	0.024	0.022	0.023	14.62	15.29	14.95	9.32	9.55	9.43
T_{14} - Sole Rice	0.082	0.083	0.083	0.024	0.022	0.023	14.97	16.02	15.49	9.63	9.82	9.73
SEm±	0.001	0.000	0.000	0.001	0.000	0.000	0.46	0.56	0.36	0.17	0.34	0.19
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

rice T_{14} recorded the maximum value of 0.514, 0.573 and 0.543 g day^{-1} in 2021, 2022 and pooled data respectively. The values were at par with pigeonpea + rice (1:3) T_3 and pigeonpea + rice (1:1) T_1 0.504 and 0.503 g day^{-1} in 2021, 0.563 and 0.562 g day^{-1} in 2022 and 0.534 and 0.533 g day^{-1} in pooled data respectively. The minimum value was recorded in pigeonpea + rice (1:2) in both the years and in case of pooled data as well (0.477, 0.547 and 0.512 g day^{-1} respectively).

4.2.1.5 Relative growth rate (g g^{-1} day^{-1})

A critical examination of the data presented in the Table 4.25, revealed that the relative growth rate of rice recorded at 30 - 60 and 60 - 90 DAS showed no significant effect during both the years (2021 and 2022) under intercropping with pigeonpea.

4.2.1.6 Net Assimilation Rate (g m^{-2} day^{-1})

Results depicted on Table 4.25 obtained from mean pooled data of 2021 and 2022 on net assimilation rate of rice showed no significant difference at 30-60 and 60-90 DAS under intercropping system with pigeonpea.

4.2.1.7 Leaf area index

Analysis of data presented on Table 4.26 showed that rice intercropped with pigeonpea had no significant influence on leaf area index during both the years (2021 and 2022) at all growth stages of plant.

4.2.2 Yield attributes

4.2.2.1 Plant stand at harvest (m^{-2})

Data on plant stand at harvest was presented at Table 4.27 revealed that under intercropping system with pigeonpea had significant influenced in between the treatments. Sole rice T_{14} recorded the maximum value of 48.67, 48.33 and 48.50 (m^{-2}) during 2021, 2022 and pooled data respectively, while pigeonpea intercropped with rice at 1:2 ratio (T_2) value 19, 19 and 19 (m^{-2})

recorded the minimum plant stand at harvest during the year 2021, 2022 and pooled data respectively. As the treatments had different row ratio the plant stand at harvest differed significantly.

4.2.2.2 Number of panicles m^{-2}

It is evident from the data presented at Table 4.27 the variation on number of panicles m^{-2} of rice was found to be significant due to intercropping system during both the experimental year (2021 and 2022) as different treatments had different row ratio. The highest number of panicle m^{-2} was observed in sole rice T_{14} (148, 158 and 153 respectively) in both the years of experimentation and in the pooled data and these values were highly superior than the rest of the treatments. The lowest value was observed in pigeonpea + rice (1:3) in 2021, 2022 and in pooled data as well (58, 59.33 and 58.67 respectively). Different row ratio in different treatments highly influenced the number of plant population which led to higher number of panicle m^{-2}. Lawrence and Gohain (2011); Shri *et al.* (2014) reported higher number of panicle m^{-2} in sole rice.

4.2.2.3 Length of panicle (cm)

The data pertaining to the length or panicle are presented in Table 4.27 Data in the table indicated that intercropping treatments had no significant impact on the panicle length of the rice.

4.2.2.4 Weight of panicle (g)

The influence of different intercropping system on weight of panicle of rice depicted on Table 4.27 did not differ significantly.

4.2.2.5 Number of grains panicle^{-1}

Data in Table 4.28 showed that intercropping system with pigeonpea did not bring any significant variation in number of grains per panicle of rice during both the study period as well as pooled analysis.

Table 4.26: Leaf area index of rice at different growth stages under intercropping system with pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	1.22	1.24	1.23	2.46	2.42	2.44	2.80	2.82	2.81
T_2 - Pigeonpea + Rice (1:2)	1.12	1.23	1.18	2.32	2.42	2.37	2.75	2.76	2.76
T_3 - Pigeonpea + Rice (1:3)	1.24	1.27	1.26	2.55	2.44	2.49	2.81	2.84	2.82
T_{14} - Sole Rice	1.33	1.32	1.33	2.62	2.50	2.56	2.94	2.91	2.92
SEm±	0.06	0.04	0.04	0.07	0.02	0.03	0.08	0.06	0.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.27: Yield attributes of rice under intercropping system with pigeonpea

Treatments	Plant stand at harvest			No. of panicle			Length of panicle			Weight of panicle		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	19.00	19.33	19.17	60.33	61.33	60.83	21.40	22.03	21.72	2.41	2.46	2.43
T_2 - Pigeonpea + Rice (1:2)	19.00	18.67	18.83	58.00	59.33	58.67	19.80	19.80	19.80	2.37	2.43	2.40
T_3 - Pigeonpea + Rice (1:3)	29.67	29.33	29.50	97.67	106.33	102.00	19.90	20.20	20.05	2.44	2.47	2.46
T_{14} - Sole Rice	48.67	48.33	48.50	148.00	158.00	153.00	20.70	21.80	21.25	2.45	2.54	2.49
SEm±	0.51	0.37	0.32	1.70	3.21	1.82	0.64	0.52	0.41	0.05	0.08	0.05
CD (P=0.05)	1.76	1.29	0.97	5.87	11.11	5.59	NS	NS	NS	NS	NS	NS

4.2.2.6 Filled grain (%)

In both the years of experimentation and also their pooled data presented in Table. 4.28 showed that the, filled grain percentage of rice did not differ significantly under intercropping system with pigeonpea.

4.2.2.7 Test weight (g)

The data on test weight of rice recorded in both years of experimentation are exhibited in Table 4.28. The test weight did not significantly vary due to intercropping system with pigeonpea.

4.2.3 Yield

4.2.3.1 Grain yield (kg ha^{-1})

Data pertaining to influence of different intercropping system with pigeonpea on grain yield of rice are presented in Table 4.28 and figure 4.3 revealed that intercropping treatments at row ratio had significant impact on the grain yield during both the experimental years. Sole rice T_{14} produced the highest grain yield (2743.34, 2836.73 and 2790.03kg ha^{-1} in 2021, 2022 and pooled data respectively) which was highly superior than the rest of the treatments. Among the intercropping system pigeonpea + rice (1:3) T_3 recorded the highest grain yield of 2375.48, 2527.50 and 2451.49 kg ha^{-1} during 2021, 2022 and pool respectively. The lowest grain yield was observed at treatment T_2 pigeonpea + rice (1:2) with value 2203.89, 2148.90 and 2176.39 kg ha^{-1} in the year 2021, 2022 and pooled data respectively. Sole cropping of rice recorded the highest grain yield among all the intercropping system. These results confirm with the findings of Mandal *et al.* (1997), who also obtained more yield of rice in sole cropping than the inclusion of intercrop. Mohan *et al.* (2023b) also reported that sole rice performed better with production of higher grain and straw yield.

4.2.3.2 Straw yield (kg ha^{-1})

Straw yield of rice crop on two consecutive years are presented in Table 4.29 and figure 4.3. The data presented in table showed that straw yield was significantly affected by intercropping system with pigeonpea. Sole rice T_{14} recorded higher value than the rest of the treatments during both the years and even in the pooled data (5399.11, 5188.93 and 5294.02 kg ha^{-1} in 2021, 2022 and pooled data respectively) which was statistically superior than the rest of the treatments. Among the intercropping system pigeonpea + rice (1:3) T_3 recorded the highest value 4693.25, 4688.06 and 4690.65 kg ha^{-1} during 2021, 2022 and pool respectively. Meanwhile the lowest straw yield was recorded in pigeonpea + rice (1:2) T_2 in both the years and similar trend was followed in the pooled data (4433.71, 4039.10 and 4236.41 kg ha^{-1} respectively). Ogutu *et al.* (2012) also reported that sole rice performed better with production of higher grain and straw yield.

4.2.3.3 Biological yield (kg ha^{-1})

The data on biological yield are presented in Table 4.29. The biological yield of rice significantly varied among treatments in both the years of study. The highest biological yield was recorded in sole rice T_{14} (8142.45, 8025.66 and 8084.06 kg ha^{-1}) in both the year of study and pooled data respectively. The lowest value was observed in pigeonpea + rice (1:2) T_2 in both the years and in the pooled data (6637.60, 6188.00 and 6412.80 kg ha^{-1} respectively). The higher value of seed yield and straw yield in sole rice T_{14} cumulatively enhanced the biological yield.

4.2.3.4 Harvest Index (%)

The result on harvest index of rice under intercropping system are presented in Table 4.29 and no significant response was observed during both the years of experimentation.

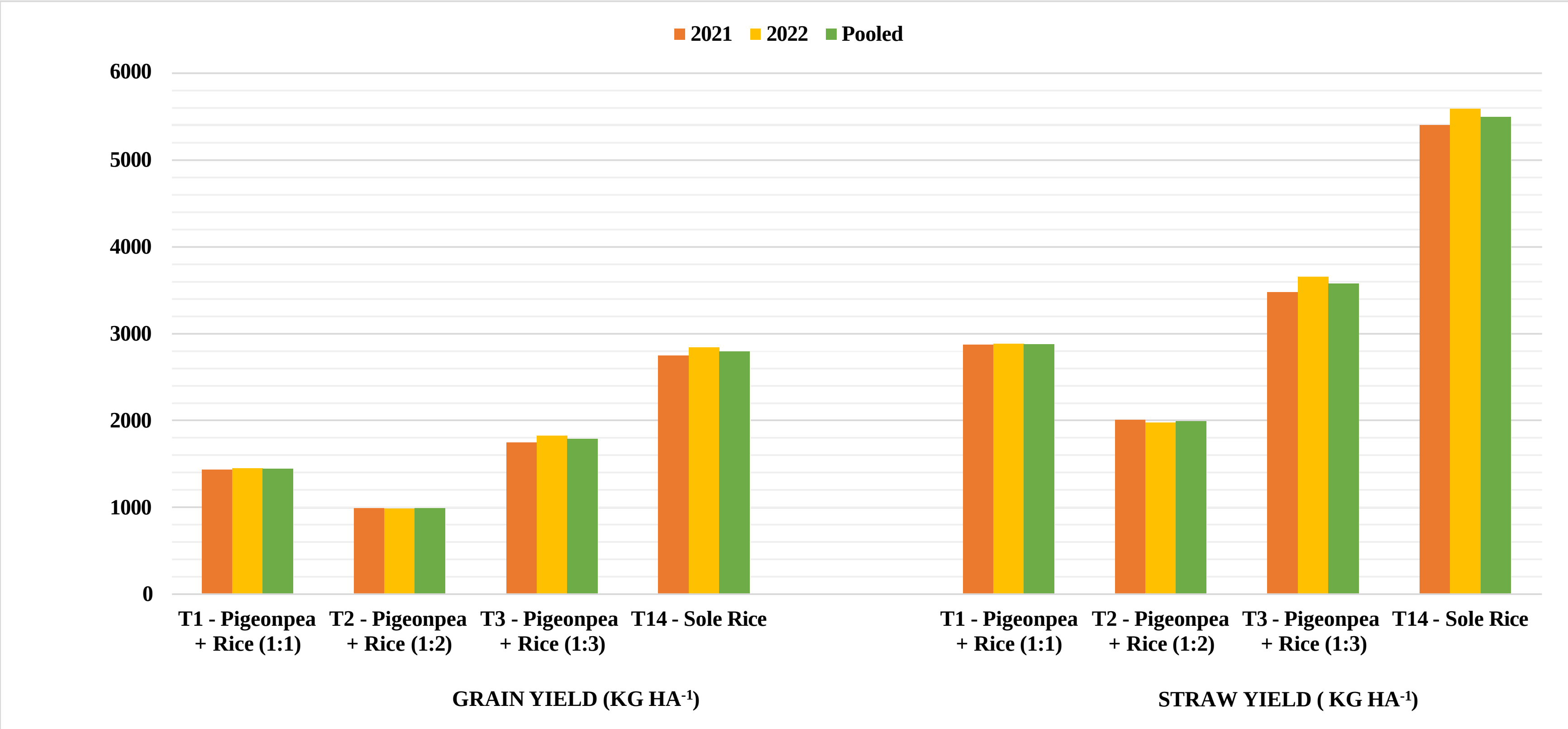

Fig. 4.3 Effect of different intercropping system with pigeonpea on grain and straw yield (kg ha^{-1}) of rice

4.2.4 Plant analysis

4.2.4.1 Nitrogen content grain (%)

A critical examination of the data presented in the Table 4.30, indicated that the nitrogen content in grain of rice showed no significant effect during the year 2021, 2022 and pool data under intercropping with pigeonpea.

4.2.4.2 Nitrogen content straw (%)

The data pertaining to nitrogen content in straw of rice presented in Table 4.30 revealed no significant difference under intercropping system with pigeonpea in 2021, 2022 and their pooled data.

4.2.4.3 Nitrogen uptake grain (kg ha^{-1})

It was apparent from Table 4.30 that the highest nitrogen uptake in grain was recorded in sole rice T_{14} (40.95, 46.99 and 43.97 kg ha^{-1} in 2021, 2022 and pooled data respectively) and was superiorly higher than the rest of the treatments. While T_2 pigeonpea + rice (1:2) recorded the lowest nitrogen uptake in grain (31.88, 34.81 and 33.35 kg ha^{-1} in 2021, 2022 and pooled data respectively). Significantly higher uptake of nutrients in grain and straw could be mainly due to their higher grain and straw yield which led to uptake of nutrients under sole rice.

4.2.4.4 Nitrogen uptake straw (kg ha^{-1})

The data on nitrogen uptake in straw of rice is presented in Table 4.30. The data revealed that it had significant effect when intercropped with pigeonpea. Sole rice T_{14} recorded the highest nitrogen uptake in straw (22.85, 22.66 and 22.76 kg ha^{-1} in 2021, 2022 and pooled data respectively) and was superiorly higher than the rest of the treatments. While T_2 Pigeonpea + Rice (1:2) recorded the lowest nitrogen uptake in straw (18.36, 17.14 and 17.75 kg ha^{-1} in 2021, 2022 and pool respectively). The higher uptake of nutrient in straw can be attributed to the fact that better vegetative growth promoted higher

Table 4.28: Yield attributes and yield of rice under intercropping system of pigeonpea

Treatments	No. of grains panicle^{-1}			Filled grain			Test weight			Grain yield		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	107.57	111.84	109.71	91.94	93.03	92.49	22.21	24.15	23.18	2363.33	2281.86	2322.60
T_2 - Pigeonpea + Rice (1:2)	105.42	107.47	106.45	91.73	92.45	92.09	21.40	23.93	22.67	2203.89	2148.90	2176.39
T_3 - Pigeonpea + Rice (1:3)	114.27	121.95	118.11	96.29	96.47	96.38	22.64	24.90	23.77	2375.48	2527.50	2451.49
T_{14} - Sole Rice	114.30	125.94	120.12	97.40	97.89	97.65	22.80	24.94	23.87	2743.34	2836.73	2790.03
SEm±	4.58	5.36	3.53	2.15	1.38	1.28	0.49	0.27	0.28	33.25	30.18	22.45
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	115.07	104.42	69.18

Table 4.29: Yield of rice under intercropping system of pigeonpea

Treatments	Straw yield			Biological yield			Harvest Index		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea + Rice (1:1)	4677.79	4244.12	4460.96	7041.12	6525.98	6783.55	33.57	34.97	34.27
T_2 - Pigeonpea + Rice (1:2)	4433.71	4039.10	4236.41	6637.60	6188.00	6412.80	33.20	34.73	33.97
T_3 - Pigeonpea + Rice (1:3)	4693.25	4688.06	4690.65	7068.73	7215.55	7142.14	33.60	35.02	34.31
T_{14} - Sole Rice	5399.11	5188.93	5294.02	8142.45	8025.66	8084.06	33.69	35.35	34.52
SEm±	67.66	51.59	42.54	98.72	71.68	61.00	0.15	0.29	0.16
CD (P=0.05)	234.14	178.53	131.09	341.63	248.04	187.96	NS	NS	NS

straw yield. The results were in close conformity with Mohan *et al.* (2023a) who reported that sole rice had higher nutrient uptake (N uptake 38.09 and 15.68 kg ha^{-1} in grain and straw respectively).

4.2.4.5 Phosphorus content grain (%)

Critical examination of the data presented in the Table 4.31, revealed that the phosphorous content in grain of rice showed no significant effect during both the years 2021 and 2022 under intercropping with pigeonpea.

4.2.4.6 Phosphorus content straw (%)

From the persual of the result presented in Table 4.31 it revealed P content in straw of rice had no significant difference under intercropping system with pigeonpea during the year 2021, 2022 and for the pooled data.

4.2.4.7 Phosphorus uptake grain (kg ha^{-1})

The results of phosphorus uptake have been presented in Table 4.31. The data revealed that phosphorus uptake in grain of rice differed significantly under intercropping system with pigeonpea. Maximum phosphorus uptake in grain (6.87, 8.60 and 7.73 kg ha^{-1} in 2021, 2022 and pooled data respectively) was observed in sole rice T_{14} and was superiorly higher than the rest of the treatments. While the minimum phosphorus uptake in grain (5.22, 6.23 and 5.72 kg ha^{-1} in 2021, 2022 and pool respectively) was observed in pigeonpea + rice (1:2) T_2. These results were in accordance with Raza *et al.* (2023) who recorded that wheat as sole crop in intercropping system produce higher phosphorus uptake in compare to other intercropping systems.

Table 4.30: Nitrogen content (%) and nitrogen uptake (kg ha^{-1}) of rice under intercropping system with pigeonpea

Treatments	N content grain			N content straw			N uptake grain			N uptake straw		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	1.46	1.64	1.55	0.417	0.425	0.421	34.51	37.35	35.93	19.52	18.04	18.78
T_2 - Pigeonpea +Rice (1:2)	1.45	1.62	1.53	0.414	0.424	0.419	31.88	34.81	33.35	18.36	17.14	17.75
T_3 - Pigeonpea +Rice (1:3)	1.47	1.65	1.56	0.420	0.427	0.423	34.93	41.71	38.32	19.72	20.00	19.86
T_{14} - Sole Rice	1.49	1.66	1.58	0.423	0.437	0.430	40.95	46.99	43.97	22.85	22.66	22.76
SEm±	0.01	0.01	0.01	0.004	0.003	0.002	0.53	0.49	0.36	0.27	0.33	0.21
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.83	1.71	1.11	0.94	1.13	0.65

Table 4.31: Phosphorus content (%) and phosphorus uptake (kg ha^{-1}) of rice under intercropping system with pigeonpea

Treatments	P content grain			P content straw			P uptake grain			P uptake straw		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.244	0.291	0.267	0.250	0.276	0.263	5.76	6.63	6.20	11.68	11.71	11.70
T_2 - Pigeonpea +Rice (1:2)	0.237	0.290	0.264	0.244	0.274	0.259	5.22	6.23	5.72	10.80	11.07	10.93
T_3 - Pigeonpea +Rice (1:3)	0.249	0.295	0.272	0.251	0.277	0.264	5.92	7.45	6.69	11.76	12.97	12.37
T_{14} - Sole Rice	0.250	0.303	0.277	0.256	0.279	0.268	6.87	8.60	7.73	13.82	14.50	14.16
SEm±	0.006	0.005	0.004	0.003	0.001	0.002	0.18	0.12	0.11	0.20	0.17	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.63	0.42	0.34	0.68	0.59	0.40

Table 4.32: Potassium content (%) and potassium uptake (kg ha^{-1}) of rice under intercropping system with pigeonpea

Treatments	K content grain			K content straw			K uptake grain			K uptake straw		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T1 - Pigeonpea +Rice (1:1)	0.519	0.533	0.526	1.70	1.71	1.70	12.26	12.17	12.21	79.36	72.44	75.90
T_2 - Pigeonpea +Rice (1:2)	0.518	0.532	0.525	1.69	1.70	1.69	11.42	11.43	11.43	74.78	68.53	71.66
T_3 - Pigeonpea +Rice (1:3)	0.520	0.538	0.529	1.71	1.72	1.71	12.35	13.59	12.97	80.08	80.46	80.27
T_{14} - Sole Rice	0.524	0.545	0.535	1.72	1.73	1.73	14.39	15.45	14.92	93.02	89.60	91.31
SEm±	0.002	0.004	0.002	0.01	0.01	0.01	0.20	0.16	0.13	0.89	0.86	0.62
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.70	0.54	0.39	3.08	2.99	1.91

4.2.4.8 Phosphorus uptake straw (kg ha^{-1})

The data presented in Table 4.32. revealed that the data on phosphorus uptake in straw of rice under intercropping system with pigeonpea was found to be significant. Sole rice T_{14} recorded the maximum phosphorus uptake in straw (13.82, 14.50 and 14.16 kg ha^{-1} in the year 2021, 2022 and pooled data respectively) and was found superiorly higher than the rest of the treatments. While pigeonpea + rice (1:2) T_2 recorded the minimum phosphorus uptake in straw (10.80, 11.07 and 10.93 kg ha^{-1} in the year 2021, 2022 and pooled data respectively). Similar results were also observed by Chongloi (2021) who reported that the soil nutrients like N, P_2O_5, K_2O, Zinc and iron uptake and balance was the highest in sole pea culture.

4.2.4.9 Potassium content grain (%)

Analysis of data presented on Table 4.32 showed that there was no significant difference on potassium content in grain of rice under intercropping system with pigeonpea during 2021, 2022 and for the pooled data.

4.2.4.10 Potassium content straw (%)

Data of potassium content in straw of rice presented in Table 4.32 did not show any difference under intercropping system with pigeonpea in 2021, 2022 and their pooled data.

4.2.4.11 Potassium uptake grain (kg ha^{-1})

Analysis of data presented in Table 4.32 showed that potassium uptake in grains of rice differed significantly due to the intercropping system under pigeonpea. The data revealed that the sole rice T_{14} recorded the highest potassium uptake in grain (14.39, 15.45 and 14.92 kg ha^{-1} in 2021, 2022 and pooled, respectively) and was superiorly higher than the rest of the treatments. The significantly lowest potassium uptake in grain (11.42, 11.43 and 11.43 kg ha^{-1} in 2021, 2022 and in pool, respectively) was recorded in pigeonpea + rice (1:2) T_2. Venkatesha (2008) also observed that sole rice had higher nutrient uptake when compared to other intercropping systems (128.1 kg K ha^{-1}).

4.2.4.12 Potassium uptake straw (kg ha^{-1})

Data on potassium uptake in straw depicted in Table 4.32 revealed that there was significant difference under intercropping system with pigeonpea. During both the years sole rice T_{14} recorded the maximum potassium uptake in straw (93.02, 89.60 and 91.31 kg ha^{-1} in 2021, 2022 and for pooled data respectively) and was superiorly higher than the rest of the treatments. Pooled data of both the years revealed that pigeonpea + rice (1:2) T_2 recorded the minimum potassium uptake in straw (74.78, 68.53 and 71.66 kg ha^{-1} in 2021, 2022 and pooled data respectively). Sole winter maize was found to have higher uptake of K as compared to maize and potato intercropping system Kour *et al.* (2014).

4.3 Sesame

4.3.1 Growth attributes

4.3.1.1 Plant height (cm)

Data pertaining to plant height of sesame are presented in Table 4.33. It was evident from the data that plant height of sesame failed to produce any significant effect under intercropping system with pigeonpea recorded at 30, 60 and 90 DAS in both the years as well as in pooled results.

4.3.1.2 Plant population (m^{-2})

A critical examination of data presented in Table 4.34 revealed that there was significant variation among the treatments in both the years. At 30 DAS, it was evident from the data that the highest plant population {30, 29.67 and 29.83 (m^{-2}) in 2021, 2022 and pooled data respectively} was found in sole sesame $T_{15,}$

which was statistically at par with the values {30, 29.67, and 29.83 (m^{-2}) in 2021, 2022 and pooled data respectively} of pigeonpea + sesame (1:3) T_6. The lowest plant population {19.67, 20 and 19.83 (m^{-2}) in both the years and pooled data respectively} was found in pigeonpea + sesame (1:2) T_5. Similarly at 60 and 90 DAS, highest plant population was found at sole sesame T_{15} {29.67, 29.33 and 29.50 (m^{-2}) at 60 DAS and 29.33 at 90 DAS in both the years (2021 and 2022) and pooled data respectively}. While the lowest plant population {19.33, 19.67 and 19.50 (m^{-2}) at 60 DAS and 90 DAS in 2021, 2022 and pooled data respectively} as that of 30 DAS was found in pigeonpea + sesame (1:2) T_5.

The sole sesame intercropping system recorded the highest plant population at all growth stages of the crop including at the harvest (plant stand at harvest) as shown in Table 4.38, and these values were statistically at par with intercropping system at 1:3 ratio. Which may be due to the fact that three rows of rice plants are taken into consideration when readings are taken per square meter. As the treatments had different row ratio the plant population or plant stand differed significantly in all the treatments. The results of present investigation are in close agreements with the findings of Tiwari (2022) in sesame for pigeonpea + sesame intercropping system who recorded higher plant population or plant stand for sole sesame.

4.3.1.3 Crop growth rate (g m^{-2} day^{-1})

Data on crop growth rate are presented in Table 4.35. Crop growth rate of sesame did not show any significant influence at 30-60 and 60-90 DAS when intercropped with pigeonpea during both the years as well as pooled data.

4.3.1.4 Absolute growth rate (g day^{-1})

The data on absolute growth rate were recorded in both the cropping period of the years which are presented in the given Table 4.35. The experiment found no significant effect of absolute growth rate of sesame at 30 - 60 and 60 - 90 DAS under intercropping with pigeonpea during both the years as well as pooled data.

4.3.1.5 Relative growth rate (g g^{-1} day^{-1})

The present study found no significant influence on relative growth rate of sesame in the cropping system with pigeonpea at 30-60 and 60-90 DAS during both the year of experimentation as shown in the Table 4.36.

4.3.1.6 Net Assimilation Rate (g m^{-2} day^{-1})

Analysis of data presented in Table 4.36 did not bring any significant variation in the net assimilation rate of sesame intercropped with pigeonpea at 30- 60 and 60-90 DAS in both the years.

4.3.1.7 Leaf area index

An inquisition of the data on leaf area index of sesame at 30, 60 and 90 DAS are exhibited in Table 4.37, the leaf area index data of sesame revealed that there was significant variation at 30 DAS and 60 DAS due to intercropping system with pigeonpea in both years of experimentation.

During 2021, the highest leaf area index (1.34 and 5.62 at 30 and 60 DAS respectively) was obtained in sole sesame T_{15} and it was at par with pigeonpea + sesame (1:3) T_6 (1.34) at 30 DAS. Significantly lowest value was recorded in pigeonpea + sesame (1:2) T_5 (1.19 and 4.43 at 30 and 60 DAS respectively).

In 2022, the highest leaf area index (1.36 and 5.63 at 30 and 60 DAS respectively) was obtained in sole sesame T_{15}, while the lowest leaf area index (1.22 and 4.61 at 30 and 60 DAS respectively) was recorded at pigeonpea + sesame (1:2) T_5. It was evident from pooled data of both the years that sole sesame T_{15} (1.35 and 5.62 at 30 and 60 DAS respectively) recorded the highest and the lowest leaf area index (1.21 and 4.52 at 30 and 60 DAS respectively) followed the similar trend as that of 2021 and 2022.

Leaf area index is a factor to determine the dry matter production of a crop and subsequently the yield. The results were in close proximity with

Table 4.33: Plant height (cm) of sesame at different growth stages under intercropping system with pigeonpea

Treatments	Plant height 30 DAS			Plant height 60 DAS			Plant height 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4- Pigeonpea + Sesame (1:1)	31.35	33.66	32.50	84.97	88.89	86.93	123.42	139.56	131.49
T_5-Pigeonpea + Sesame (1:2)	29.82	33.18	31.50	79.80	88.16	83.98	118.93	137.46	128.19
T_6- Pigeonpea + Sesame (1:3)	32.57	36.05	34.31	85.98	89.54	87.76	122.23	144.10	133.17
T_{15} - Sole Sesame	33.43	38.12	35.77	86.40	90.50	88.45	123.76	144.91	134.33
SEm±	0.75	1.05	0.64	1.43	1.69	1.11	2.02	2.52	1.61
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.34: Plant population (m^{-2}) of sesame at different growth stages under intercropping system with pigeonpea

Treatments	Plant population 30 DAS			Plant population 60 DAS			Plant population 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4- Pigeonpea + Sesame (1:1)	20.00	20.00	20.00	20.00	19.67	19.83	19.67	19.67	19.67
T_5-Pigeonpea + Sesame (1:2)	19.67	20.00	19.83	19.33	19.67	19.50	19.33	19.67	19.50
T_6- Pigeonpea + Sesame (1:3)	29.67	29.00	29.33	29.33	29.00	29.17	28.67	29.00	28.83
T_{15} - Sole Sesame	30.00	29.67	29.83	29.67	29.33	29.50	29.33	29.33	29.33
Sem±	0.19	0.47	0.25	0.32	0.52	0.30	0.51	0.64	0.41
CD (P=0.05)	0.67	1.63	0.78	1.10	1.79	0.94	1.76	2.21	1.26

Table 4.35: CGR (g m^{-2} day^{-1}) and AGR (g day^{-1}) of sesame at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	CGR (30-60 DAS)			CGR (60-90 DAS)			AGR (30-60 DAS)			AGR (60-90 DAS)		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_4- Pigeonpea + Sesame (1:1)	11.49	12.34	11.91	9.39	14.03	11.71	0.284	0.370	0.327	0.282	0.421	0.351
T5-Pigeonpea + Sesame (1:2)	11.37	11.94	11.66	8.09	13.99	11.04	0.276	0.358	0.317	0.243	0.420	0.331
T_6- Pigeonpea + Sesame (1:3)	11.74	12.37	12.06	9.43	14.35	11.89	0.285	0.371	0.328	0.283	0.431	0.357
T_{15} - Sole Sesame	12.08	12.62	12.35	10.32	14.90	12.61	0.321	0.379	0.350	0.310	0.447	0.378
SEm±	0.19	0.20	0.14	0.52	0.29	0.30	0.013	0.006	0.007	0.015	0.009	0.009
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.36: RGR (g g^{-1} day^{-1}) and NAR (g m^{-2} day^{-1}) of sesame at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	RGR (30-60 DAS)			RGR (60-90 DAS)			NAR (30-60 DAS)			NAR) (60-90 DAS)		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_4- Pigeonpea + Sesame (1:1)	0.065	0.058	0.062	0.018	0.022	0.020	1.73	1.81	1.77	1.34	1.37	1.36
T_5-Pigeonpea + Sesame (1:2)	0.066	0.063	0.065	0.016	0.023	0.019	1.66	1.75	1.71	1.32	1.36	1.34
T_6- Pigeonpea + Sesame (1:3)	0.065	0.058	0.061	0.017	0.022	0.020	1.74	1.83	1.79	1.35	1.38	1.36
T_{15} - Sole Sesame	0.062	0.058	0.060	0.018	0.023	0.020	1.80	1.85	1.83	1.36	1.39	1.38
SEm±	0.001	0.002	0.001	0.001	0.000	0.000	0.03	0.03	0.02	0.01	0.02	0.01
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Darshan *et al*. (2009) who reported that sole sesame had the highest value among the other intercropping system (pigeonpea + sesame).

4.3.2 Yield attributes

4.3.2.1 Plant stand at harvest (m^{-2})

Data pertaining to plant stand at harvest presented at Table 4.38 revealed that plant stand due to intercropping system with pigeonpea had significant influenced in between the treatments. During 2021, 2022 and pooled data of both the year, sole sesame T_{15} (29, 29.33 and 29.17 respectively) obtained the maximum value which as significantly at par with pigeonpea + sesame (1:3) T_6 (28.67 and 28.83 in 2022 and pooled data respectively) while pigeonpea intercropped with sesame at 1:2 T_2 (19.33, 19.33 and 19.33 in both the experimental years and pooled data respectively) recorded the minimum plant stand at harvest. As the treatments had different row ratio the plant stand of harvest differed significantly.

4.3.2.2 Number of capsule plant^{-1}

The capsule numbers of sesame plant^{-1} are presented in the Table 4.38. The data revealed that intercropping system with pigeonpea exerted significant influence on number of capsule plant^{-1} during both the years of experimentation. During both the years of experimentation, sole sesame T_{15} recorded the maximum number of capsule plant^{-1} (74.54 in 2021 and 77.27 in 2022 respectively). The values were significantly at par with pigeonpea + sesame T_6 (71.62 and 75.28 in 2021) and pigeonpea + sesame T_4 (71.27 and 75.22 in 2022). In pooled data the maximum number of capsule plant^{-1} was also recorded in sole sesame T_{15} (75.24). The minimum value was recorded in pigeonpea + sesame (1:2) T_5 (66.16, 66.76 and 68.46 in the year 2021, 2022 and pooled data respectively).

The higher value attributing to yield parameters are due to lack of inter space competition under sole cropping that would otherwise happen in intercropping system. Similar finding was reported by Tiwari (2022) in sesame crop.

4.3.2.3 Number of seeds capsule^{-1}

Data pertaining to number of seeds capsule^{-1} of sesame are depicted in Table 4.38. Sesame when intercropped with pigeonpea did not show any significant influence on the number of seeds per capsule in both the years of experimentation.

4.3.3.4 Weight of capsule plant^{-1} (g)

The perusal of data in the weight of capsule plant^{-1} is presented in Table 4.39. Sesame did not display any significant results for the weight of capsule plant^{-1} under intercropping system.

4.3.2.5 Test weight (g)

The data on test weight of sesame under intercropping system with pigeonpea have been presented in Table 4.39. Intercropping system with pigeonpea did not result in significant variation in test weight of sesame during two years of experimentation as well as pooled analysis.

4.3.3 Yield

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

Data pertaining to grain yield due to intercropping system with pigeonpea are presented in Table 4.39 and figure 4.4. It was revealed from the table that seed yield was significantly affected by the different intercropping treatments during both the years and pooled data. Among the intercropping system sole sesame T_{15} produced the highest yield (718.18, 765.56 and 741.87 kg ha^{-1} in 2021, 2022 and pooled data respectively) and was statistically at par with pigeonpea + sesame (1:3) T_6 (614.93 and 662.64 kg ha^{-1} in 2021 and 2022 respectively) in both the years of experimentation. Meanwhile, the lowest grain

Table 4.37: LAI of sesame at 30, 60 and 90 DAS under intercropping system with pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4- Pigeonpea + Sesame (1:1)	1.25	1.26	1.26	5.24	5.39	5.32	7.64	7.72	7.68
T_5-Pigeonpea + Sesame (1:2)	1.19	1.22	1.21	4.43	4.61	4.52	7.51	7.54	7.53
T_6- Pigeonpea + Sesame (1:3)	1.27	1.29	1.28	5.37	5.41	5.39	7.92	7.76	7.84
T_{15} - Sole Sesame	1.34	1.36	1.35	5.62	5.63	5.62	8.00	7.77	7.88
SEm±	0.02	0.02	0.01	0.05	0.18	0.09	0.34	0.22	0.20
CD (P=0.05)	0.08	0.06	0.04	0.16	0.61	0.28	NS	NS	NS

Table 4.38: Yield attributes of sesame under intercropping system with pigeonpea

Treatments	Plant stand at harvest			No. of capsule plant^{-1}			No. of seeds capsule^{-1}		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4- Pigeonpea + Sesame (1:1)	19.67	19.67	19.67	71.27	75.22	73.25	42.31	43.82	43.07
T_5-Pigeonpea + Sesame (1:2)	19.33	19.33	19.33	66.16	66.76	66.46	41.43	42.52	41.98
T_6- Pigeonpea + Sesame (1:3)	29.00	28.67	28.83	71.62	75.28	73.45	42.90	44.12	43.51
T_{15} - Sole Sesame	29.00	29.33	29.17	74.54	77.27	75.90	43.94	46.02	44.98
SEm±	0.57	0.51	0.38	1.09	1.40	0.89	2.02	0.88	1.10
CD (P=0.05)	1.97	1.76	1.18	3.78	4.83	2.73	NS	NS	NS

Table 4.39: Yield attributes and yield of sesame under intercropping system with pigeonpea

Treatments	Weight of capsule plant^{-1}			Test weight			Seed yield		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4- Pigeonpea + Sesame (1:1)	22.89	23.31	23.10	1.97	1.99	1.98	573.03	539.26	556.15
T_5- Pigeonpea + Sesame (1:2)	21.87	22.54	22.20	1.91	1.96	1.94	509.26	513.71	511.49
T_6- Pigeonpea + Sesame (1:3)	24.32	23.45	23.89	2.00	2.01	2.00	614.93	662.64	638.78
T_{15} - Sole Sesame	24.78	23.58	24.18	2.03	2.02	2.02	718.18	765.56	741.87
SEm±	1.22	1.40	0.93	0.06	0.05	0.04	30.43	30.10	21.40
CD (P=0.05)	NS	NS	NS	NS	NS	NS	105.31	104.17	65.95

Table 4.40: Yield of sesame under intercropping system with pigeonpea

Treatments	Stover yield			Biological yield			Harvest index		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4- Pigeonpea + Sesame (1:1)	1541.18	1414.51	1477.85	2114.21	1953.78	2033.99	27.10	27.60	27.35
T_5- Pigeonpea + Sesame (1:2)	1383.33	1376.66	1379.99	1892.59	1897.03	1894.81	26.87	27.06	26.97
T_6- Pigeonpea + Sesame (1:3)	1649.67	1729.67	1689.67	2264.59	2392.30	2328.45	27.13	27.70	27.42
T_{15} - Sole Sesame	1896.44	1980.77	1938.61	2614.62	2746.33	2680.48	27.46	27.92	27.69
SEm±	75.60	86.11	57.30	104.60	117.30	78.58	0.37	0.30	0.24
CD (P=0.05)	261.62	297.99	176.55	361.97	405.90	242.13	NS	NS	NS

yield was produced in pigeonpea + sesame (1:2) T_5 (509.26, 513.71 and 511.49 kg ha^{-1} respectively). The sole sesame recorded superior yield over rest of intercropping system. The lesser competition for resources might be probable reason for better vegetative growth of plant under sole cropping system that reflected into better attainment of yield of sesame. Similar finding was reported in sesame by Kumar and Kushwaha (2018) in pigeonpea intercropping system and Darshan *et al*. (2009) who reported that sole sesame had the highest value among the other intercropping system (pigeonpea + sesame).

4.3.3.2 Stover yield (kg ha^{-1})

Data related to stover yield due to intercropping system with pigeonpea are presented in Table 4.40 and figure 4.4. Sole sesame T_{15} recorded the highest value over rest of the treatments during both the years and even in pooled data (1896.44, 1980.77 and 1938.61 kg ha^{-1} in 2021, 2022 and pooled respectively), which was statistically at par with pigeonpea + sesame (1:3) T_6 (1649.67 and 1729.67 kg ha^{-1}) in 2021 and 2022 respectively. Lowest stover yield was recorded in piegeonpea + sesame (1:2) T_5 (1383.33, 1376.66 and 1379.99 kg ha^{-1} in 2021, 2022 and pooled respectively). These results were in close proximity with Kumar *et al.* (2018) who reported that sole sesame performed better with production of higher grain yield and straw yield compared to other intercrop system.

4.3.3.3 Biological yield (kg ha^{-1})

Data on biological yield due to intercropping system with pigeonpea are presented in Table 4.40. From the data it was revealed that sole sesame T_{15} recorded the highest value over rest of the treatments during both the years and even in pooled data (2614.62, 2746.33 and 2680.48 kg ha^{-1} in 2021, 2022 and pooled respectively), which was statistically at par with pigeonpea + sesame (1:3) T_6 (2264.59 and 2392.30 kg ha^{-1}) in 2021 and 2022 respectively. Higher seed yield and straw yield resulted in higher biological yield of sesame in sole sesame. Tiwari (2021) observed that among intercropping systems, sole cropping of mustard crop recorded maximum (6302.41, 6349.33 and 6325.87 kg ha^{-1}) biological yield, which was significantly superior over the rest of the treatments.

4.3.3.4 Harvest Index (%)

Results presented in Table 4.40 showed that harvest index of sesame when intercropped with pigeonpea did not set forth any significant difference during individual years (2021 and 2022) and pooled analysis.

4.3.4 Plant analysis

4.3.4.1 Nitrogen content seed (%)

Data of nitrogen content in seed of sesame presented in Table 4.41 revealed that nitrogen content in seed failed to produce any significant effect under intercropping system with pigeonpea during 2021, 2022 and in pooled data.

4.3.4.2 Nitrogen content stover (%)

Result of nitrogen content in stover of sesame recorded in both the years of experiment and pooled data represented in Table 4.41 found no significant difference under intercropping system with pigeonpea.

4.3.4.3 Nitrogen uptake seed (kg ha^{-1})

A critical examination of the data presented in the Table 4.41, found that nitrogen uptake in seed of sesame varied significantly among the treatments in both the experimental years. It was observed that the highest nitrogen uptake in seed (20.61, 22.45 and 21.53 kg ha^{-1} in the year 2021, 2022 and pool data respectively) was obtained in sole sesame T_{15} and was found to be at par with pigeonpea + sesame (1:3) T_6 (19.15 kg ha^{-1} in 2022). The lowest nitrogen uptake in seed of sesame (14.42, 14.59 and 14.50 kg ha^{-1} in 2021, 2022 and pool data respectively) was obtained in pigeonpea + sesame (1:2) T_5. Kotadiya *et al.* (2023) reported that the highest nitrogen uptake by seed (24.16 kg ha^{-1} in pool)

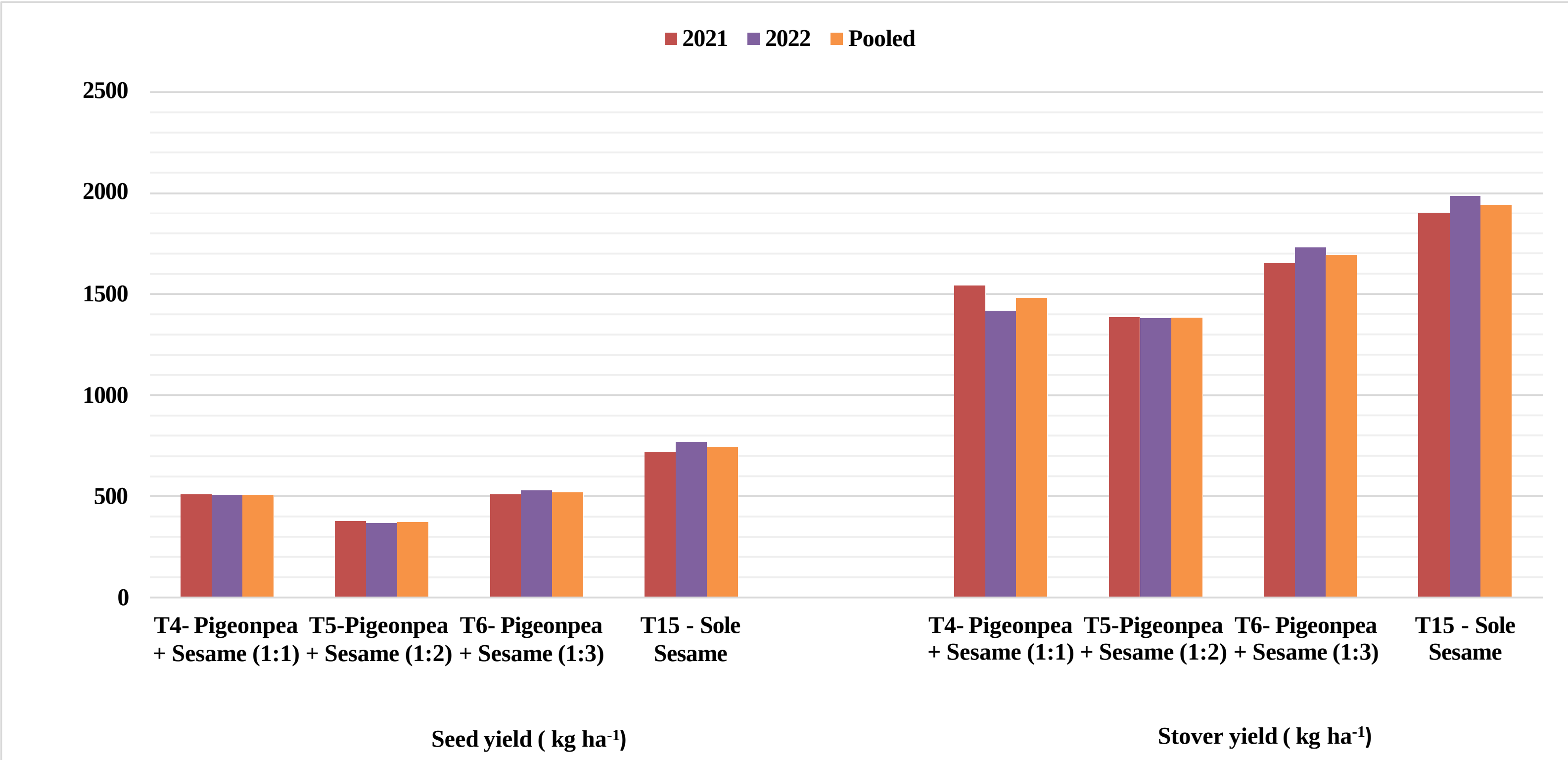

Fig. 4.4 Effect of different intercropping system with pigeonpea on seed and stover yield (kg ha^{-1}) of sesame

and stover (12.23 kg ha^{-1} in pool) was observed in sole sesame which might be due to the fact that proper utilization of resources is more efficient in sole sesame than that of the system wherein more competition existed due to intercrop.

4.3.4.4 Nitrogen uptake stover (kg ha^{-1})

An inquisition of data presented in Table 4.41 revealed that nitrogen uptake in stover of sesame had significant influence under intercropping system with pigeonpea. From the data given in table 4.41 it is evident that the sole sesame T_{15} recorded the maximum nitrogen uptake in stover (27.02, 29.88 and 28.45 kg ha^{-1} in the year 2021, 2022 and pool data respectively) and the value was at par with pigeonpea + sesame (1:3) T_6 with the value being 25.88 kg ha^{-1} in the year 2022. Meanwhile pigeonpea + sesame (1:2) T_5 recorded the minimum nitrogen uptake in stover (19.28, 20.37 and 19.82 kg ha^{-1} in 2021, 2022 and pool data respectively). Similar results were also reported by Prajapat *et al.* (2011) and Prajapat *et al.* (2012).

4.3.4.5 Phosphorus content seed (%)

Data regarding phosphorus content in seed of sesame presented in Table 4.42 showed no significant difference during 2021, 2022 and pooled data under intercropping with pigeonpea.

4.3.4.6 Phosphorus content stover (%)

A critical examination of the data presented in the Table 4.42, recorded that the phosphorus uptake in stover of sesame showed no significant effect during both the years of experimentation and their pooled data under intercropping with pigeonpea.

4.3.4.7 Phosphorus uptake seed (kg ha^{-1})

It is evident from result presented in Table 4.42 that phosphorus uptake in

Table 4.41: Nitrogen content (%) and nitrogen uptake (kg ha^{-1}) of sesame under intercropping system with pigeonpea

Treatments	N content seed			N content stover			N uptake seed			N uptake stover		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_4 - Pigeonpea + Sesame (1:1)	2.85	2.86	2.86	1.41	1.49	1.45	16.33	15.42	15.88	21.74	21.10	21.42
T_5 - Pigeonpea + Sesame (1:2)	2.83	2.84	2.84	1.39	1.48	1.44	14.42	14.59	14.50	19.28	20.37	19.82
T_6 - Pigeonpea + Sesame (1:3)	2.86	2.89	2.88	1.42	1.50	1.46	17.58	19.15	18.37	23.36	25.88	24.62
T_{15} – Sole Sesame	2.87	2.93	2.90	1.43	1.51	1.47	20.61	22.45	21.53	27.02	29.88	28.45
SEm±	0.01	0.03	0.01	0.01	0.01	0.01	0.84	0.96	0.64	0.88	1.43	0.84
CD (P=0.05)	NS	NS	NS	NS	NS	NS	2.90	3.33	1.97	3.05	4.94	2.59

Table 4.42: Phosphorus content (%) and phosphorus uptake (kg ha^{-1}) of sesame under intercropping system with pigeonpea

Treatments	P content seed			P content stover			P uptake seed			P uptake stover		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_4 - Pigeonpea + Sesame (1:1)	0.535	0.543	0.539	0.192	0.205	0.198	3.07	2.93	3.00	2.95	2.90	2.93
T_5 - Pigeonpea + Sesame (1:2)	0.529	0.536	0.533	0.190	0.199	0.195	2.69	2.76	2.73	2.63	2.75	2.69
T_6 - Pigeonpea + Sesame (1:3)	0.537	0.547	0.542	0.193	0.206	0.200	3.30	3.63	3.46	3.18	3.56	3.37
T_{15} – Sole Sesame	0.540	0.553	0.546	0.196	0.211	0.203	3.88	4.24	4.06	3.72	4.17	3.95
SEm±	0.002	0.004	0.002	0.001	0.003	0.002	0.16	0.18	0.12	0.15	0.21	0.13
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.56	0.64	0.38	0.53	0.72	0.40

Table 4.43: Potassium content (%) and potassium uptake (kg ha^{-1}) of sesame under intercropping system with pigeonpea

Treatments	K content seed			K content stover			K uptake seed			K uptake stover		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_4 - Pigeonpea + Sesame (1:1)	0.625	0.638	0.632	1.17	1.22	1.19	3.58	3.44	3.51	17.88	17.22	17.55
T_5 - Pigeonpea + Sesame (1:2)	0.623	0.637	0.630	1.16	1.21	1.18	3.17	3.27	3.22	16.13	16.61	16.37
T_6 - Pigeonpea + Sesame (1:3)	0.627	0.640	0.634	1.18	1.23	1.20	3.86	4.24	4.05	19.41	21.22	20.31
T_{15} – Sole Sesame	0.631	0.643	0.637	1.19	1.24	1.21	4.53	4.93	4.73	22.49	24.56	23.53
SEm±	0.002	0.001	0.001	0.01	0.01	0.00	0.19	0.20	0.14	0.88	1.09	0.70
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.66	0.69	0.42	3.03	3.76	2.15

seed of sesame showed significant effect under intercropping system with pigeonpea. The highest phosphorus uptake in seed (3.88, 4.24 and 4.06 kg ha^{-1} in 2021, 2022 and for pooled data respectively) was recorded in sole sesame T_{15} and the value was significantly at par with pigeonpea + sesame (1:3) T_6 during 2022 with the value of 3.63 kg ha^{-1}.

Where else the lowest phosphorus uptake in seed of sesame was recorded in pigeonpea + sesame (1:2) T_5 (2.69, 2.76 and 2.73kg ha^{-1} in 2021, 2022 and pool data, respectively). The findings are in close agreement with those obtained by Yadav *et al*. (2017) in sole sesame crop.

4.3.4.8 Phosphorus uptake stover (kg ha^{-1})

Analysis of data presented on Table 4.42 depicted that sesame had significant influence under intercropping system with pigeonpea and the sole sesame T_{15} recorded the highest phosphorous uptake in stover (3.72, 4.17 and 3.95 kg ha^{-1} in 2021, 2022 and pooled respectively) and the value was found to be at par with pigeonpea + sesame (1:3) T_6 (3.56 kg ha^{-1} in 2022). Pigeonpea + sesame (1:2) T_5 recorded the lowest phosphorous uptake in stover (2.63, 2.75 and 2.69 kg ha^{-1} in 2021, 2022 and pool data respectively). These findings are in accordance with the results reported by Shivran and Yadav (2016) in sesame.

4.3.4.9 Potassium content seed (%)

From the persual of the result it was evident from the data presented in Table 4.43, that the potassium content in seed of sesame showed no significant effect during the years 2021 and 2022 and pooled data under intercropping with pigeonpea.

4.3.4.10 Potassium content stover (%)

Results tabulated on Table 4.43 revealed that the potassium uptake in stover of sesame showed no significant effect during year 2021, 2022 and pooled data under intercropping with pigeonpea.

4.3.4.11 Potassium uptake seed (kg ha^{-1})

Data represented in Table 4.43 showed that potassium uptake in seed of sesame had a significant influence on the treatments. Sole sesame T_{15} recorded the maximum potassium uptake in seed (4.53, 4.93 and 4.73 kg ha^{-1} in 2021, 2022 and pooled data) and was superiorly higher than the rest of the treatments. Meanwhile, pigeonpea + sesame (1:2) T_5 recorded the minimum potassium uptake in seed (3.17, 3.27 and 3.22 kg ha^{-1} in 2021, 2022 and pool respectively). Kotadiya *et al.* (2023) observed that among the different intercropping system examined, significantly higher uptake of potassium seed and stover were recorded with treatment of sole sesame during both the years and pooled analysis.

4.3.4.12 Potassium uptake stover (kg ha^{-1})

Analysis of data presented in Table 4.43 portrayed that sesame had a significant influence under intercropping system with pigeonpea. The highest potassium uptake in stover (22.49, 24.56 and 23.53 kg ha^{-1} in 2021, 2022 and pooled respectively) was observed in sole sesame T_{15} and the value was found to be significantly at par with pigeonpea + sesame (1:3) T_6 (21.22 kg ha^{-1} in 2022). Pigeonpea + sesame (1:2) T_5 recorded the lowest potassium uptake in stover (16.13, 16.61 and 16.37 kg ha^{-1} in 2021, 2022 and pool data respectively). The results are in conformity with the findings of Pragatheeswaran *et al.* (2021) in sunflower in comparison with sunflower + greengram intercropping system.

4.4 Greengram

4.4.1 Growth attributes

4.4.1.1 Plant height (cm)

The data on plant height as affected by intercropping system with pigeonpea is presented in Table 4.44. The data revealed that plant height of greengram showed significant influence at 30 and 60 DAS. During 2021 maximum plant height (35.30 and 57.21 cm at 30 and 60 DAS respectively) was found in sole greengram T_{16} and it was significantly at par with pigeonpea +

greengram (1:3) T_9 (34.65 and 54.59 cm at 30 and 60 DAS respectively) and pigeonpea + greengram (1:1) T_7 (34.25 and 54.21 cm at 30 and 60 DAS respectively). While pigeonpea + greengram (1:2) T_8 was found to record the lowest plant height of 31.71 and 50.18 cm at 30 and 60 DAS respectively.

Similarly in 2022 sole greengram T_{16} recorded the maximum plant height (38.78 and 66.57 cm at 30 and 60 DAS respectively) and the value was at par with pigeonpea + greengram (1:3) T_9 (65.06 cm at 60 DAS) and pigeonpea + greengram (1:1) T_7 (64.73 cm at 60 DAS). Lowest value of plant height was found at pigeonpea + greengram (1:2) T_8 (35.74 and 60.43 cm at 30 and 60 DAS respectively). Pooled data of both the years also revealed that sole greengram T_{16} recorded the maximum plant height (37.04 and 61.89 cm at 30 and 60 DAS respectively) and the value was at par with pigeonpea + greengram (1:3) T_9 (59.83 cm at 60 DAS) and pigeonpea + greengram (1:1) T_7 (59.47 cm at 60 DAS). The lowest value of plant height for pooled data was found in pigeonpea + greengram (1:2) T_8 (33.73 and 55.31 cm at 30 and 60 DAS respectively). Similar results were also reported by Barthakur *et al.* (1985); Joy *et al.* (1987) and Lawrence and Gohain (2011) at plant height 60 DAS.

4.4.1.2 Plant population (m^{-2})

Results on data of plant population m^{-2} presented at Table 4.45 revealed intercropping system with pigeonpea had significant influenced on the treatments. In the first experimental year 2021, sole greengram T_{16} (30, 29.67 and 29.67 at 30, 60 and 90 DAS) recorded the highest value, while pigeonpea + greengram (1:3) T_9 (29.33, 29.33 and 29.33 at 30, 60 and 90 DAS respectively) was significantly at par with the highest value. Pigeonpea + greengram (1:2) T_8 recorded the minimum plant population m^{-2} with the value of 19.67, 19.33 and 19 at 30, 60 and 90 DAS respectively). Similarly in the second year of experiment 2022, sole greengram T_{16} (30, 30 and 29.33 at 30, 60 and 90 DAS respectively) recorded the highest plant population m^{-2}, and it was at par with pigeonpea + greengram (1:3) T_9 (29.67, 29.67 and 29 at 30, 60 and 90 DAS respectively). The minimum value of plant population m^{-2} at 2022 was recorded with pigeonpea + greengram (1:2) T_8 (19.33, 18.67 and 19 at 30, 60 and 90 DAS respectively). Pooled data also recorded sole greengram T_{16} to have the highest plant population m^{-2} (30, 29.83 and 29.50 at 30, 60 and 90 respectively) and the data were at par with pigeonpea + greengram (1:3) T_9 (29.50, 29.50 and 29. 17 at 30, 60 and 90 DAS respectively). While minimum plant population m^{-2} was recorded in pigeonpea + greengram (1:2) T_8 (19.50, 19.17 and 18.83 at 30, 60 and 90 DAS respectively). A critical study of the data summarized in table made it clear that plant population at all growth stages of crop was superior in sole greengram as compare to intercropping as the treatments had different row ratio which contributed to having different plant population. These results were in agreement with Kumar (2009) in mustard intercropping system and Bagri (2017) in greengram.

4.4.1.3 Crop growth rate (g m^{-2} day^{-1})

The data on effect of intercropping system with pigeonpea on crop growth rate were presented in the Table 4.46. At 30 - 60 DAS greengram showed significant difference in the crop growth rate during both the years of study. Sole greengram T_{16} recorded the highest value (4.30, 4.00 and 4.15 g m^{-2} day^{-1} during 2021, 2022 and pool data) and they were statistically at par with pigeonpea + greengram (1:3) T_9 (4.27 and 4.10 g m^{-2} day^{-1} in 2021 and pooled data respectively) and pigeonpea + greengram (1:1) T_7 (4.26 g m^{-2} day^{-1} in 2021). The lowest value for crop growth rate was recorded in pigeonpea + greengram (1:2) T_8 being 4.04, 3.91 and 3.97 g m^{-2} day^{-1} in 2021, 2022 and the pooled data. There was no significant difference due to intercropping system at 60 - 90 DAS in both the years and pooled data.

Nambiar *et al.* (1983) and Ghosh (2004) reported that intercrops like maize, sorghum and pearl millet limited the light from reaching the plant canopy of groundnut thereby reducing photosynthesis, which further lowered the CGR.

4.4.1.4 Absolute growth rate (g day^{-1})

It is apparent from the data in Table 4.46 that absolute growth rate in greengram exhibited significant difference among the intercropping system with pigeonpea at 30 - 60 DAS during the experimentation period. Significantly highest absolute growth rate was obtained in sole sesame T_{16} (0.129, 0.120 and 0.124 g day^{-1} during the year 2021, 2022 and their mean data respectively). Pigeon pea + greengram (1:3) T_9 and pigeonpea + greengram (1:1) T_7 were statistically at par with the highest value (0.128 and 0.128 g day^{-1} during 2021 and 0.123 and 0.122 g day^{-1} during pooled data respectively). The lowest AGR value was observed in pigeonpea + greengram (1:2) T_8 (0.121, 0.117 and 0.119 g day^{-1} in 2021, 2022 and pooled data respectively).

4.4.1.5 Relative growth rate (g g^{-1} day^{-1})

The data pertaining to relative growth rate as affected by intercropping system with pigeonpea is presented in Table 4.47. The data revealed no such significant influence on relative growth yield of greengram at 30 - 60 and 60 - 90 DAS when intercropped with pigeonpea.

4.4.1.6 Net Assimilation Rate (g m^{-2} day^{-1})

The perusal of data pertaining to net assimilation rate of greengram under intercropping system with pigeonpea has been depicted in Table 4.47. Net assimilation rate did not show any such significant dissimilarity at 30-60 and 60-90 DAS during both years of the experiment.

4.4.1.7 Leaf Area Index

The data on leaf area index of greengram have been presented in Table 4.48. Greengram when intercropped with pigeonpea did not exhibit any significant variability in the leaf area index at 30, 60 and 90 DAS during both the years of study.

4.4.2 Yield attributes

4.4.2.1 Plant stand at harvest (m^{-2})

The critical analysis of the data revealed that plant stand at harvest presented at Table 4.49. and had a significant influenced in between the treatments due to intercropping system with pigeonpea. Sole greengram T_{16} {29.67, 29.33 and 29.17 (m^{-2}) in 2021, 2022 and pool respectively} resulted in maximum value which was significantly at par with pigeonpea + greengram (1:3) T_9 {29.33, 28.67 and 29 (m^{-2}) in 2021, 2022 and pooled data respectively}. Pigeonpea intercropped with greengram (1:2) T_8 {19, 18.67 and 18.83 (m^{-2}) in both the experimental years and pooled data respectively} recorded the minimum plant stand at harvest. As the treatments had different row ratio the plant stand of harvest differed significantly.

4.4.2.2 Number of pods plant^{-1}

The data on number of pods plant^{-1} of greengram as influenced by intercropping system with pigeonpea have been presented in Table 4.49. Variation on number of pods plant^{-1} showed significant difference during the period of experimentation. The highest number of pods plant^{-1} was recorded at sole greengram T_{16} (81.76, 88.58 and 85.17 in 2021, 2022 and their pool data respectively) and these data were at par with treatment pigeonpea + greengram (1:3) T_9 (75.69, 86.64 and 81.17 in 2021, 2022 and the pooled data respectively) and pigeonpea + greengram (1:1) T_7 (74.50, 84.75 and 79.63 in 2021, 20221 and pooled data respectively). The lowest number of pods plant^{-1} was revealed in pigeonpea + greengram (1:2) T_8 recording 67.76, 73.42 and 70.59 in the year 2021, 2022 and pooled data respectively. Bagri (2017) stated that higher number of pods plant^{1} was obtained in sole greengram in compare to intercropping system and mixed cropping system.

Table 4.44: Plant height (cm) of greengram at different growth stages under intercropping system with pigeonpea

Treatments	Plant height 30 DAS			Plant height 60 DAS			Plant height 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	34.24	36.20	35.22	54.21	64.73	59.47	61.91	69.64	65.78
T_8 -Pigeonpea + Greengram (1:2)	31.71	35.74	33.73	50.18	60.43	55.31	57.50	69.50	63.50
T_9 - Pigeonpea + Greengram (1:3)	34.65	36.32	35.48	54.59	65.06	59.83	62.62	71.37	67.00
T_{16} - Sole Greengram	35.30	38.78	37.04	57.21	66.57	61.89	63.64	74.26	68.95
SEm±	0.63	0.52	0.41	1.32	0.97	0.82	1.35	1.31	0.94
CD (P=0.05)	2.19	1.79	1.26	4.56	3.35	2.52	NS	NS	NS

Table 4.45: Plant population (m^{-2}) of greengram at different growth stages under intercropping system with pigeonpea

Treatments	Plant population 30 DAS			Plant population 60 DAS			Plant population 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	20.00	20.00	20.00	19.67	19.33	19.50	19.33	19.00	19.17
T_8 -Pigeonpea + Greengram (1:2)	19.67	19.33	19.50	19.33	19.00	19.17	19.00	18.67	18.83
T_9 - Pigeonpea + Greengram (1:3)	29.33	29.67	29.50	29.33	29.67	29.50	29.33	29.00	29.17
T_{16} - Sole Greengram	30.00	30.00	30.00	29.67	30.00	29.83	29.67	29.33	29.50
SEm±	0.32	0.22	0.19	0.48	0.40	0.31	0.40	0.32	0.25
CD (P=0.05)	1.10	0.74	0.59	1.66	1.37	0.96	1.37	1.10	0.78

Table 4.46: CGR (g m^{-2} day^{-1}) and AGR (g day^{-1}) of greengram at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	CGR (30-60 DAS)			CGR (60-90 DAS)			AGR (30-60 DAS)			AGR (60-90 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	4.26	3.89	4.07	4.69	6.16	5.42	0.128	0.117	0.122	0.141	0.185	0.163
T_8 -Pigeonpea + Greengram (1:2)	4.04	3.91	3.97	4.47	5.83	5.15	0.121	0.117	0.119	0.134	0.175	0.155
T_9 - Pigeonpea + Greengram (1:3)	4.27	3.92	4.10	4.72	6.17	5.45	0.128	0.118	0.123	0.142	0.185	0.163
T_{16} - Sole Greengram	4.30	4.00	4.15	4.74	6.25	5.50	0.129	0.120	0.124	0.142	0.187	0.165
SEm±	0.04	0.01	0.02	0.13	0.23	0.13	0.001	0.000	0.001	0.004	0.007	0.004
CD (P=0.05)	0.14	0.04	0.07	NS	NS	NS	0.004	0.001	0.002	NS	NS	NS

Table: 4.47 RGR (g g^{-1} day^{-1}) and NAR (g m^{-2} day^{-1}) of greengram at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	RGR (30-60 DAS)			RGR (60-90 DAS)			NAR (30-60 DAS)			NAR (60-90 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	0.031	0.022	0.027	0.017	0.019	0.018	0.495	0.506	0.501	0.364	0.375	0.370
T_8 -Pigeonpea + Greengram (1:2)	0.031	0.022	0.027	0.017	0.018	0.018	0.485	0.498	0.492	0.353	0.341	0.347
T_9 - Pigeonpea + Greengram (1:3)	0.031	0.022	0.026	0.017	0.019	0.018	0.529	0.535	0.532	0.372	0.386	0.379
T_{16} - Sole Greengram	0.030	0.022	0.026	0.017	0.019	0.018	0.578	0.582	0.580	0.420	0.439	0.429
SEm±	0.001	0.000	0.000	0.000	0.001	0.000	0.024	0.031	0.020	0.024	0.021	0.016
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.48: LAI of greengram at 30, 60 and 90 DAS under intercropping system with pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	1.28	1.34	1.31	1.46	1.48	1.47	1.27	1.29	1.28
T_8 -Pigeonpea + Greengram (1:2)	1.27	1.31	1.29	1.43	1.44	1.43	1.26	1.28	1.27
T_9 - Pigeonpea + Greengram (1:3)	1.29	1.35	1.32	1.47	1.49	1.48	1.35	1.32	1.34
T_{16} - Sole Greengram	1.30	1.37	1.34	1.51	1.52	1.51	1.36	1.38	1.37
SEm±	0.01	0.02	0.01	0.02	0.02	0.01	0.03	0.03	0.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.49: Yield attributes of greengram under intercropping system with pigeonpea

Treatments	Plant stand at harvest			No. of pods plant^{-1}			No. of seeds pod^{-1}		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Greengram (1:1)	19.33	19.00	19.17	74.50	84.75	79.63	12.87	12.83	12.85
T_2 - Pigeonpea +Greengram (1:2)	19.00	18.67	18.83	67.76	73.42	70.59	12.64	12.46	12.55
T_3 - Pigeonpea +Greengram (1:3)	29.33	28.67	29.00	75.69	86.64	81.17	13.31	13.39	13.35
T_4 - Sole Greengram	29.67	29.00	29.33	81.76	88.58	85.17	13.34	13.44	13.39
SEm±	0.40	0.25	0.24	2.32	2.79	1.81	0.57	0.40	0.35
CD (P=0.05)	1.37	0.88	0.73	8.01	9.65	5.58	NS	NS	NS

Table 4.50 Yield attributes and yield of greengram under intercropping system with pigeonpea

Treatments	Weight of pod plant^{-1}			Test weight			Seed yield		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	30.69	37.54	34.12	38.66	34.31	36.49	566.52	540.82	553.67
T_8 -Pigeonpea + Greengram (1:2)	25.88	36.73	31.31	38.36	33.14	35.75	511.07	521.15	516.11
T_9 - Pigeonpea + Greengram (1:3)	35.46	39.54	37.50	38.89	35.52	37.21	579.71	598.94	589.33
T_{16} - Sole Greengram	35.72	40.33	38.03	39.10	35.66	37.38	671.85	695.66	683.76
SEm±	2.95	4.91	2.86	0.53	0.60	0.40	26.95	30.03	20.18
CD (P=0.05)	NS	NS	NS	NS	NS	NS	93.27	103.92	62.17

Table 4.51 Yield of greengram under intercropping system with pigeonpea

Treatments	Stover yield			Biological yield			Harvest Index		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + Greengram (1:1)	1708.85	1459.51	1584.18	2288.57	2000.33	2144.45	25.05	27.04	26.04
T_8 -Pigeonpea + Greengram (1:2)	1556.34	1449.65	1502.99	2067.41	1970.80	2019.10	24.73	26.40	25.57
T_9 - Pigeonpea + Greengram (1:3)	1719.57	1612.19	1665.88	2292.76	2211.12	2251.94	25.29	27.07	26.18
T_{16} - Sole Greengram	1951.54	1864.87	1908.21	2623.39	2560.54	2591.97	25.56	27.21	26.39
SEm±	56.42	79.49	48.74	81.84	107.78	67.67	0.41	0.39	0.28
CD (P=0.05)	195.25	275.09	150.19	283.20	372.98	208.50	NS	NS	NS

4.4.2.3 No. of seeds pod^{-1}

The perusal data of the number of seeds pod^{-1} as influenced by intercropping system with pigeonpea have been depicted in Table 4.49. There was no significant variation in the number of seeds per pod of greengram during both the years of study.

4.4.2.4 Weight of pod plant^{-1} (g)

Data pertaining to weight of pod per plant of greengram have been presented in Table 4.50. The data displayed no significant difference in the weight of pod per plant under intercropping system with pigeonpea.

4.4.2.5 Test weight (g)

Data depicted in Table 4.50 showed that test weight of greengram did not bring any significant variation under intercropping system with pigeonpea during individual year of study and on pooled basis.

4.4.3 Yield

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

Adaption of different intercropping system with pigeonpea practices markedly influence the seed yield of greengram in both the years, the data is presented on Table 4.50 and figure 4.5. Significantly superior crop yield was recorded in sole greengram T_{15} (671.85, 695.66 and 683.76 kg ha^{-1} during 2021, 2022 and pooled data respectively. Among the intercropping system pigeonpea + greengram (1:3) T_9 (579.71 and 598.94 kg ha^{-1} in the year 2021 and 2022 respectively) recorded the highest seed yield. While the minimum value was recorded in pigeonpea + greengram (1:2) T_8 (511.07, 521.15 and 516.11 kg ha^{-1} in both the years of experiment 2021, 2022 and their pooled data respectively. The yield of the intercrops has reduced considerably with intercropping of pigeonpea.

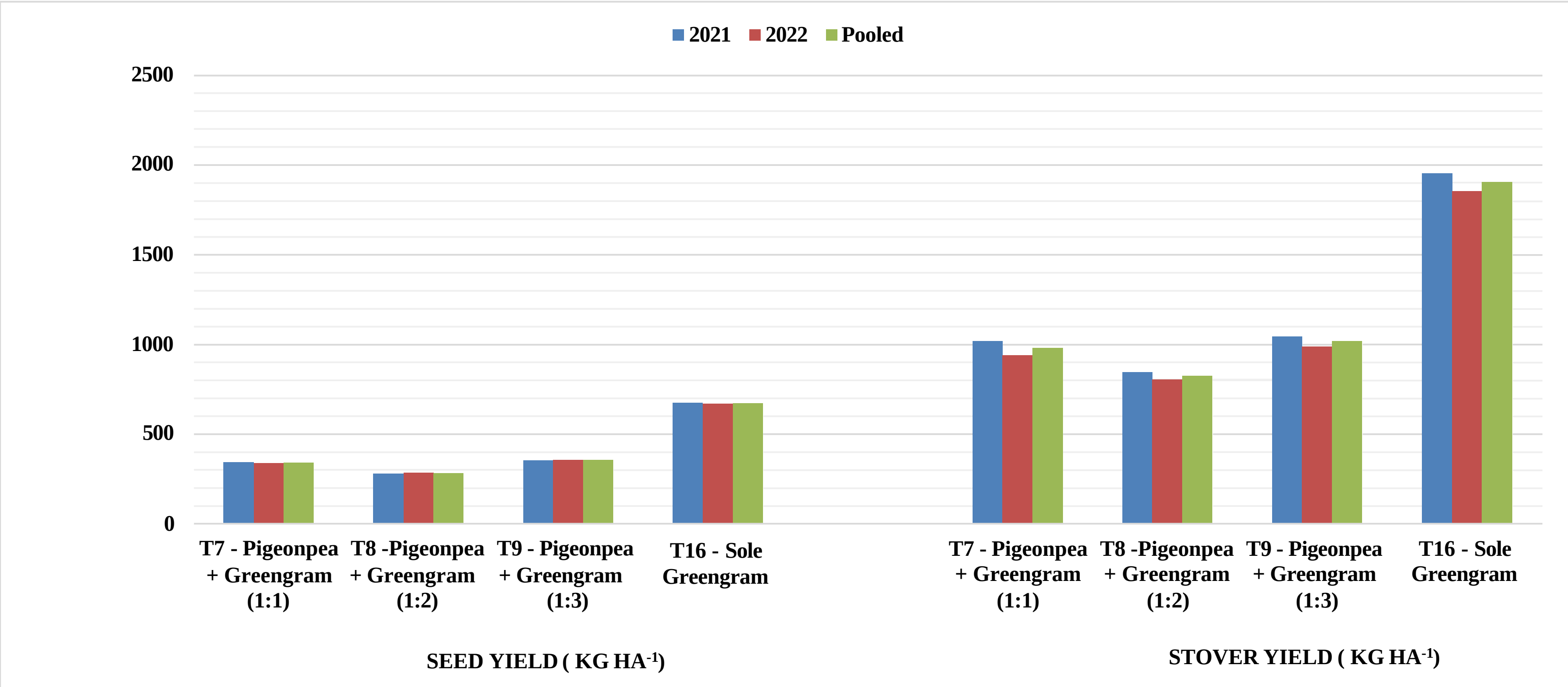

Fig. 4.5 Effect of different intercropping system with pigeonpea on seed and stover yield (kg ha^{-1}) of greengram

Deshmukh *et al.* (2020) reported that sole greengram recorded more yield in comparison with greengram grown as intercrop with pigeonpea. Syafruddin and Suwardi (2020) also reported that the grain yield of mungbean in intercropping was lower than monoculture. Intercropping of mungbean in maize gave mungbean grain yield 0.54 to 1.15 t ha^{-1}, while in monoculture 2.30 t ha^{-1}. Similar results of higher yield were observed in sole greengram by Babu and Padmalatha (2021) and Kaparwan *et al.* (2021) in chickpea crop.

4.4.3.2 Stover yield (kg ha^{-1})

Data representing stover yield due to intercropping system with pigeonpeaare presented in Table 4.51 and figure 4.5 was found to have significant effect on the stover yield of greengram. Maximum stover yield was obtained in sole greengram T_{16} over rest of the treatments during both the years and even in pooled data (1951.54, 1864.87 and 1908.21 kg ha^{-1} in 2021, 2022 and pooled respectively), which was statistically at par with pigeonpea + greengram (1:3) T_9 (1612.19 kg ha^{-1}) in 2022. Lowest stover yield was recorded in pigeonpea + greengram (1:2) T_8 (1556.34, 1449.65 and1502.99 kg ha^{-1} respectively) in 2021, 2022 and pooled. Babu and Padmalatha (2021) conducted a field experiment and concluded that greengram recorded higher yields in sole greengram than pigeonpea + greengram (1:5) system which were in similar line of results observed.

4.4.3.3 Biological yield (kg ha^{-1})

Data presented in Table 4.51 on biological yield due to intercropping system with pigeonpea revealed that sole greengram T_{16} recorded the highest value among the treatments (2623.39, 2560.54 and 2591.97 kg ha^{-1} in 2021, 2022 and pooled respectively) during all the experiment years and its mean data, and it was statistically at par with pigeonpea + greengram (1:3) T_9 with value 2211.12 kg ha^{-1} in 2022. The lowest value was recorded in pigeonpea + greengram (1:2) T_8 (2067.41, 1970.80 and 2019.10 kg ha^{-1} during 2021, 2022 and pool respectively). The higher value of seed yield and stover yield in sole greengram cumulatively enhanced the biological yield. The finding was supported by the result of the previous studies given by Deshmukh *et al.* (2020) and in their experiments on intercropping.

4.4.3.4 Harvest Index (%)

It is apparent from the data in Table 4.51 that greengram when intercropped with pigeonpea did not produce any significant variations in the harvest index during the study period.

4.4.4 Plant analysis

4.4.4.1 Nitrogen content seed (%)

The data pertaining to nitrogen content in seed of greengram presented in Table 4.52 revealed no significant difference under intercropping system with pigeonpea during 2021, 2022 and for the pooled data.

4.4.4.2 Nitrogen content stover (%)

A critical examination of the data is presented in the Table 4.52, it was recorded that the nitrogen content in stover of greengram showed no significant effect during both the years (2021 and 2022) under intercropping with pigeonpea.

4.4.4.3 Nitrogen uptake seed (kg ha^{-1})

The data on nitrogen uptake in seed of greengram is presented in Table 4.52, the data indicated that it was significantly influenced when intercropped with pigeonpea. Sole greengram T_{16} recorded the highest nitrogen uptake in seed (24.03, 25.48 and 24.75 kg ha^{-1}in 2021, 2022 and pooled data respectively) and was found to be at par with pigeonpea + greengram (1:3) T_9 21.86 kg ha^{-1} in the year 2022. Pigeonpea + greengram (1:2) T_8 recorded the lowest nitrogen uptake in seed (18.08, 18.79 and 18.43 kg ha^{-1} in 2021, 2022 and pool respectively).

Table 4.52: Nitrogen content (%) and nitrogen uptake (kg ha^{-1}) of greengram under intercropping system with pigeonpea

Treatments	N content seed			N content stover			N uptake seed			N uptake stover		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + GG (1:1)	3.55	3.63	3.59	0.488	0.491	0.490	20.36	19.62	19.99	8.34	7.17	7.76
T_8 - Pigeonpea + GG (1:2)	3.54	3.61	3.57	0.487	0.490	0.489	18.08	18.79	18.43	7.58	7.10	7.34
T_9 - Pigeonpea + GG (1:3)	3.57	3.65	3.61	0.489	0.492	0.490	20.67	21.86	21.27	8.41	7.93	8.17
T_{16} – Sole Greengram	3.58	3.66	3.62	0.490	0.494	0.492	24.03	25.48	24.75	9.56	9.21	9.38
SEm±	0.01	0.01	0.01	0.000	0.001	0.000	0.93	1.07	0.71	0.28	0.39	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS	3.23	3.70	2.19	0.95	1.35	0.74

Table 4.53: Phosphorus content (%) and phosphorus uptake (kg ha^{-1}) of greengram under intercropping system with pigeonpea

Treatments	P content seed			P content stover			P uptake seed			P uptake stover		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_7 - Pigeonpea + GG (1:1)	0.553	0.575	0.564	0.153	0.174	0.164	3.17	3.11	3.14	2.62	2.54	2.58
T_8 - Pigeonpea + GG (1:2)	0.552	0.571	0.562	0.147	0.171	0.159	2.82	2.98	2.90	2.28	2.48	2.38
T_9 - Pigeonpea + GG (1:3)	0.554	0.578	0.566	0.154	0.176	0.165	3.21	3.46	3.34	2.64	2.84	2.74
T_{16} – Sole Greengram	0.558	0.582	0.570	0.159	0.180	0.169	3.75	4.05	3.90	3.10	3.35	3.23
SEm±	0.001	0.002	0.001	0.002	0.002	0.001	0.14	0.17	0.11	0.09	0.15	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.49	0.59	0.34	0.30	0.51	0.26

Table 4.54: Potassium content (%) and potassium uptake (kg ha^{-1}) of greengram under intercropping system with pigeonpea

Treatments	K content seed			K content stover			K uptake seed			K uptake stover		
	2021	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**	**2021**	**2022**	**Pooled**
T_7 - Pigeonpea + GG (1:1)	1.41	1.56	1.48	2.68	2.74	2.71	8.06	8.42	8.24	45.85	39.94	42.90
T_8- Pigeonpea + GG (1:2)	1.39	1.53	1.46	2.67	2.73	2.70	7.12	7.98	7.55	41.61	39.53	40.57
T_9 - Pigeonpea + GG (1:3)	1.42	1.57	1.49	2.69	2.75	2.72	8.21	9.39	8.80	46.31	44.27	45.29
T_{16} – Sole Greengram	1.43	1.58	1.51	2.71	2.77	2.74	9.62	10.97	10.29	52.91	51.64	52.27
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.35	0.47	0.29	1.64	2.12	1.34
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.20	1.62	0.90	5.69	7.32	4.13

The highest nitrogen uptake in sole greengram might be due to nitrogen fixation from atmosphere to nodules that creates favorable influence of nitrogen on root proliferation and anchorage which in turn absorbs higher amounts of nutrients from rhizosphere and supply to the crop resulting in higher dry matter production as also reported by Singh *et al.* (2008) in maize based intercropping systems

4.4.4.4 Nitrogen uptake stover (kg ha^{-1})

It is apparent from the Table 4.52, the intercropping system with pigeonpea were significant on nitrogen uptake in stover. The highest nitrogen uptake in stover was recorded in sole greengram T_{16} (9.56, 9.21 and 9.38 kg ha^{-1}in 2021, 2022 and pooled data respectively) and was found to be at par with pigeonpea + greengram (1:3) T_9 (7.93 kg ha^{-1} during 2022). While the lowest nitrogen uptake in stover was recorded in pigeonpea + greengram (1:2) T_8 with 7.58, 7.10 and 7.34 kg ha^{-1} in 2021, 2022 and pooled data respectively. Mohankumar *et al.* (2012) also observed higher nitrogen uptake in stover in sole greengram.

4.4.4.5 Phosphorus content seed (%)

From the persual of the result it was evident from the data presented in Table 4.53 that phosphorus content in seed of greengram showed no significant difference under intercropping system with pigeonpea during both the years and the pooled data.

4.4.4.6 Phosphorus content stover (%)

A close examination of the data presented in the Table 4.53 reported that the phosphorus content in stover of greengram showed no significant effect during 2021, 2022 and pooled data under intercropping with pigeonpea.

4.4.4.7 Phosphorus uptake seed (kg ha^{-1})

An inference of the data presented in Table 4.53 revealed that the data on phosphorus uptake in seed of greengram under intercropping system with pigeonpea was found to be significant. Sole greengram T_{16} recorded the highest phosphorus uptake in seed (3.75, 4.05 and 3.90 kg ha^{-1} in the year 2021, 2022 and pooled data respectively) and was at par with pigeonpea + greengram (1:3) T_9 with value 3.46 kg ha^{-1} in 2022. While pigeonpea + greengram (1:2) T_8 recorded the lowest Phosphorus content in seed (2.82, 2.98 and 2.90 kg ha^{-1} in the year 2021, 2022 and their mean respectively). Similar results were reported by Girisha *et al.* (2020) in blackgram where the P uptake in seed (9.38 kg ha^{-1}) and stover (6.25 kg ha^{-1}) was higher in sole blackgram as compared to the row proportions, the higher nutrient uptake could be attributed to increased plant population of blackgram.

4.4.4.8 Phosphorus uptake stover (kg ha^{-1})

The results of phosphorus uptake of stover in greengram have been presented in Table 4.53. The data revealed that phosphorus uptake in stover of greengram differed significantly under intercropping system with pigeonpea. Significantly, the highest phosphorus uptake in stover was observed in sole greengram T_{16} with 3.10, 3.35 and 3.23 kg ha^{-1} in 2021, 2022 and pooled data respectively and the data was significantly at par with pigeonpea + greengram (1:3) T_9 with 2.84 kg ha^{-1} in the year 2022. Meanwhile, significantly, the lowest phosphorus uptake in stover was observed in pigeonpea + greengram (1:2) T_8 with 2.28, 2.48 and 2.38 kg ha^{-1} in 2021, 2022 and pool respectively. The results of present investigation are in close agreements with the findings of Singh *et al*. (2013) who noted that sole mungbean recorded significantly higher nitrogen and phosphorus uptake than intercropped mungbean due to higher plant population and biomass production.

4.4.4.9 Potassium content seed (%)

Data of potassium content in seed indicated in Table 4.54 revealed that no significant difference was observed under intercropping system with pigeonpea in 2021, 2022 and pooled data.

4.4.4.10 Potassium content stover (%)

Analysis of data depicted on Table 4.54 showed that there was no significant influence on potassium content in stover under intercropping system with pigeonpea during the years 2021, 2022 and the pooled data.

4.4.4.11 Potassium uptake seed (kg ha^{-1})

Data tabulated in Table 4.54 indicated that intercropping system with pigeonpea significantly influenced the potassium uptake in seed of greengram in both the years of experiment. In 2021, 2022 and for pooled data of both the years, it was observed that sole greengram T_{16} recorded the maximum potassium uptake in seed (9.62, 10.97 and 10.29 kg ha^{-1} respectively) and was at par with pigeonpea + greengram (1:3) T_9 with 9.39 kg ha^{-1} in 2022. Whereas, pigeonpea + greengram (1:2) T_8 recorded the minimum potassium uptake in seed with 7.12, 7.98 and 7.55 kg ha^{-1} for the respective years. Kumar *et al.* (2016) in his experiment on American cotton-based legume intercropping systems obtained higher nutrient uptake in sole crop.

4.4.4.12 Potassium uptake stover (kg ha^{-1})

Data related to potassium uptake in stover of greengram under intercropping system with pigeonpea presented on Table 4.54 showed significant results. Sole greengram T_{16} recorded the highest potassium uptake in stover (52.91, 51.64 and 52.27 kg ha^{-1} in 2021, 2022 and pooled respectively) during the experimentation year and was superiorly higher than the rest of the treatments. Pigeonpea + greengram (1:2) T_8 recorded the minimum potassium uptake in stover with 41.61, 39.53 and 40.57 kg ha^{-1} in 2021, 2022 and pooled respectively. Higher potassium uptake in seed and stover of sole greengram may be due to higher seed yield and stover yield which lead to higher potassium uptake. Higher dry matter accumulation and greater availability of nitrogen, phosphorus and potassium resulted in increased nitrogen, phosphorus and potassium uptake by crop in sole cropping system. Similar findings were also reported by Yakudu *et al.* (2010).

4.5 Soybean

4.5.1 Growth attributes

4.5.1.1 Plant height (cm)

Data presented in Table 4.55 showed that intercropping of soybean with pigeonpea varied significantly in the initial growth stage of plant soybean and had failed to show any significant effect on the later growth stage during the period of study. At 30 DAS the maximum plant height (33.50, 36.85 and 35.17 cm in 2021, 2022 and pool respectively) was recorded in sole soybean T_{17} and was significantly at par with pigeonpea + soybean (1:3) T_{12} (32.30, 35.46 and 33.88 cm in 2021, 2022 and pooled data respectively) and pigeonpea + soybean (1:1) T_{10} (32.12, 34.53 and 33.33 cm during 2021, 2022 and pool respectively). The lowest treatment was recorded in Pigeonpea + soybean (1:2) T_{11} (26.89, 32.28 and 29.59 cm in both the years of experimentation and pooled data respectively). Taller plant height in the soybean may be due to the absence of competition among the intercrop. These results are in conformity with the experiment results of Aye (2013) and Yokha (2015).

4.5.1.2 Plant population (m^{-2})

Data of plant population m^{-2} given in Table 4.56 revealed soybean plant population m^{-2} had significant influenced on the treatments due to intercropping system with pigeonpea. In the first experimental year 2021, sole soybean T_{17} {30, 29.67 and 29 (m^{-2}) at 30, 60 and 90 DAS respectively} recorded the highest value, which was significantly at par with pigeonpea + soybean (1:3) T_{12} {29.67, 29.50 and 29.33 (m^{-2}) at 30, 60 and 90 DAS respectively}.

Pigeonpea + soybean (1:2) T_{11} recorded the minimum plant population m^{-2} with the value of 19.67, 19.67 and 19.67 (m^{-2}) at 30, 60 and 90 DAS, respectively. Similarly in the second year of experiment 2022, sole soybean T_{17} {29.67, 29.67and 29.33 (m^{-2}) at 30, 60 and 90 DAS respectively} recorded the highest plant population m^{-2}, and it was at par with pigeonpea + soybean (1:3) T_{12} {29.33, 29.33 and 29 (m^{-2}) at 30, 60 and 90 DAS respectively}. Minimum value of plant population m^{-2} at 2022 was recorded with pigeonpea + soybean (1:2) T_{11} {19, 19and 19 (m^{-2}) at 30, 60 and 90 DAS respectively}.

Pooled data also recorded sole soybean T_{17} to have the highest plant population m^{-2} {29.83, 29.67 and 29.17 (m^{-2}) at 30, 60 and 90 respectively} and the data were at par with pigeonpea + soybean (1:3) T_{12} {29.50, 29.33 and 29 (m^{-2}) at 30, 60 and 90 DAS respectively}. While minimum plant population m^{-2} was recorded in pigeonpea + soybean (1:2) T_{11} (19.33, 19.33 and 19.33 at 30, 60 and 90 DAS respectively).

Sole soybean obtained maximum plant population in all the growth stages of crop, due different row ratio the plant population differed significantly. Pali *et al*. (2000) and Kumar *et al.* (2002) reported maximum plant population in intercropping linseed with mustard. Bailey-Elkin *et al.* (2022) also reported higher plant population in field pea intercropping system.

4.5.1.3 Crop growth rate (g m^{-2} day^{-1})

The data regarding effect of intercropping system with pigeonpea on CGR of soybean is presented in the Table 4.57. At 30 - 60 DAS soybean crop growth rate was found significant during both the years of study and mean data.

Table 4.55: Plant height (cm) of soybean at different growth stage under intercropping system with pigeonpea

Treatments	Plant height 30 DAS			Plant heighT 60 DAS			Plant height 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	32.12	34.53	33.33	68.88	71.96	70.42	84.07	92.94	88.50
T_{11} - Pigeonpea + Soybean (1:2)	26.89	32.28	29.59	68.37	71.33	69.85	83.90	90.64	87.27
T_{12} - Pigeonpea + Soybean (1:3)	32.30	35.46	33.88	70.37	74.89	72.63	85.62	93.56	89.59
T_{17} - Sole Soybean	33.50	36.85	35.17	72.59	77.50	75.04	87.58	94.98	91.28
SEm±	1.26	0.72	0.73	1.80	1.47	1.16	1.66	1.10	1.00
CD (P=0.05)	4.37	2.48	2.24	NS	NS	NS	7.81	NS	NS

Table 4.56: Plant population (m^{-2}) of soybean at different growth stage under intercropping system with pigeonpea

Treatments	Plant population 30 DAS			Plant population 60 DAS			Plant population 90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	20.00	20.00	20.00	20.00	19.67	19.83	19.67	19.33	19.50
T_{11} - Pigeonpea + Soybean (1:2)	19.67	19.00	19.33	19.67	19.00	19.33	19.67	19.00	19.33
T_{12} - Pigeonpea + Soybean (1:3)	29.67	29.33	29.50	29.33	29.33	29.33	29.00	29.00	29.00
T_{17} - Sole Soybean	30.00	29.67	29.83	29.67	29.67	29.67	29.00	29.33	29.17
SEm±	0.25	0.27	0.19	0.43	0.22	0.24	0.35	0.51	0.31
CD (P=0.05)	0.88	0.94	0.57	1.49	0.74	0.74	1.20	1.76	0.95

Table 4.57 CGR (g m^{-2} day^{-1}) and AGR (g day^{-1}) of soybean at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	CGR (30-60 DAS)			CGR (60-90 DAS)			AGR (30-60 DAS)			AGR (60-90 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	12.37	13.16	12.77	13.23	12.97	13.10	0.371	0.395	0.383	0.397	0.389	0.393
T_{11} - Pigeonpea + Soybean (1:2)	12.31	12.81	12.56	13.28	13.11	13.19	0.369	0.384	0.377	0.398	0.393	0.396
T_{12} - Pigeonpea + Soybean (1:3)	12.58	13.24	12.91	13.60	13.50	13.55	0.377	0.397	0.387	0.408	0.405	0.406
T_{17} - Sole Soybean	12.77	13.37	13.07	14.09	13.80	13.95	0.383	0.401	0.392	0.423	0.414	0.418
SEm±	0.08	0.08	0.06	0.48	0.32	0.29	0.002	0.002	0.002	0.014	0.010	0.009
CD (P=0.05)	0.27	0.29	0.18	NS	NS	NS	0.008	0.009	0.005	NS	NS	NS

Table 4.58 RGR (g g^{-1} day^{-1}) and NAR (g m^{-2} day^{-1}) of soybean at 30-60 and 60-90 DAS under intercropping system with pigeonpea

Treatments	RGR (30-60 DAS)			RGR (60-90 DAS)			NAR (30-60 DAS)			NAR (60-90 DAS)		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	0.068	0.067	0.068	0.022	0.021	0.021	2.52	3.07	2.80	6.35	6.27	6.31
T_{11} - Pigeonpea + Soybean (1:2)	0.068	0.067	0.068	0.022	0.021	0.022	2.49	2.88	2.69	5.69	6.21	5.95
T_{12} - Pigeonpea + Soybean (1:3)	0.067	0.066	0.066	0.022	0.021	0.022	2.82	3.14	2.98	6.39	6.42	6.41
T_{17} - Sole Soybean	0.067	0.065	0.066	0.022	0.021	0.022	2.97	3.35	3.16	6.41	6.44	6.43
SEm±	0.001	0.001	0.000	0.001	0.000	0.000	0.38	0.21	0.22	0.17	0.24	0.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Sole soybean T_{17} recorded the highest value (12.77, 13.37 and 13.07 g m^{-2} day^{-1} at 30-60 DAS during 2021, 2022 and pool data respectively) and they were statistically at par with pigeonpea + soybean (1:3) T_{12} (12.58, 13.24 and 12.91 at 30-60 DAS g m^{-2} day^{-1} in 2021, 2022 and pooled data respectively) and pigeonpea + soybean (1:1) T_{10} (13.16 g m^{-2} day^{-1} at 30-60 DAS in 2022). The lowest value for CGR was recorded in pigeonpea + soybean (1:2) T_{11} of 12.31,12.81 and 12.56 g m^{-2} day^{-1} in 2021, 2022 and the pooled data respectively. There was no significant difference due to intercropping system at 60 - 90 DAS in both the years and pooled data. Sole soybean obtained higher CGR in comparisons with soybean as intercrop. Rathiya *et al.* (2010) reported that reduced leaf area and available sunlight underneath the canopy in intercropping may lead to lower CGR of intercrops.

4.5.1.4 Absolute growth rate (g day^{-1})

It is evident from the data presented in Table 4.57 revealed that the absolute growth at of soybean varied significantly among the treatments under intercropping with pigeonpea at 30 - 60 DAS. Sole soybean T_{17} recorded the highest values 0.383, 0.401 and 0.392 g day^{-1} at 30 - 60 DAS in 2021, 2022 and pooled data respectively. The values were at par with pigeonpea + soybean (1:3) T_{12} (377, 0.397 and 0.387 g day^{-1} at 30 - 60 DAS during 2021, 2022 and pool respectively) and pigeonpea + soybean (1:1) T_{10} 0.395 g day^{-1} at 30 - 60 DAS in 2022. The minimum value was recorded in pigeonpea + soybean (1:2) T_{11} in both the years and in pooled data as well (0.369, 0.384 and 0.377 g day^{-1} at 30 - 60 DAS respectively).

4.5.1.5 Relative growth rate (g g^{-1} day^{-1})

An examination of data presented in Table 4.58 showed that the relative growth rate of soybean at 30-60 and 60-90 DAS under intercropping system with pigeonpea did not reveal any significant changes during individual years and pooled analysis.

4.5.1.6 Net Assimilation Rate (g m^{-2} day^{-1})

An appraisal of observed data on net assimilation rate presented in Table 4.58 elucidated that soybean when intercropped with pigeonpea did not exhibit any significant results at 30-60 and 60-90 DAS.

4.5.1.7 Leaf Area Index

A reference to data presented in Table 4.59 indicated that the LAI produced significant variation at 30 DAS in soybean due to intercropping system with pigeonpea during both years of experimentation and pooled basis. The highest leaf area index (1.54, 1.66 and 1.60 during 2021, 2022 and pool respectively) was obtained in sole soybean T_{17} and it was at par with pigeonpea + soybean (1:3) T_{12} (1.53, 1.64 and 1.58 in 2021, 2022 and pool data respectively) and pigeonpea + soybean (1:1) T_{10} (1.51, 1.62 and 1.57 in 2021, 2022 and pool data respectively). The significantly lowest value was recorded in pigeonpea + soybean (1:2) T_{11} (1.47, 1.53 and 1.50 during the study period and its pooled data respectively). The results were in close proximity with Mandal *et al*. (2014) who found out that LAI of intercrops reduced under intercropping system treatments due to competition for light and space.

4.5.2 Yield attributes

4.5.2.1Plant stand at harvest (m^{-2})

Analysis of the data presented at Table 4.60 clearly indicates that plant stand at harvest and had significant influenced among the treatments due to intercropping system with pigeonpea. Sole soybean T_{17} {29.33, 29 and 29.17 (m^{-2}) in 2021, 2022 and pool respectively} resulted in maximum value which was significantly at par with pigeonpea + soybean (1:3) T_{12} {29, 28.67 and 28.83 (m^{-2}) in 2021, 2022 and pooled data respectively}. Pigeonpea intercropped with soybean (1:2) T_{11} {19.33, 19 and 19.17 (m^{-2}) in both the experimental years and pooled data respectively} recorded the minimum plant stand at harvest. As the treatments had different row ratio the plant stand at harvest differed significantly.

Table 4.59 LAI of soybean at different growth stages under intercropping system with pigeonpea

Treatments	30 DAS			60 DAS			90 DAS		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	1.51	1.62	1.57	2.62	2.71	2.67	2.31	2.36	2.33
T_{11} - Pigeonpea + Soybean (1:2)	1.47	1.53	1.50	2.61	2.69	2.65	2.23	2.34	2.28
T_{12} - Pigeonpea + Soybean (1:3)	1.53	1.64	1.58	2.63	2.75	2.69	2.33	2.40	2.37
T_{17} - Sole Soybean	1.54	1.66	1.60	2.68	2.77	2.72	2.35	2.45	2.40
SEm±	0.01	0.01	0.01	0.02	0.07	0.04	0.05	0.06	0.04
CD (P=0.05)	0.05	0.04	0.03	NS	NS	NS	NS	NS	NS

Table 4.60 Yield attributes of soybean under intercropping system with pigeonpea

Treatments	Plant stand at harvest			No. of pods plant^{-1}			No. of seeds pod^{-1}		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	19.67	19.33	19.50	43.35	45.16	44.25	2.67	2.87	2.77
T_{11} - Pigeonpea + Soybean (1:2)	19.33	19.00	19.17	40.77	43.44	42.11	2.60	2.80	2.70
T_{12} - Pigeonpea + Soybean (1:3)	29.00	28.67	28.83	43.81	46.03	44.92	2.73	2.93	2.83
T_{17} - Sole Soybean	29.33	29.00	29.17	44.79	47.31	46.05	2.93	3.00	2.97
SEm±	0.32	0.52	0.30	0.39	0.62	0.37	0.19	0.09	0.10
CD (P=0.05)	1.10	1.79	0.94	1.36	2.16	1.14	NS	NS	NS

Table 4.61: Yield attributes and yield of soybean under intercropping system with pigeonpea

Treatments	Weight of pod plant^{-1}			Seed index			Seed yield		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	54.73	56.28	55.50	10.24	10.34	10.29	1213.30	1219.63	1216.47
T_{11} - Pigeonpea + Soybean (1:2)	49.48	49.59	49.54	10.02	9.83	9.93	1120.18	1125.11	1122.65
T_{12} - Pigeonpea + Soybean (1:3)	55.03	56.81	55.92	10.30	10.38	10.34	1302.62	1344.45	1323.54
T_{17} - Sole Soybean	55.28	57.99	56.63	10.53	10.55	10.54	1434.08	1446.68	1440.38
SEm±	1.77	1.74	1.24	0.12	0.24	0.13	39.00	29.95	24.59
CD (P=0.05)	NS	NS	NS	NS	NS	NS	134.95	103.64	75.76

Table 4.62: Yield of soybean under intercropping system with pigeonpea

Treatments	Stover yield			Biological yield			Harvest Index		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	2125.91	2056.25	2091.08	3339.21	3275.88	3307.55	36.35	37.23	36.79
T_{11} - Pigeonpea + Soybean (1:2)	1967.79	1917.79	1942.79	3087.97	3042.90	3065.44	36.27	36.98	36.62
T_{12} - Pigeonpea + Soybean (1:3)	2267.57	2262.23	2264.90	3570.19	3606.69	3588.44	36.49	37.28	36.88
T_{17} - Sole Soybean	2496.71	2426.71	2461.71	3930.79	3873.39	3902.09	36.48	37.35	36.92
SEm±	78.80	48.80	46.34	117.36	78.22	70.52	0.19	0.12	0.11
CD (P=0.05)	272.69	168.88	142.80	406.13	270.68	217.29	NS	NS	NS

4.5.2.2 Number of pods plant^{-1}

An examination of data on number of pods plant^{-1} of soybean under intercropping system with pigeonpea during both the years of crop growth period are presented in Table 4.60. Variation on number of pods plant^{-1} due to intercropping system was found to be significant during the period of experimentation. The highest number of pods plant^{-1} was recorded for sole soybean T_{17} (44.79, 47.31 and 46.05 in 2021, 2022 and their mean data), and these data were at par with treatment pigeonpea + soybean (1:3) T_{12} (43.81, 46.03 and 44.92 in 2021, 2022 and the pooled data respectively) and pigeonpea + greengram (1:1) T_{10} 45.16 in 20221. The lowest number of pods plant^{-1} was revealed in pigeonpea + soybean (1:2) T_{11} recording 40.77, 43.44 and 42.11 in the year 2021, 2022 and pooled data respectively. Bagri (2017) reported higher number of pods plant^{1} in sole soybean in comparison to intercropping system and mixed cropping system in the experiment.

4.5.2.3 No. of seeds pod^{-1}

Data pertaining to the effect of intercropping system on number of seeds pod^{-1} in soybean presented in Table 4.60 indicated that the intercropping system did not influence the number of seeds pod^{-1} during individual years as well as in pooled analysis.

4.5.2.4 Weight of pod plant^{-1}

A perusal of recorded and calculated data presented in Table 4.61 did not establish any significant differences on weight of pod plant^{-1} of soybean when intercropped with pigeonpea.

4.5.2.5 Test weight (g)

The results in Table 4.61 elucidated that soybean intercropped with pigeonpea during both the years did not reveal any significant variability in the test weight of soybean.

4.5.3 Yield

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

The persual of data presented in Table 4.61 and figure 4.6 indicates that different intercropping system with pigeonpea on soybean practices markedly influence the seed yield during the experimental years. Significantly superior crop yield was recorded in sole soybean T_{17} (1434.08, 1446.68 and 1440.38 kg ha^{-1} respectively) during 2021, 2022 and pooled data and it was significantly at par with pigeonpea + soybean (1:3) T_{12} (1302.62 and1344.45kg ha^{-1} in the year 2021 and 2022 respectively). And the minimum value was recorded in pigeonpea + soybean (1:2) T_{11} (1120.18, 1125.11 and 1122.65 kg ha^{-1} in both the years of experiment 2021, 2022 and their pooled data respectively). The maximum seed yield recorded in sole soybean may be due to maximum plant population per unit area the results corroborate with the findings of Kasbe *et al*. (2010) in soybean + pigeonpea intercropping system. Kithan (2012) in maize + soybean intercropping system and Yokha (2015) in soybean intercropping system.

4.5.3.2 Stover yield (kg ha^{-1})

It is apparent from the data presented in Table 4.62 and figure 4.6 on stover yield of soybean. The data presented in table 4.62 showed that soybean stover yield was significantly affected by intercropping system with pigeonpea. Sole soybean T_{17} produce higher stover value than the rest of the treatments during both the years and even in the pooled data (2496.71, 2426.71 and 2461.7 kg ha^{-1} during 2021, 2022 and pooled data respectively), which was statistically at par with the intercropping system pigeonpea + soybean (1:3) T_{12} (2267.57 and 2262.23 kg ha^{-1} during 2021 and 2022 respectively). Meanwhile the lowest stover yield was recorded in pigeonpea + soybean (1:2) T_{11} in both the years and similar trend was followed in the pooled data (1967.79, 1917.79 and 1942.79 kg ha^{-1} respectively). The sole cropping system noted marginally higher stover yield.

The reduction in stover yield in different row ratio over sole crops was mainly due to low plant population. Relevant research findings were also given by Poddar *et al.* (2013) in sole chickpea and Dhale *et al.* (2022) in sole soybean

4.5.3.3 Biological yield (kg ha^{-1})

The data pertaining to biological yield presented in Table 4.62 due to intercropping system with pigeonpea revealed that sole soybean T_{17} recorded the highest value among the treatments (3930.79, 3873.39 and 3902.09 kg ha^{-1} in 2021, 2022 and pooled respectively) during all the experiment years and its mean data, and it was statistically at par with pigeonpea + soybean (1:3) T_{12} with value 3570.19 and 3606.69 kg ha^{-1} during 2021 and 2022 respectively. The lowest value for biological yield was recorded in pigeonpea + soybean (1:2) T_{11} (3087.97, 3042.90 and 3065.44 during 2021, 2022 and mean respectively).

The higher seed and stover yield in sole soybean cumulatively enhanced the biological yield. These finding were supported by the result of the previous studies given by Dhale *et al.* (2022) and in their experiments on intercropping, their finding revealed that, the T_7 -sole soybean significantly recorded the highest (1478 kg ha^{-1}) seed yield, straw and biological yield as compared to other treatments (soybean + pigeonpea).

4.5.3.4 Harvest Index (%)

The data on the harvest index of soybean as influenced by intercropping system with pigeonpea have been represented in Table 4.62. The harvest index failed to show any significant difference during the period of experimentation.

4.5.4 Plant analysis

4.5.4.1 Nitrogen content seed (%)

Data indicated in Table 4.63 revealed that nitrogen content in seed of soybean failed to show any significant influenced under intercropping system with pigeonpea during both the years of experimentation and the pooled data.

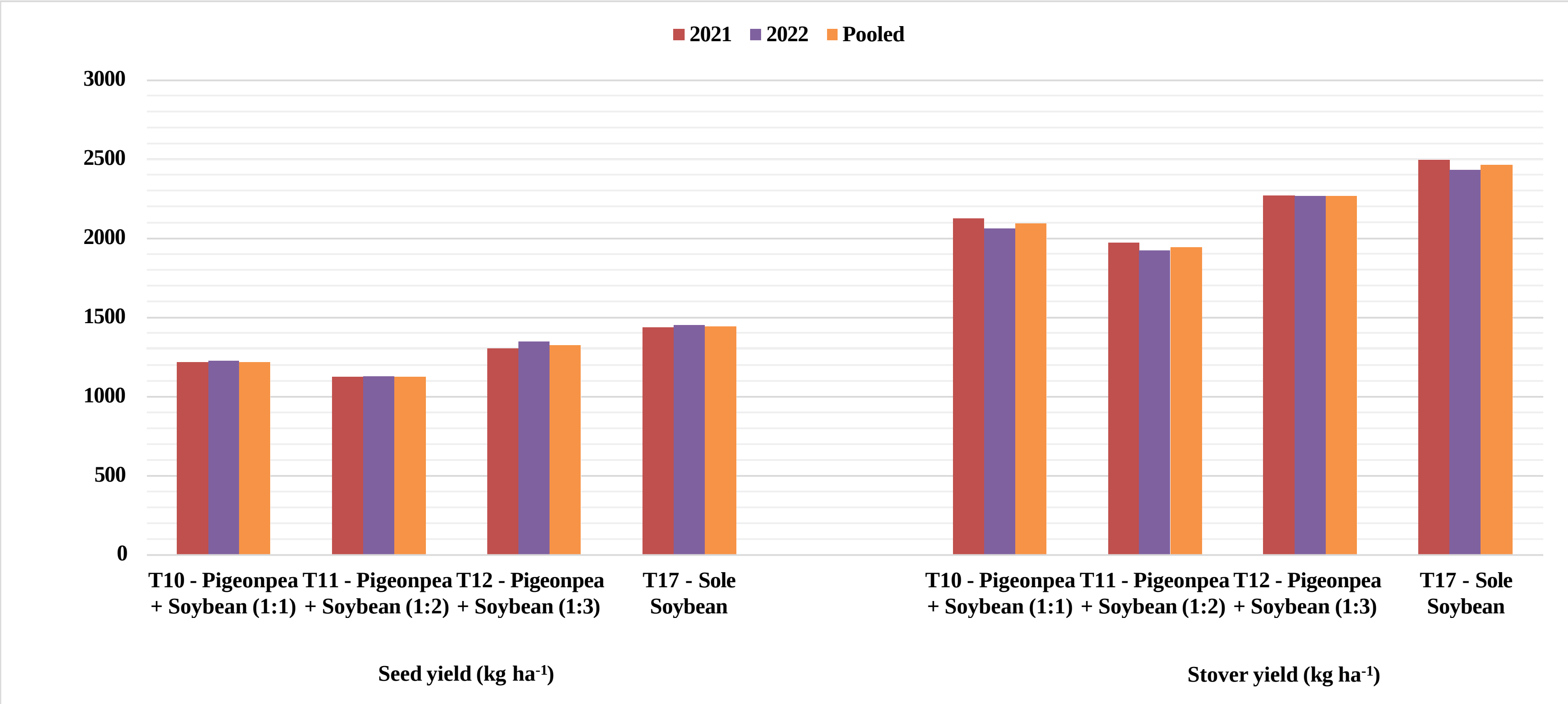

Fig. 4.6 Effect of different intercropping systems with pigeonpea on seed and stover yield (kg ha^{-1}) of soybean

4.5.4.2 Nitrogen content stover (%)

Result of nitrogen content in stover of soybean represented in Table 4.63: showed that there was no significant effect under intercropping system with pigeonpea during both the years (2021 and 2022) and for the pooled data.

4.5.4.3 Nitrogen uptake seed (kg ha^{-1})

A critical examination of the data presented in the Table 4.63, found that nitrogen uptake in seed of soybean varied significantly among the treatments. It was observed that the highest nitrogen uptake in seed (66.97, 70.31 and 68.64 kg ha^{-1} in the year 2021, 2022 and pool data respectively) was obtained in sole soybean T_{17} and was found to be at par with pigeonpea + soybean (1:3) T_{12} in the year 2021 (60.71 kg ha^{-1}). The lowest nitrogen uptake in seed of soybeanwas obtained in pigeonpea + soybean (1:2) T_{11} with 51.98, 53.40 and 52.69 kg ha^{-1} in 2021, 2022 and pool data respectively. Manjunath *et al.* (2023) also reported higher nutrient uptake in sole soybean in comparison with soybean + millets intercropping system.

4.5.4.4Nitrogen uptake stover (kg ha^{-1})

An inquisition of data presented in Table 4.63 revealed nitrogen uptake in stover of soybean had significant influence under intercropping system with pigeonpea. From the data given in table 4.62 it is evident that the sole soybean T_{17} recorded the maximum nitrogen uptake in stover (50.19, 60.91 and 55.55 kg ha^{-1} in the year 2021, 2022 and pool data respectively) and the value was at par with pigeonpea + soybean (1:3) T_{12} with 45.36 kg ha^{-1} in the year 2021. Meanwhile the minimum nitrogen uptake in stover was recorded in pigeonpea + soybean (1:2) T_{11} with 38.96, 45.92 and 42.44 kg ha^{-1} in 2021, 2022 and pool data respectively. Meena *et al.* (2008) also reported similar findings of higher nitrogen uptake in sole cluster bean.

Table 4.63: Nitrogen content (%) and nitrogen uptake (kg ha^{-1}) of soybean under intercropping system with pigeonpea

Treatments	N content seed			N content stover			N uptake seed			N uptake stover		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	4.65	4.84	4.75	1.99	2.43	2.21	56.42	59.07	57.74	42.30	50.04	46.17
T_{11} - Pigeonpea + Soybean (1:2)	4.64	4.75	4.69	1.98	2.39	2.19	51.98	53.40	52.69	38.96	45.92	42.44
T_{12} - Pigeonpea + Soybean (1:3)	4.66	4.85	4.75	2.00	2.45	2.23	60.71	65.14	62.92	45.36	55.51	50.43
T_{17} – Sole Soybean	4.67	4.86	4.77	2.01	2.51	2.26	66.97	70.31	68.64	50.19	60.91	55.55
SEm±	0.01	0.02	0.01	0.01	0.02	0.01	1.85	1.28	1.12	1.54	1.42	1.05
CD (P=0.05)	NS	NS	NS	NS	NS	NS	6.41	4.42	3.47	5.32	4.91	3.22

Table 4.64: Phosphorus content (%) and phosphorus uptake (kg ha^{-1}) of soybean under intercropping system with pigeonpea

Treatments	P content seed			P content stover			P uptake seed			P uptake stover		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	0.254	0.267	0.260	0.176	0.194	0.185	3.08	3.25	3.17	3.75	3.99	3.87
T_{11} - Pigeonpea + Soybean (1:2)	0.252	0.265	0.259	0.175	0.190	0.183	2.82	2.98	2.90	3.45	3.65	3.55
T_{12} - Pigeonpea + Soybean (1:3)	0.255	0.268	0.261	0.178	0.196	0.187	3.32	3.60	3.46	4.03	4.44	4.24
T_{17} – Sole Soybean	0.257	0.270	0.264	0.182	0.199	0.191	3.69	3.90	3.80	4.54	4.84	4.69
SEm±	0.001	0.001	0.001	0.003	0.002	0.002	0.10	0.08	0.06	0.13	0.08	0.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.36	0.27	0.20	0.44	0.28	0.23

Table 4.65: Potassium content (%) and potassium uptake (kg ha^{-1}) of soybean under intercropping system with pigeonpea

Treatments	K content seed			K content stover			K uptake seed			K uptake stover		
	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled	2021	2022	Pooled
T_{10} - Pigeonpea + Soybean (1:1)	1.47	1.52	1.49	2.20	2.29	2.25	17.80	18.49	18.15	46.76	47.15	46.96
T_{11}- Pigeonpea + Soybean (1:2)	1.45	1.51	1.48	2.19	2.28	2.24	16.25	16.95	16.60	43.04	43.79	43.42
T_{12} - Pigeonpea + Soybean (1:3)	1.48	1.53	1.51	2.21	2.30	2.26	19.32	20.52	19.92	50.12	52.03	51.07
T_{17} – Sole Soybean	1.49	1.54	1.51	2.23	2.32	2.28	21.32	22.23	21.78	55.68	56.30	55.99
SEm±	0.01	0.01	0.01	0.01	0.01	0.01	0.57	0.45	0.36	1.73	1.07	1.02
CD (P=0.05)	NS	NS	NS	NS	NS	NS	1.99	1.55	1.12	5.99	3.69	3.13

4.5.4.5 Phosphorus content seed (%)

Data regarding phosphorus content in the seed of soybean presented in Table4.64 showed no significant difference during 2021, 2022 and pooled data under intercropping with pigeonpea.

4.5.4.6 Phosphorus content stover (%)

A critical examination of the data presented in the Table 4.64, it was recorded that the phosphorus uptake in stover of soybean showed no significant effect during both the years (2021 and 2022) and pooled data under intercropping with pigeonpea.

4.5.4.7 Phosphorus uptake seed (kg ha^{-1})

It is evident from result presented in Table 4.64 that phosphorus uptake in the seed of soybean showed a significant effect under intercropping system with pigeonpea. The highest phosphorus uptake in seed was recorded in sole soybean T_{17} with 3.69, 3.90 and 3.80 kg ha^{-1} in 2021, 2022 and for pooled data respectively. Whereas, pigeonpea + soybean (1:2) T_{11} (2.82, 2.98 and 2.90 kg ha^{-1} in 2021, 2022 and pool data, respectively) recorded the lowest phosphorus uptake in seed of soybean. Similarly, Mohan *et al.* (2023a) reported the highest nitrogen uptake in seed 6.69, 6.93 and 6.80 kg ha^{-1} of sole soybean during 2019, 2020 and pool data respectively.

4.5.4.8 Phosphorus uptake stover (kg ha^{-1})

Analysis of data presented on Table 4.64 depicted that soybean had significant influence under intercropping system with pigeonpea and the sole soybean T_{17} recorded the highest phosphorus uptake in stover with 4.54, 4.84 and 4.69 kg ha^{-1} in 2021, 2022 and pooled respectively. Meanwhile, pigeonpea + soybean (1:2) T_{11} recorded the lowest phosphorus uptake in stover with 3.45, 3.65 and 3.55 kg ha^{-1} in 2021, 2022 and pool data respectively. The results were in conformity with Karparwan *et al.* (2021) in chickpea and mustard intercropping systems.

4.5.4.9 Potassium content seed (%)

It was evident from the data presented in Table 4.65, that the potassium content in seed of soybean showed no significant effect during the years 2021 and 2022 and pooled data under intercropping with pigeonpea.

4.5.4.10 Potassium content stover (%)

Results depicted on Table 4.65 revealed that the potassium uptake in stover of soybean showed no significant effect during year 2021, 2022 and pooled data under intercropping with pigeonpea.

4.5.4.11 Potassium uptake seed (kg ha^{-1})

Data represented on Table 4.65 showed that potassium uptake in the seed of soybean had a significant influence among the treatments. Sole soybean T_{17} recorded the maximum potassium uptake in seed with 21.32, 22.23 and 21.78 kg ha^{-1} in years 2021, 2022 and pooled respectively and was superiorly higher than the rest of the treatments. Meanwhile, pigeonpea + soybean (1:2) T_{11} recorded the minimum potassium uptake in seed with 16.25, 16.95 and 16.60 kg ha^{-1} in 2021, 2022 and pool respectively. Higher K uptake may be due to higher K content, dry matter and its translocation from vegetative parts to reproductive parts in the later stages of crop growth and development stage.

4.5.4.12 Potassium uptake stover (kg ha^{-1})

Analysis of data presented on Table 4.65 portrayed that soybean had a significant influence under intercropping system with pigeonpea. The highest potassium uptake in stover (55.68, 56.30 and 55.99 kg ha^{-1} in 2021, 2022 and pooled respectively) was observed in sole soybean T_{17} and the value was found to be significantly at par with pigeonpea + soybean (1:3) T_{12} (50.12 kg ha^{-1} in 2021). The lowest potassium uptake in stover was recorded in Pigeonpea + soybean (1:2) T_{11} (43.04, 43.79 and 43.42 kg ha^{-1} in 2021, 2022 and pooled data respectively). The results of the present investigation are in close agreement with the findings of Shivakumar *et al.* (2022b) who recorded higher P uptake of seed (22.07, 24.10 and 23.08 kg ha^{-1} in 2019, 2022 and mean) and stover (47.95, 51.03 and 49.49 kg ha^{-1} in 2019, 2022 and mean) in sole chickpea in sequential intercropping systems.

II Intercropping competitive indices

4.6.1 Pigeonpea equivalent yield (PEY)

Pigeonpea equivalent yield was significantly influenced by different intercropping systems (Table 4.66). Pigeonpea + soybean (1:3) T_{12} produced the highest PEY (1116.53, 11152.39 and 1134.46 kg ha^{-1} in 2021, 2022 and pooled respectively) which was significantly higher than the rest of the treatments. The lowest value of PEY was produced in pigeonpea + rice (1:2) T_2 (629.68, 613.97 and 621.83 in 2021, 2022 and pooled data respectively). Intercropping system produce significantly higher PEY value than sole pigeonpea system because of higher yield of both crops and their relative market prices of intercrop than sole cropping system. The higher PEY in pigeonpea + soybean (1:3) intercropping may be due to the higher yield of pigeonpea and soybean coupled with better utilization of the natural resources by the component crops in intercropping system. Similar results were also reported by Sharmili and Manoharan (2018) and Keerthanapriya *et. al* (2019).

4.6.2 Land equivalent ratio (LER)

The land equivalent ratio is the relative land under sole crop required to produce the same yield obtained under mixed/intercropping system under the same management practices. Land equivalent ratio values more than one in all intercropping systems indicates the yield advantage in intercropping over sole cropping. The land equivalent ratio was computed and exhibited in Table 4.67. It varied significantly due to different intercropping system. LER value in each and every system was more than 1.0 except for the treatment with the sole crop. The LER was observed marginally higher under pigeonpea + soybean (1:1) T_{10} (1.81, 1.81 and 1.81 in 2021, 2022 and pooled data respectively) intercropping

Table 4.66: Pigeonpea equivalent yield (PEY) of pigeonpea under different intercropping system

Treatments	Pigeonpea equivalent yield (PEY)		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	675.24	651.96	663.60
T_2 - Pigeonpea +Rice (1:2)	629.68	613.97	621.83
T_3 - Pigeonpea +Rice (1:3)	678.71	722.14	700.43
T_4 - Pigeonpea +Sesame (1:1)	900.48	847.41	873.94
T_5 - Pigeonpea +Sesame (1:2)	800.27	807.25	803.76
T_6- Pigeonpea +Sesame (1:3)	966.31	1041.29	1003.80
T_7 - Pigeonpea +Greengram (1:1)	818.84	772.60	795.72
T_8 - Pigeonpea +Greengram (1:2)	730.10	744.50	737.30
T_9 - Pigeonpea +Greengram (1:3)	828.16	855.62	841.89
T_{10} - Pigeonpea +Soybean (1:1)	1039.97	1045.40	1042.68
T_{11} - Pigeonpea +Soybean (1:2)	960.15	964.38	962.27
T_{12} - Pigeonpea +Soybean (1:3)	1116.53	1152.39	1134.46
T_{13} - Sole Pigeonpea	-	-	-
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	24.88	24.98	17.63
CD (P=0.05)	71.66	71.96	49.80

Table 4.67: Land equivalent ratio (LER) and area time equivalent ratio (ATER) of pigeonpea under different intercropping system

Treatments	Land equivalent ratio (LER)			Area time equivalent ratio (ATER)		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	1.68	1.67	1.67	1.27	1.20	1.23
T_2 - Pigeonpea +Rice (1:2)	1.50	1.49	1.50	1.12	1.06	1.09
T_3 - Pigeonpea +Rice (1:3)	1.47	1.49	1.48	1.05	1.01	1.03
T_4 - Pigeonpea +Sesame (1:1)	1.69	1.62	1.66	1.40	1.26	1.33
T_5 - Pigeonpea +Sesame (1:2)	1.44	1.47	1.45	1.18	1.08	1.13
T_6- Pigeonpea +Sesame (1:3)	1.51	1.52	1.51	1.20	1.13	1.16
T_7 - Pigeonpea +Greengram (1:1)	1.71	1.67	1.69	1.31	1.21	1.26
T_8 - Pigeonpea +Greengram (1:2)	1.55	1.53	1.54	1.18	1.10	1.14
T_9 - Pigeonpea +Greengram (1:3)	1.48	1.48	1.48	1.07	1.02	1.05
T_{10} - Pigeonpea +Soybean (1:1)	1.81	1.81	1.81	1.42	1.33	1.37
T_{11} - Pigeonpea +Soybean (1:2)	1.50	1.52	1.51	1.15	1.09	1.12
T_{12} - Pigeonpea +Soybean (1:3)	1.58	1.60	1.59	1.16	1.12	1.14
T_{13} - Sole Pigeonpea	1.00	1.00	1.00	1.00	1.00	1.00
T_{14} - Sole Rice	1.00	1.00	1.00	1.00	1.00	1.00
T_{15} - Sole Sesame	1.00	1.00	1.00	1.00	1.00	1.00
T_{16} – Sole Greengram	1.00	1.00	1.00	1.00	1.00	1.00
T_{17} – Sole Soybean	1.00	1.00	1.00	1.00	1.00	1.00
SEm±	0.04	0.03	0.03	0.03	0.02	0.02
CD (P=0.05)	0.12	0.08	0.07	0.08	0.07	0.05

Table 4.68: Relative crowding coefficient (RCC) of pigeonpea under different intercropping system

Treatments	Relative crowding coefficient					
	$K_{pigeonpea}$			$K_{intercrop}$		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	4.46	6.85	5.65	6.56	4.12	5.34
T_2 - Pigeonpea +Rice (1:2)	4.70	5.47	5.09	2.05	1.58	1.81
T_3 - Pigeonpea +Rice (1:3)	4.55	4.48	4.51	2.31	2.96	2.64
T_4 - Pigeonpea +Sesame (1:1)	8.02	10.94	9.48	4.69	2.58	3.63
T_5 - Pigeonpea +Sesame (1:2)	5.21	5.74	5.47	1.46	1.29	1.38
T_6- Pigeonpea +Sesame (1:3)	5.70	5.67	5.69	3.54	4.06	3.80
T_7 - Pigeonpea +Greengram (1:1)	6.01	7.99	7.00	7.82	4.55	6.18
T_8 - Pigeonpea +Greengram (1:2)	6.95	7.14	7.04	2.09	2.29	2.19
T_9 - Pigeonpea +Greengram (1:3)	4.79	4.95	4.87	4.31	3.53	3.92
T_{10} - Pigeonpea +Soybean (1:1)	24.48	26.35	25.42	6.34	3.19	4.77
T_{11} - Pigeonpea +Soybean (1:2)	5.42	5.74	5.58	1.86	1.18	1.52
T_{12} - Pigeonpea +Soybean (1:3)	6.10	6.18	6.14	3.72	1.74	2.73
T_{13} - Sole Pigeonpea	-	-	-	-	-	-
T_{14} - Sole Rice	-	-	-	-	-	-
T_{15} - Sole Sesame	-	-	-	-	-	-
T_{16} – Sole Greengram	-	-	-	-	-	-
T_{17} – Sole Soybean	-	-	-	-	-	-
SEm±	0.47	0.84	0.48	1.06	0.70	0.63
CD (P=0.05)	1.34	2.41	1.35	3.05	2.01	1.79

Table 4.69: Relative crowding coefficient (RCC) of pigeonpea under different intercropping system

Treatments	K_{system}		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	11.02	10.97	10.99
T_2 - Pigeonpea +Rice (1:2)	6.75	7.05	6.90
T_3 - Pigeonpea +Rice (1:3)	6.86	7.45	7.15
T_4 - Pigeonpea +Sesame (1:1)	12.70	13.52	13.11
T_5 - Pigeonpea +Sesame (1:2)	6.66	7.03	6.85
T_6- Pigeonpea +Sesame (1:3)	9.23	9.73	9.48
T_7 - Pigeonpea +Greengram (1:1)	13.83	12.54	13.18
T_8 - Pigeonpea +Greengram (1:2)	9.04	9.43	9.24
T_9 - Pigeonpea +Greengram (1:3)	9.10	8.48	8.79
T_{10} - Pigeonpea +Soybean (1:1)	30.83	29.53	30.18
T_{11} - Pigeonpea +Soybean (1:2)	7.28	6.92	7.10
T_{12} - Pigeonpea +Soybean (1:3)	9.82	7.92	8.87
T_{13} - Sole Pigeonpea	-	-	-
T_{14} - Sole Rice	-	-	-
T_{15} - Sole Sesame	-	-	-
T_{16} – Sole Greengram	-	-	-
T_{17} – Sole Soybean	-	-	-
SEm±	1.30	1.06	0.84
CD (P=0.05)	3.73	3.05	2.36

Table 4.70: Aggressivity (A) of pigeonpea under different intercropping system

Treatments	Aggressivity					
	$A_{pigeonpea}$			$A_{intercrop}$		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	-0.10	0.12	0.01	0.10	-0.12	-0.01
T_2 - Pigeonpea +Rice (1:2)	0.90	1.05	0.98	-0.90	-1.05	-0.98
T_3 - Pigeonpea +Rice (1:3)	1.25	1.20	1.23	-1.25	-1.20	-1.23
T_4 - Pigeonpea +Sesame (1:1)	0.16	0.41	0.29	-0.16	-0.41	-0.29
T_5 - Pigeonpea +Sesame (1:2)	1.09	1.18	1.14	-1.09	-1.18	-1.14
T_6- Pigeonpea +Sesame (1:3)	1.43	1.42	1.43	-1.43	-1.42	-1.43
T_7 - Pigeonpea +Greengram (1:1)	-0.01	0.22	0.10	0.01	-0.22	-0.10
T_8 - Pigeonpea +Greengram (1:2)	1.17	1.22	1.19	-1.17	-1.22	-1.19
T_9 - Pigeonpea +Greengram (1:3)	1.29	1.33	1.31	-1.29	-1.33	-1.31
T_{10} - Pigeonpea +Soybean (1:1)	0.23	0.24	0.23	-0.23	-0.24	-0.23
T_{11} - Pigeonpea +Soybean (1:2)	1.00	1.05	1.02	-1.00	-1.05	-1.02
T_{12} - Pigeonpea +Soybean (1:3)	1.47	1.44	1.45	-1.47	-1.44	-1.45
T_{13} - Sole Pigeonpea	0.00	0.00	0.00	0.00	0.00	0.00
T_{14} - Sole Rice	0.00	0.00	0.00	0.00	0.00	0.00
T_{15} - Sole Sesame	0.00	0.00	0.00	0.00	0.00	0.00
T_{16} – Sole Greengram	0.00	0.00	0.00	0.00	0.00	0.00
T_{17} – Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	0.08	0.09	0.06	0.08	0.09	0.06
CD (P=0.05)	0.22	0.25	0.16	0.22	0.25	0.16

Table 4.71: Competition ratio of pigeonpea under different intercropping system

Treatments	Competition ratio					
	$CR_{pigeonpea}$			$CR_{intercrop}$		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	0.95	1.08	1.01	1.06	0.93	0.99
T_2 - Pigeonpea +Rice (1:2)	1.75	1.93	1.84	0.57	0.52	0.55
T_3 - Pigeonpea +Rice (1:3)	2.09	2.02	2.05	0.48	0.50	0.49
T_4 - Pigeonpea +Sesame (1:1)	1.11	1.30	1.20	0.91	0.78	0.84
T_5 - Pigeonpea +Sesame (1:2)	2.06	2.20	2.13	0.50	0.46	0.48
T_6- Pigeonpea +Sesame (1:3)	2.28	2.25	2.27	0.45	0.46	0.45
T_7 - Pigeonpea +Greengram (1:1)	1.00	1.15	1.07	1.01	0.88	0.94
T_8 - Pigeonpea +Greengram (1:2)	2.05	2.11	2.08	0.50	0.48	0.49
T_9 - Pigeonpea +Greengram (1:3)	2.12	2.18	2.15	0.47	0.46	0.47
T_{10} - Pigeonpea +Soybean (1:1)	1.14	1.14	1.14	0.88	0.88	0.88
T_{11} - Pigeonpea +Soybean (1:2)	1.86	1.90	1.88	0.54	0.53	0.54
T_{12} - Pigeonpea +Soybean (1:3)	2.21	2.16	2.19	0.45	0.46	0.46
T_{13} - Sole Pigeonpea	0.00	0.00	0.00	0.00	0.00	0.00
T_{14} - Sole Rice	0.00	0.00	0.00	0.00	0.00	0.00
T_{15} - Sole Sesame	0.00	0.00	0.00	0.00	0.00	0.00
T_{16} – Sole Greengram	0.00	0.00	0.00	0.00	0.00	0.00
T_{17} – Sole Soybean	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	0.10	0.11	0.08	0.03	0.03	0.02
CD (P=0.05)	0.30	0.33	0.22	0.08	0.09	0.06

system which was significantly at par with pigeonpea + greengram (1:2) T_7 at 1.71 in 2021. The least LER was noted in pigeonpea + sesame (1:3) T_5 (1.44, 1.47 and 1.45) during 2021, 2022 and pooled study.

When compared to sole with intercrop mean the rest of treatment means recorded higher values of land equivalent ratio than sole pigeonpea during two years and in pooled. It may be due to the fact that the component crops have combined effect of better utilization of growth resources than sole cropping of companion crops and converting them more efficiently resulting in higher yield per unit area than that produced by sole cropping. Similar findings were reported Ahlawat *et al.* 2005 and Tripathi and Kushwaha (2013).

4.6.3 Area time equivalent ratio (ATER)

The ATER provides a more realistic comparison of yield advantage of intercropping to that of sole cropping. However, crop production is a function of both crop duration (time) and land area. ATER ratio took into account the time for which the crops were in the field. Intercropping advantage in term of ATER of pigeonpea based intercropping system are presented in Table 4.67. Higher value of ATER was observed in pigeonpea + soybean (1:1) T_{10} (1.41, 1.27 and 1.34 in 2021, 2022 and pooled data respectively) intercropping system. Meanwhile, the lowest value of ATER was recorded with sole crop of pigeonpea, rice, greengram and soybean. ATER values were higher in the above-mentioned intercropped treatments due to higher combined seed yield of both the crops (*viz.* sole crop and intercrop combined) per unit area and longer duration of the crop present on the land from planting to harvest. The results were in conformity with Dhandayuthapani and Kuzhanthaivel (2015) and Yenebala (2017).

4.6.4 Relative crowding coefficient (RCC)

The data regarding the RCC are depicted in Table 4.68 and 4.69. RCC values were greater in all the treatments indicating that the crops produced more than expected yield. All the intercropping combinations under different intercropping systems with pigeonpea proved to be advantageous which was evident from the product value K. Pigeonpea + soybean (1:1) T_{10} recorded the highest K value (30.83, 29.53 and 30.18 in 2021, 2022 and pooled data respectively) and lowest value of K was obtained in pigeonpea+sesame (1:2) T_5 (6.66, 7.03 and 6.85 in 2021, 2022 and pooled data respectively) for the system. These results corroborated with the finding of Dwivedi *et al*. (2015) and Sethy (2019).

4.6.5 Aggressivity

Data pertaining to aggressivity (A) are presented in Table 4.70. The data on the aggressivity of different intercropping systems indicated that aggressivity values were positive in almost all the intercropping systems which indicated the dominance of pigeonpea. Higher aggressivity was recorded in pigeonpea + soybean (1:3) T_{12} (1.47, 1,44 and 1.45 in 2021, 2022 and pooled data respectively) and lower aggressivity in pigeonpea + rice (1:1) T_1 (-0.10, 0.12 and 0.01 in 2021, 2022 and pooled data respectively). However, the negative aggressivity value of pigeonpea in pigeonpea + rice (1:1) T_1 (-0.10) and pigeonpea + sesame (1:1) T_7 (-0.01) in 2021 was observed, which indicates the dominant effect of the component crop on main crop. Similar results were confirmed by and Ram and Meena (2014): Ravindra (2019) in pigeonpea intercropping system.

4.6.6 Competition ratio

Analysis of data on Competition ratio (CR) are presented in the Table 4.71. CR was the ratio of individual LER's of the two component crops, corrected by multiplying with their sowing proportion. Competition ratio (CR) during both the year of experimentation was higher in pigeonpea + soybean (1:3) T_{12} (2.28, 2.25 and 2.27 in 2019, 2022 and their mean respectively) system. The lowest CR value was found in pigeonpea + rice (1:1) T_1 (0.95, 1.08 and 1.01 in 2019, 2022 and their pool data respectively). In both the years, the CR of soybean was highest with intercrops. Keerthanapriya *et al.* (2019) also reported similar results.

III Soil analysis

4.7.1 pH

Data related to the soil pH of pigeonpea with intercrops as influenced by different treatments are summarized in Table 4.72, from mean pooled data of 2021 and 2022 and it can be observed that soil pH failed to show any significant difference under intercropping system with pigeonpea.

4.7.2 Organic carbon (%)

The data pertaining to soil organic carbon are presented in Table 4.72. Data in the table 4.72 indicate that under intercropping system with pigeonpea treatments had no significant impact on the soil organic carbon in the first year of experiment in 2021 but was influenced significantly in 2022 and pooled data. The highest soil organic carbon was found in pigeonpea + soybean (1:3) T_{12} (1.63 and 1.62 % during 2022 and pooled data respectively) and was significantly at par with pigeonpea + soybean (1:1) T_{10} (1.55 and 1.56 % during 2022 and pooled data respectively), pigeonpea + greengram (1:3) T_9 (1.54 and 1.56 during 2022 and pool respectively), pigeonpea + soybean (1:2) T_{11} (1.52 and 1.54 % during 2022 and pooled data) and pigeonpea + greengram (1:1) T_{11} with 1.52 % during 2022. The lowest soil organic carbon was found in sole rice T_{14} (1.32 and 1.35 % during 2022 and pooled data respectively) Chidowe *et al.* (2017) reported higher organic carbon in sole crop (maize) in their experiment.

4.7.3 Available nitrogen (kg ha^{-1})

The data presented in Table 4.73. revealed that the data on available nitrogen in soil under intercropping system with pigeonpea was found to be significant. Pigeonpa + soybean (1:3) T_{12} recorded the maximum available nitrogen in soil (271.87, 288.42 and 280.15 kg ha^{-1} in the year 2021, 2022 and pooled data respectively) and was at par with pigeonpea + soybean (1:1) T_{10} (267.62, 285.08 and 276.35 kg ha^{-1} in the year 2021, 2022 and pooled data respectively), pigeonpea + greengram (1:3) T_9 (263.98, 282.57 and 276.35 kg ha^{-1} in the year 2021, 2022 and pooled data respectively), pigeonpea + soybean (1:2) T_{11} (258.99, 275.88 and 267.43 kg ha^{-1} in the year 2021, 2022 and pooled data respectively) and pigeonpea + greengram (1:2) T_8 (255.14 and 2262.13 kg ha^{-1} in the year 2021 and 2022 respectively). The minimum available nitrogen in soil was recorded in sole rice (229.05, 242.43 and 235.74 kg ha^{-1} in the year 2021, 2022 and pooled data respectively).

Intercropping resulted in a significant increase in available soil nitrogen content. Singh *et al.* (2008) in their experiment observed the highest values of available soil N, P and K were recorded after harvest of crops in intercropping system of maize + soybean.

4.7.4 Available phosphorus (kg ha^{-1})

A critical examination of the data presented in the Table 4.73, revealed that the available phosphorus of soil failed to show any significant effect during the years 2021 and 2022 under intercropping with pigeonpea, but had significant effect on their pooled data. Pigeonpa + soybean (1:3) T_{13} recorded the highest value for available phosphorus in soil (24.77 kg ha^{-1} in the pooled data) and was significantly at par with pigeonpea + soybean (1:1) T_{10} (24.56 kg ha^{-1} in pooled data), pigeonpea+ greengram (1:3) T_9 (24.26 kg ha^{-1} in their pooled data), pigeonpea + sesame (1:3) T_6 (23.76 kg ha^{-1} in the mean data) and pigeonpea + greengram (1:1) T_7 (23.70 kg ha^{-1} in the pool data). The lowest available phosphorus in soil was recorded in sole rice (21.93 kg ha^{-1} in pooled data). Similar findings were reported by Padhi and Panigrahi (2006).

4.7.5 Available potassium (kg ha^{-1})

From the persual of the result it was evident from the data presented in Table 4.74, that the available potassium in soil showed no significant effect during the years 2021 and 2022 and pooled data under intercropping with pigeonpea.

Table 4.72: Soil pH and soil organic carbon (%) of pigeonpea under different intercropping system

Treatments	Soil pH			Soil organic carbon		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	4.94	4.76	4.85	1.38	1.37	1.38
T_2 - Pigeonpea +Rice (1:2)	4.98	4.88	4.93	1.47	1.44	1.46
T_3 - Pigeonpea +Rice (1:3)	5.01	4.92	4.97	1.44	1.39	1.42
T_4 - Pigeonpea +Sesame (1:1)	4.90	4.75	4.83	1.50	1.46	1.48
T_5 - Pigeonpea +Sesame (1:2)	4.96	4.83	4.89	1.55	1.52	1.53
T_6- Pigeonpea +Sesame (1:3)	4.99	4.90	4.95	1.53	1.49	1.51
T_7 - Pigeonpea +Greengram (1:1)	4.93	4.75	4.84	1.53	1.50	1.52
T_8 - Pigeonpea +Greengram (1:2)	4.96	4.87	4.92	1.52	1.50	1.51
T_9 - Pigeonpea +Greengram (1:3)	5.03	4.91	4.97	1.57	1.54	1.56
T_{10} - Pigeonpea +Soybean (1:1)	4.84	4.68	4.76	1.58	1.55	1.56
T_{11} - Pigeonpea +Soybean (1:2)	4.95	4.81	4.88	1.55	1.52	1.54
T_{12} - Pigeonpea +Soybean (1:3)	4.99	4.89	4.94	1.63	1.62	1.63
T_{13} - Sole Pigeonpea	5.11	5.16	5.13	1.49	1.50	1.50
T_{14} - Sole Rice	5.04	4.94	4.99	1.37	1.32	1.35
T_{15} - Sole Sesame	5.06	5.03	5.04	1.41	1.38	1.39
T_{16} – Sole Greengram	5.08	4.97	5.03	1.47	1.44	1.46
T_{17} – Sole Soybean	5.09	5.04	5.07	1.46	1.45	1.46
SEm±	0.05	0.13	0.07	0.05	0.04	0.03
CD (P=0.05)	NS	NS	NS	NS	0.11	0.09

Table 4.73: Available nitrogen (kg ha^{-1}) and available phosphorus (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	Available nitrogen			Available phosphorus		
	2021	2022	Pooled	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	244.14	252.88	248.51	23.33	23.29	23.31
T_2 - Pigeonpea +Rice (1:2)	244.57	254.14	249.35	22.97	23.09	23.03
T_3 - Pigeonpea +Rice (1:3)	247.44	257.90	252.67	23.42	23.40	23.41
T_4 - Pigeonpea +Sesame (1:1)	244.86	254.97	249.92	23.16	23.08	23.12
T_5 - Pigeonpea +Sesame (1:2)	249.75	261.94	255.84	23.22	23.20	23.21
T_6- Pigeonpea +Sesame (1:3)	250.95	260.86	255.91	23.71	23.81	23.76
T_7 - Pigeonpea +Greengram (1:1)	249.29	260.85	255.07	23.51	23.88	23.70
T_8 - Pigeonpea +Greengram (1:2)	255.14	262.13	258.63	23.50	23.50	23.50
T_9 - Pigeonpea +Greengram (1:3)	263.98	282.57	273.28	24.13	24.38	24.26
T_{10} - Pigeonpea +Soybean (1:1)	267.62	285.08	276.35	24.47	24.64	24.56
T_{11} - Pigeonpea +Soybean (1:2)	258.99	275.88	267.43	23.48	23.61	23.55
T_{12} - Pigeonpea +Soybean (1:3)	271.87	288.42	280.15	24.52	25.02	24.77
T_{13} - Sole Pigeonpea	249.14	259.99	254.57	23.44	23.46	23.45
T_{14} - Sole Rice	229.05	242.43	235.74	21.01	22.85	21.93
T_{15} - Sole Sesame	244.44	253.88	249.16	22.82	22.95	22.88
T_{16} – Sole Greengram	243.88	248.70	246.29	22.92	23.14	23.03
T_{17} – Sole Soybean	242.35	250.79	246.57	23.07	23.17	23.12
SEm±	5.68	9.13	5.38	0.63	0.51	0.41
CD (P=0.05)	16.36	26.30	15.19	NS	NS	1.15

Table 4.74: Available potassium (kg ha^{-1}) of pigeonpea under different intercropping system

Treatments	Available potassium		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	158.14	157.90	158.02
T_2 - Pigeonpea +Rice (1:2)	159.94	160.38	160.16
T_3 - Pigeonpea +Rice (1:3)	167.55	172.93	170.24
T_4 - Pigeonpea +Sesame (1:1)	154.56	154.56	154.56
T_5 - Pigeonpea +Sesame (1:2)	158.82	164.86	161.84
T_6- Pigeonpea +Sesame (1:3)	164.86	172.03	168.45
T_7 - Pigeonpea +Greengram (1:1)	152.32	155.90	154.11
T_8 - Pigeonpea +Greengram (1:2)	158.48	163.52	161.00
T_9 - Pigeonpea +Greengram (1:3)	161.73	169.09	165.41
T_{10} - Pigeonpea +Soybean (1:1)	148.29	151.42	149.86
T_{11} - Pigeonpea +Soybean (1:2)	150.98	159.94	155.46
T_{12} - Pigeonpea +Soybean (1:3)	160.83	168.45	164.64
T_{13} - Sole Pigeonpea	148.29	148.49	148.39
T_{14} - Sole Rice	143.36	145.15	144.26
T_{15} - Sole Sesame	146.05	146.05	146.05
T_{16} – Sole Greengram	148.74	158.48	153.61
T_{17} – Sole Soybean	150.08	158.81	154.45
SEm±	17.24	13.93	11.08
CD (P=0.05)	NS	NS	NS

Table 4.75: Cost of cultivation (Rs. ha^{-1}) of pigeonpea under different intercropping system

Treatments	Cost of cultivation		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	35514.66	35598.66	35556.66
T_2 - Pigeonpea +Rice (1:2)	35640.26	35724.26	35682.26
T_3 - Pigeonpea +Rice (1:3)	35496.26	35580.26	35538.26
T_4 - Pigeonpea +Sesame (1:1)	35304.26	35388.26	35346.26
T_5 - Pigeonpea +Sesame (1:2)	35240.26	35324.26	35282.26
T_6- Pigeonpea +Sesame (1:3)	35096.26	35180.26	35138.26
T_7 - Pigeonpea +Greengram (1:1)	35504.26	35588.26	35546.26
T_8 - Pigeonpea +Greengram (1:2)	35540.26	35624.26	35582.26
T_9 - Pigeonpea +Greengram (1:3)	35396.26	35480.26	35438.26
T_{10} - Pigeonpea +Soybean (1:1)	36516.26	36600.26	36558.26
T_{11} - Pigeonpea +Soybean (1:2)	36828.26	36912.26	36870.26
T_{12} - Pigeonpea +Soybean (1:3)	33743.64	33827.64	33785.64
T_{13} - Sole Pigeonpea	35144.26	35228.26	35186.26
T_{14} - Sole Rice	31728.74	31812.74	31770.74
T_{15} - Sole Sesame	36536.91	36620.91	36578.91
T_{16} – Sole Greengram	35997.53	36081.53	36039.53
T_{17} – Sole Soybean	40201.16	40285.16	40243.16
SEm±	-	-	-
CD (P=0.05)	-	-	-

Table 4.76: Gross returns (Rs. ha^{-1}) of pigeonpea under different intercropping system

Treatments	Gross return		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	130174.76	133339.76	131757.26
T_2 - Pigeonpea +Rice (1:2)	115610.85	117379.87	116495.36
T_3 - Pigeonpea +Rice (1:3)	109418.37	112271.53	110844.95
T_4 - Pigeonpea +Sesame (1:1)	151451.01	147416.14	149433.58
T_5 - Pigeonpea +Sesame (1:2)	128127.45	129914.06	129020.75
T_6- Pigeonpea +Sesame (1:3)	132385.29	137772.30	135078.79
T_7 - Pigeonpea +Greengram (1:1)	142610.46	140730.46	141670.46
T_8 - Pigeonpea +Greengram (1:2)	128620.69	130349.38	129485.03
T_9 - Pigeonpea +Greengram (1:3)	119387.23	122359.72	120873.47
T_{10} - Pigeonpea +Soybean (1:1)	168783.20	151671.06	160227.13
T_{11} - Pigeonpea +Soybean (1:2)	139708.03	131528.65	135618.34
T_{12} - Pigeonpea +Soybean (1:3)	145528.22	138885.37	142206.80
T_{13} - Sole Pigeonpea	98769.69	100171.59	99470.64
T_{14} - Sole Rice	57566.26	59329.07	58447.66
T_{15} - Sole Sesame	79948.39	85201.99	82575.19
T_{16} – Sole Greengram	68161.10	66821.44	67491.27
T_{17} – Sole Soybean	87293.15	88014.36	87653.75
SEm±	-	-	-
CD (P=0.05)	-	-	-

Table 4.77: Net returns (Rs. ha^{-1}) of pigeonpea under different intercropping system

Treatments	Net returns		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	94660.10	97741.10	96200.60
T_2 - Pigeonpea +Rice (1:2)	79970.59	81655.61	80813.10
T_3 - Pigeonpea +Rice (1:3)	73922.11	76691.27	75306.69
T_4 - Pigeonpea +Sesame (1:1)	116146.75	112027.88	114087.32
T_5 - Pigeonpea +Sesame (1:2)	92887.19	94589.80	93738.49
T_6- Pigeonpea +Sesame (1:3)	97289.03	102592.04	99940.53
T_7 - Pigeonpea +Greengram (1:1)	107106.20	105142.20	106124.20
T_8 - Pigeonpea +Greengram (1:2)	93080.43	94725.12	93902.77
T_9 - Pigeonpea +Greengram (1:3)	83990.97	86879.46	85435.21
T_{10} - Pigeonpea +Soybean (1:1)	132266.94	115070.80	123668.87
T_{11} - Pigeonpea +Soybean (1:2)	102879.77	94616.39	98748.08
T_{12} - Pigeonpea +Soybean (1:3)	111784.58	105057.73	108421.16
T_{13} - Sole Pigeonpea	63625.43	64943.33	64284.38
T_{14} - Sole Rice	25837.52	27516.32	26676.92
T_{15} - Sole Sesame	43411.48	48581.08	45996.28
T_{16} – Sole Greengram	32163.58	30739.91	31451.74
T_{17} – Sole Soybean	47091.99	47729.20	47410.59
SEm±	-	-	-
CD (P=0.05)	-	-	-

Table 4.78: B:C ratio of pigeonpea under different intercropping system

Treatments	B:C ratio		
	2021	2022	Pooled
T_1 - Pigeonpea +Rice (1:1)	2.67	2.76	2.71
T_2 - Pigeonpea +Rice (1:2)	2.24	2.29	2.26
T_3 - Pigeonpea +Rice (1:3)	2.08	2.16	2.12
T_4 - Pigeonpea +Sesame (1:1)	3.29	3.25	3.27
T_5 - Pigeonpea +Sesame (1:2)	2.64	2.68	2.66
T_6- Pigeonpea +Sesame (1:3)	2.77	2.92	2.84
T_7 - Pigeonpea +Greengram (1:1)	3.02	3.02	3.02
T_8 - Pigeonpea +Greengram (1:2)	2.62	2.66	2.64
T_9 - Pigeonpea +Greengram (1:3)	2.37	2.45	2.41
T_{10} - Pigeonpea +Soybean (1:1)	3.62	3.27	3.45
T_{11} - Pigeonpea +Soybean (1:2)	2.79	2.56	2.68
T_{12} - Pigeonpea +Soybean (1:3)	3.31	3.11	3.21
T_{13} - Sole Pigeonpea	1.81	1.81	1.81
T_{14} - Sole Rice	0.81	0.86	0.84
T_{15} - Sole Sesame	1.19	1.33	1.26
T_{16} – Sole Greengram	0.89	0.95	0.92
T_{17} – Sole Soybean	1.17	1.18	1.18
SEm±	-	-	-
CD (P=0.05)	-	-	-

IV Economics

Economics of a treatment is directly related to the success of that particular treatment and the extra input and outcome due to the treatment. Data on economic analysis are presented in Table 4.75, 4.76,4.77 and 4.78

4.8.1 Cost of cultivation

From the data presented in the Table 4.75, revealed that the highest cost of cultivation was recorded in sole soybean T_{17} (Rs. 40201.16, 40285.16 and 40243.16 in 2021, 2022 and pool data ha^{-1}) which may be due to higher requirement of seed of soybean in sole crop. The lowest cost of cultivation was recorded in sole rice T_{13} (Rs. 31728.74, 31812.74 and 31770.74 in 2021, 2022 and pool data ha^{-1}). Similar finding of higher cost of cultivation in sole soybean in pigeonpea intercropping system was also reported by Singh (2015).

4.8.2 Gross returns

As per the data given in Table 4.76, the higher value of gross return was observed in pigeonpea + soybean (1:1) T_{10} (Rs.168783.20, 151671.06, and 160227.13 ha^{-1} in 2021, 2022 and pooled data respectively) while the lowest value of gross return was observed in sole rice T_{14} (Rs. 57566.26, 59329.07 and 58447.66 in 2021, 2022 and pooled data respectively).

4.8.3 Net returns (Rs. ha^{-1})

Intercropping of pigeonpea + soybean (1:1) T_{10} obtained the highest net return value given in table 4.77 (Rs. 132266.94, 115070.80, and 123668.87 ha^{-1} in 2021, 2022 and pooled data respectively) followed by pigeonpea + sesame (1:1) T_4 (Rs. 116146.75, 112027.88, and 114087.32 ha^{-1} in 2021, 2022 and pooled data respectively). The lowest value of net return was obtained in sole rice T_{14} (Rs. 25837.52, 27516.32 and 26676.92 in 2021, 2022 and pooled data respectively). The higher gross returns resulted in higher net returns. These results are in close proximity to those obtained by Hussainy *et al*. (2020) and

Sai Ram *et al.* (2020) who also reported that higher net returns from intercropping over monocropping. All the intercropping systems gave substantially high net income over monocropping.

4.8.4 B:C ratio

Among the intercropping systems the highest B:C ratio (table 4.78) was recorded in pigeonpea + soybean (1:1) T_{10} with 3.62, 3.27 and 3.45 in 2021, 2022 and pooled respectively, followed by pigeonpea + sesame (1:1) T_4 (3.29,3.25 and 3.27 in 2021, 2022 and pooled data respectively). Sole rice T_{14} recorded the lowest B:C ratio (0.81, 0.86 and 0.84 in 2021, 2022 and pooled data respectively). An increased B:C ratio in intercropping system due to yield of intercrop was obtained in all the intercropping systems. Bhadu *et al*. (2020) also found that intercropping system of pigeonpea was more remunerative in respect of B:C ratio, net monetary return and gross monetary return in contrast to sole cropping.

Plate 1: General view of the experimental field

Plate 2: Different intercropping system at early growth stage

Plate 3: Different intercropping system at vegetative stage

Plate 4: Different crops under intercropping system at flowering stage

Plate 5(a): Different intercropping system at reproductive stage

Plate 5(b): Different intercropping system at reproductive stage

Plate 6: Harvested seeds of different crops

Plate 7: Laboratory analysis

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

The present study was conducted at the experimental farm of School of Agricultural Sciences, Nagaland University, Campus- Medziphema, Nagaland to evaluate the "Performance of pigeonpea based cropping systems under rainfed conditions of Nagaland" during the *kharif* season of 2021 and 2022 with the following objectives:

1. To study the effect of different intercrops on growth and yield of pigeonpea.
2. To find out suitable intercrops for pigeonpea.
3. To work out the economics of different treatments.

The experiment was laid out in randomised block design consisting of seventeen treatment combinations and the treatments were replicated three times. The prominent results of the present investigation are summarized below:

5.1 Summary

5.1.1 Growth attributes

Pigeonpea

- T_{13} (sole pigeonpea) performed significantly superior over other intercropping systems. Higher growth parameters *viz*., plant height (cm), plant population (m^{-2}), number of primary branches^{-1}, crop growth rate (g m^{-2} day^{-1}), absolute growth rate (g day^{-1}) {at 30-60 DAS (2022 and pooled), 60-90 DAS (pooled), 90- 120 DAS (2022, pooled)},relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS, net assimilation rate (g m^{-2} day^{-1}) at 30 DAS in pooled data and leaf area index during both the years and pooled data in sole pigeonpea was observed which were significantly at par with T_{10} (pigeonpea + soybean (1:1)).

- No significant effect on relative growth rate (g g^{-1} day^{-1}) at 60-90, 90- 120 DAS, absolute growth rate (g day^{-1}) {at 30-60 DAS (2021), 60-90 DAS (2021 and 2022), 90-120 DAS (2021)}, net assimilation rate (g m^{-2} day^{-1}) at 30-60 DAS (in 2021 and 2022), 60-90 DAS, 90-120 DAS.

Rice

- Significantly higher value of plant height (cm) at 30 DAS, plant population (m^{-2}), crop growth rate (g m^{-2} day^{-1}) at 30-60 DAS and absolute growth rate (g day^{-1}) at 30-60 DAS during 2021, 2022 and pooled data in T_{14} (sole rice) was recorded and these data were at par with T_3 (pigeonpea + rice (1:3)) intercropping system.

- No significant difference was recorded on plant height at 60 and 90 DAS, crop growth rate (g m^{-2} day^{-1}) at 60-90 DAS and absolute growth rate (g day^{-1}) at 60 - 90 DAS), relative growth rate (g g^{-1} day^{-1}) net assimilation rate (g m^{-2} day^{-1}) and leaf area index during both the years and pooled data.

Sesame

- Sole sesame T_{15} registered the highest value for growth parameters *viz.*, plant population (m^{-2}) and leaf area index at 30 and 60 DAS during both the years and pooled data which was at par with pigeonpea + sesame (1:3).
- There was no significant difference between different treatments on plant height (cm), crop growth rate (g m^{-2} day^{-1}), relative growth rate (g g^{-1} day^{-1}), absolute growth rate (g day^{-1}), net assimilation rate (g m^{-2} day^{-1}) and leaf area index at 90 DAS during 2021, 2022 and pooled data.

Greengram

- The highest growth parameters *viz.*, plant height (cm) at 30 and 60 DAS, plant population (m^{-2}), crop growth rate (g m^{-2} day^{-1}) at 30-60 DAS and absolute growth rate (g day^{-1}) at 30-60 DAS during 2021, 2022 and pooled data was observed in T_{16} (sole greengram), and was significantly at par with T_8 (pigeonpea + greengram (1:3)).

- No significant effect on different intercropping system was recorded in the plant growth parameters *viz.*,on plant height at 90 DAS, crop growth rate (g m^{-2} day^{-1}) at 60-90 DAS and absolute growth rate (g day^{-1}) at 60- 90 DAS, relative growth rate (g g^{-1} day^{-1}) net assimilation rate (g m^{-2} day^{-1}) and leaf area index during both the years and pooled data.

Soybean

- Intercropping of soybean with pigeonpea varied significantly in the initial growth stage of plant during both years of experimentation. T_{17} (sole soybean) at 30, 60 and 90 DAS respectively recorded the highest value for plant population, crop growth rate (g m^{-2} day^{-1}) at 30 – 60 DAS, absolute growth rate (g day^{-1}) at 30 – 60 DAS and leaf area index at 30 - 60 DAS which was significantly at par with T_{12} (pigeonpea + soybean (1:3)).
- Growth parameters *viz.*, plant height at later stage of crop growth (90 DAS), crop growth rate (g m^{-2} day^{-1}) at 60-90 DAS and absolute growth rate (g day^{-1}) at 60 - 90 DAS, relative growth rate (g g^{-1} day^{-1}) net assimilation rate (g m^{-2} day^{-1}) and leaf area index during both the years and pooled data failed to show any significant effect.

5.1.2 Yield attributes and crop yield

Pigeonpea

- Yield attributes *viz.*, plant stand at harvest (m^{-2}) and number of pods $plant^{-1}$ were significantly higher in T_{13} (sole pigeonpea).
- Seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) were recorded significantly higher in T_{13} (sole pigeonpea) during both the years of experiment.
- Higher values in growth parameters resulted in higher value of yield and yield parameters. These data were significantly at par with T_{10} (pigeonpea + soybean (1:1)) intercropping system.

- While number of seeds pod^{-1}, pod length (cm), weight of pod plant^{-1} (g), and seed index (g) was not significantly effected under different pigeonpea intercropping system during the experimentation period.

Rice

- T_{14} (sole rice) recorded higher yield attributes *viz*., plant stand at harvest and number of panicle (m^{-2})
- Significantly higher grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and biological yield (kg ha^{-1}) was also recorded in sole rice, and was statistically at par with T_3 (pigeonpea + rice (1:3)).
- Likewise, length of panicle (cm), weight of panicle (g), number of grains panicle^{-1}, filled grain (%), test weight (g) and harvest index (%) failed to show any significant effect.

Sesame

- Higher yield attributes viz., plant stand at harvest and number of capsule plant^{-1} was observed in T_{15} (sole sesame).
- Seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and biological yield (kg ha^{-1}) was the highest in sole sesame.
- T_6 (Pigeonpea + sesame (1:3)) was par with sole rice.
- No significant effect on number of seeds capsule^{-1}, weight of capsule plant^{-1}, test weight (g) and harvest index (%) was observed.

Greengram

- T_{16} (sole greengram) registered higher plant stand at harvest and number of pods plant^{-1}.
- Likewise, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and biological yield (kg ha^{-1}) was also registered the highest in T_{16} (sole greengram), which was at par with T_6 pigeonpea + greengram (1:3).
- Number of seeds pod^{-1}, weight of pod (g), test weight (g) and harvest index (%) showed no significant differences during intercropping system with pigeonpea.

Soybean

- Plant stand at harvest and number of pods plant^{-1} were recorded highest in sole soybean.
- T_{17} (sole soybean) recorded higher seed yield (kg ha^{-1}), stover yield (kg ha^{-1}) and biological yield (kg ha^{-1}) which was at par with T_9 (pigeonpea + greengram (1:3)).
- No significant effect on number of seeds pod^{-1}, weight of pod (g), test weight (g) and harvest index (%) was observed.

5.1.3 Plant analysis

Pigeonpea

- Significantly highest N, P and K content (%) was registered in T_{13} (sole pigeonpea) followed by pigeonpea + soybean (1:1) under intercropping system with pigeonpea during both the years of study.
- Similarly, in N, P and K uptake (kg ha^{-1}) T_{13} (sole pigeonpea) registered highest significant value and was at par with T_{10} (pigeonpea + soybean (1:1)) under intercropping system with pigeonpea during both the years of study.

Rice

- N, P and K content (%) in grain and straw of rice showed no significant difference under intercropping system with pigeonpea during the experiment period.
- While N, P and K uptake (kg ha^{-1}) in grain and straw was recorded highest in T_{14} (sole rice) and was superiorly higher than rest of the treatments under different intercropping systems during 2021, 2022 and pooled data.

Sesame

- There was no significantly difference on N, P and K content (%) in seed and stover of sesame under intercropping system with pigeonpea during both the years and pooled data.

- The significantly highest N, P and K uptake (kg ha^{-1}) was observed in T_{14} (sole sesame) which was superior than rest of the treatments under different intercropping with pigeonpea during both the years of experiment.

Greengram

- There was no significant difference on N, P and K (%) in seed and stover of greengram under different intercropping with pigeonpea during both the years of experiment.
- The highest N, P and K uptake (kg ha^{-1}) was recorded in T_{16} (sole greengram), which was superior than rest of the treatments under different intercropping with pigeonpea during both the years of experiment.

Soybean

- There was no significant difference on N, P and K (%) in seed and stover of soybean under different intercropping with pigeonpea during both the years of experiment.
- The highest value of N, P and K uptake uptake (kg ha^{-1}) was registered in T_{17} (sole soybean) superior than rest of the treatments under different intercropping with pigeonpea during both the years of experiment.

5.1.4 Intercropping competitive indices

- T_{12} (pigeonpea + soybean (1:3)) produced the highest PEY value which was significantly higher than the rest of the treatments in both the years.
- LER value in each and every system was more than 1.0 except the treatment with sole crop. The LER was observed marginally higher under T_{10} (pigeonpea + soybean (1:1)) during both the years.
- Higher value of ATER and RCC of system was observed in T_{10} (pigeonpea + soybean (1:1)) in both the years.
- While higher aggressivity and competition ratio was recorded in T_{12} (pigeonpea + soybean (1:3)) during the experiment period.

5.1.5 Soil anaylsis

- Application of different intercropping systems did not show any significant difference on the soil pH during both the years of studies.
- Soil OC failed to show any significance during the first year but had significant effect during the second year and pooled data.
- The highest value for available soil N (kg ha^{-1}) was recorded in T_3 (pigeonpea + rice (1:3)) in both the years.
- Available soil P (kg ha^{-1}) did not show no any significant effect during 2021 and 2022 but had significant effect on the pooled data.
- Effect of intercropping system failed to show any significant response on available soil K (kg ha^{-1}) during both the years.

5.1.6 Economics

- T_{17} (sole soybean) recorded the highest cost of cultivation followed by T_{11} (pigeonpea + soybean (1:2)) among the intercropping system.
- The highest gross returns (Rs. ha^{-1}), net returns (Rs. ha^{-1}) and B:C ratio was found in T_{10} (pigeonpea + soybean (1:1)) during both the years.

Conclusion

On the basis of the results of two years of experimentations during *kharif* 2021 and 2022 on pigeon based intercropping system was concluded as under:

- Growth paramters *viz.*, plant height (cm), plant population (m^{-2}), number of primary branches^{-1}, crop growth rate (g m^{-2} day^{-1}), relative growth rate (g g^{-1} day^{-1}) at 30-60 DAS, absolute growth rate (g day^{-1}) {at 30-60 DAS (2022 and pooled), 60-90 DAS (pooled), 90-120 DAS (2022, pooled)}, net assimilation rate (g m^{-2} day^{-1}) at 30 DAS in pooled data and leaf area index during both the years and pooled data in T_{13} (sole pigeonpea) was observed which were significantly at par with T_{10} (pigeonpea + soybean

(1:1)).

Yield attributes *viz*., plant stand at harvest (m^{-2}) and number of pods plant^{-1} were significantly higher in sole pigeonpea. Seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), biological yield (kg ha^{-1}) and harvest index (%) were recorded significantly higher in T_{13} (sole pigeonpea) followed by T_{10} (pigeonpea + soybean (1:1)) during both the years of experiment.

- T_{10} (pigeonpea +soybean (1:1)) recorded maximum gross returns, net returns and B:C ratio indicating the intercropping system to be most beneficial.
- Soybean as intercrop followed by sesame as intercrop in pigeonpea intercropping system was found to perform better in comparison to other intercrops.
- Thus, it can be concluded that T_{10} (pigeonpea + soybean (1:1)) was found to be best treatment for higher productivity and profitability of pigeonpea based intercropping system in rainfed conditions of Nagaland.

Future line of work

- It is apparent from the study that suitable intercropping systems boost resource use efficiency, yield, productivity and profitability of the system as a whole.
- There is a need for further studies on proportion of intercrops in pigeonpea based intercropping system.
- Multi-location and multi-seasonal field experiments are to be conducted for confirmation and stability on yield performance of the crop.
- However, these results are only indicative and require further studies, to arrive at some more consistent and final conclusion for making recommendations to the farmers.

REFERENCES

REFERENCES

Addo-Quaye, A. A., Darkwa, A. A. and Ocloo, G. K. 2011. Growth analysis of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. *Journal of Agricultural and Biological Sciences*. **6**(6): 34-44.

Adeniyan, O. N., Aluko, O. A., Olanipekum, S. O., Olasoji, J. O. and Aduramigba-Modupe, V. O. 2014. Growth and yield performance of cassava/maize intercrop under different plant population density of maize. *Journal of Agricultural Science*. **6**(8): 35-40.

Agegnehu, G., Ghizaw, A. and Sinebo, W. 2008. Yield potential and land - use efficiency of wheat and faba bean mixed intercropping. *Agronomy for Sustainable Development.* **28:** 257- 63.

Ahlawat, I. P. S., Gangaiah, B. and Singh, O. 2005. Production potential of chickpea (*Cicer arietinum*)-based intercropping systems under irrigated conditions. *Indian Journal of Agricultural Sciences*.**50**: 27-30.

Ahamad, A., Kumar, K., Roy, N. and Kumar, D. 2017. Response of integrated nutrient management on productivity and nutrient uptake of rainfed pigeonpea based intercropping systems. *Journal of Pharmacognosy and Phytochemistry*. **1**: 516-518.

Amanullah., Khalid, S., Khalil, F., Elshikh, M. S., Alwahibi, S. M., Alkahtani, J., Imranuddin and Imran. 2021. Growth and dry matter partitioning response in cereal-legume intercropping under full and limited irrigation regimes. *Scientific Reports*. **11**(12585): 1-15.

Anonymous. 2023. Nagaland Statistical Handbook. Directorate of Economics and Statistics Government of Nagaland.

Anonymous. 2022. www.iipr.icar.gov.in

Ansari, M. A., Rana, K. S. 2012. Effect of transpirational suppressants and nutrients on productivity and moisture-use efficiency of pearlmillet (*Pennisetum glaucum*)-pigeonpea (*Cajanus cajan*) intercropping system under rainfed conditions. *Indian Journal of Agricultural Sciences*. **82**(8): 676-680.

Arpita, B., Malik, G. G., Banerjee, M. and Palai, J. B. 2021. Effect of sesame + pulses intercropping systems on growth, yield and quality parameters of sesame. *The Pharma Innovation Journal*. **10**(8): 712-717.

Aye, N. 2013. Study of sunflower (*Helianths annus* L.) and Soybean (*Glycine max* L. Merill) intercropping and their effect on weed parameters. M.Sc. (Ag.) Thesis, Nagaland University, Medziphema.

Babu, S. K., and Padmalatha, Y. 2021. Evaluation of pigeonpea (*Cajanus cajan* L.) based intercropping systems in Krishna district of Andhra Pradesh. *The Pharma Innovation Journal*. **10**(10): 619-623.

Bagri, P. S. 2017. Assessment of pigeonpea in various cropping systems under rainfed situation. M.Sc. (Ag) Thesis, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur.

Bailey-Elkin, W. Carkner, M. and Entz, M. H. 2022. Intercropping organic field peas with barley, oats and mustard improves weed control but has variable effects on grain yield and net returns. *Canadian Journal of Plant Science*. **102**(3): 515- 528.

Bajpai, R. P. and Singh, V. K. 1992. Performance of pigeonpea (*Cajanus cajan*)- based intercropping in rainfed condition. *Indian Journal of Agronomy*. **37**(4):655-658.

Barthakur, B. C., Das, G. R., Baruah, A. R. and Dutta, T. C. 1985. Field manual for rainfed agriculture in Assam. Directorate of Research, Assam Agricultural University. pp 34.

Bhadu, K., Gupta, V., Rawat, G. S. and Sharma, J. 2020. Comparative performance of pigeonpea (*Cajanus cajan* (L). Millsp.) Based intercropping systems with short duration pulses and oilseed crops in gird region of Madhya Pradesh. *International Journal of Chemical Studies*. **8**(5): 192-194.

Bhagat, R. P. 2002. Intercropping of pigeonpea and maize under rainfed condition. *Journal of Research*. **14**: 233-235.

Bhardwaj, R., Kushwaha, H. S., Birla, J., Turkar, Y. and Patidar. K. 2023. Studies on nutrient management in pigeon pea [*Cajanus cajan* (L.) Millsp.] based intercropping system. *Legume Research*. **46**(8):1048-1053.

Behara, B. D., Singh, G. S.and Senapati, P.C. 1998. New vistas for Agriculture in rainfed plateaus of Orissa. *Indian Farming*. **47**(12):14-16.

Billore, S. D., Vyas, A. K. and Joshi, O. P. 2009. Effect of integrated nutrient management in soybean (*Glycine max* L.) and pigeonpea (*Cajanus cajan* L.) intercropping on productivity, energy budgeting and competition functions. *Journal of Food legumes*. **22**:124-126.

Biradar, S. A., Devarnavadagi, V. S., Hotkar, Shivalingappa., Kolhar. B. C. and Rathod, S. C. 2020. Performance of pigeon pea (*Cajanus cajan* L.) based intercropping system with millets under Northern Dry Zone of Karnataka. *Journal of Krishi Vigyan*. **9**(1): 277-281

Bray, R. H. and Kunz, L. T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Science*. **59:** 39-45.

Chaudhary, M., Kumar, R., Yadav, A., Maurya, S. K., Sahu, S. and Tiwari, A. 2022. Best Row Ratio Combinations of Agronomic Crops in the Intercropping System: An Overview. *International Journal of Plant & Soil Science.* **34**(22): 645-654.

Chidowe, O. A., Destiny, M. Y. and Aisha, A. 2017. Soil organic carbon concentrations and stocks under maize/legume cropping system in alfisols of a savanna zone, Nigeria. *British Journal of Applied Science & Technology*. **21**(1): 1-12.

Chhetri, B. and Sinha, A. C. 2020. Advantage of maize (*Zea mays*)-based intercropping system to different nutrient management practices. *Indian Journal of Agronomy*. **65**(1): 25-32.

Chongloi, K. L. 2021. Soil nutrient uptake and balance as influenced by intercropping and integrated nutrient management. *International Journal of Current Microbiology and Applied Sciences.* **10**(02): 1176-1184.

Choudhary, A. K., Thakur, R. C. and Kumar, N. 2007. Effect of organic manures and chemical fertilizers on productivity and profitability in wheat-rice crop sequence. *Oryza*. **44**(3): 239-242.

Choudhary, S. K. and Thakur, S. K. 2005. Productivity of pigeonpea (*Cajanus cajan*) – based intercrops. *Indian Journal of Agricultural Sciences*. **75**(8): 496-97.

Darshan, R., Hiremath, S. M. and Harsha, K. N. 2009. Pigeonpea - sesame intercropping systems for sustained production in northern transition zone of Karnataka. *Journal of Crop and Weed*. **5**(1): 305-307.

Das, K. K. 2012. Performance of pigeonpea + soybean cropping system as influenced by sources and levels of phophorus and their residual efeect on succeeding wheat. Ph.D. Thesis. Chaudhary Charan Singh University, Meerut. UP.

Dass, A. and Sudhishri, S. 2010. Intercropping in fingermillet (*Eleusine coracana*) with pulses for enhanced productivity, resource conservation and soil fertility in uplands of Southern Orissa. *Indian Journal of Agronomy*. **55**(2): 89-94.

Debata, D. K and Das, L. K. 2024. Performance of turmeric (*Curcuma longa* L) and pigeon pea (*Cajanus Cajan* L.) intercropping system under North Eastern Ghat Zone of Odisha, India. *Journal of Scientific Research and Reports*. **30**(4):179-186.

Deshmukh, P. Swapnil., Surve, V., Patel, H. H., Patel, T. U. and Patel, D. D. 2020. Effect of row spacing and intercropping in pigeon pea under rainfed condition of South Gujarat. *Journal of Pharmacognosy and Phytochemistry*. **9**(1): 1571-1573.

De Wit, C. T. 1960. On competition. Versl. Land Bouwk Onderzoek. **66:** 1-82.

Dhandayuthapani, U. N., Loganathan., V. and Latha, K. R. 2015. Growth parameters of pigeonpea and greengram as influenced by different cropping geometry and intercropping ratio. *Environment and We and International Journal of Science and Technology*. 101-106.

Dhandayuthapani, U. N., and R. L. Kuzhanthaive. 2015. Analysis of light transmission ratio and yield advantages of pigeonpea in relation to intercrop and different plant population. *African Journal of Agricultural Research*. **10**(8):731-736.

Dhale, S. Y., Asewar, B.V., Chand, Shaikh. Wasim., Mirza, IAB. and Narkhede, W. N. 2022. Effect of soybean: Pigeonpea strip cropping on growth parameters, yield attributes and yield under mechanization. *The Pharma Innovation Journal*. **11**(7): 684-687

Dwivedi, A., Dev, I., Kumar, V., Yadav, R. S., Yadav, M. and Gupta, D. 2015. Potential role of maize-legume intercropping systems to improve soil fertility status under smallholder farming systems for sustainable agriculture in India. *International Journal of Life Sciences Biotechnology and Pharma Research*. **4**(3):145.

Egbe, O. M. and Kalu, B. A. 2009. Evaluation of pigeonpea [*Cajanus cajan* (l.) millsp.] genotypes for intercropping with tall sorghum (*Sorghum bicolor* (l.) moench) in Southern Guinea Savanna of Nigeria. *ARPN Journal of Agricultural and Biological Science*. **4**(4): 54-65.

Egbe, O. M. and Bar-Anyam, M. N. 2011. Effects of sowing density of intercropped pigeonpea with sorghum on biomass yield and nitrogen fixation in southern guinea savanna of Nigeria. *Production Agriculture and Technology Journal*. **7**(1): 1-14.

Fatokimi, E. O., Tanimonure, V. A. 2021. Analysis of the current situation and future outlooks for pigeon pea (*Cajanus cajan*) production in Oyo State, Nigeria: a Markov Chain model approach. *Journal of Agriculture and Food Research*. **6**(100218): 1-8.

Ghosh, P. K. 2004. Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. *Field Crops Research*. **88:** 227-237.

Girisha, G. C., Bhairappanavar, S. T. and Koler, P. 2020. Effect of finger millet + blackgram intercropping system on growth and yield of finger millet. *MysoreJournal of Agricultural Sciences*. **54** (3): 91-100.

Gregory, F. G. 1926. The effects of climatic conditions on the growth of barley. *Annals of Botany*. **40:** 1-26.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for agricultural research. 2nd Edition, John Wiley and Sons, New York (USA). Pp 639.

Halvankar, G. B., Varghese, P., Taware, S. P. and Raut, V. M. 2000. Evaluation of intercropping patterns of soyabean (*Glycine max*) in pigeonpea (*Cajanus cajan*). *Indian Journal of Agronomy*. **45**(3): 530-533.

Heggenstaller, A. H., Liebman, M. and Anex, R. P. 2009. Growth analysis of biomass production in Sole-Crop and Double-Crop corn systems. *Crop Science*. **49**: 2215-2224.

Hiebsch, C. K. 1980. Principles of intercropping: Effect of N fertilization and crop duration on equivalency ratios in intercrops versus monoculture comparisons. Ph.D. Thesis, North Carolina State University, Raleigh.

Hussainy, S. A. H., Brindavathy, R. and Vaidyhanathan, R. 2020. Production potential of groundnut (*Arachis hypogaea* L.) under intercropping system – A review. *Crop Research*. **55**(1-2): 36- 47.

Jabbar, A., Ahmad, R., Ullah, E. and Nazir, M. M. 2005. Agronomic approaches for productivity enhancement of upland rice based intercropping system strip plantation. *Pakistan Journal of Agricultural Sciences*. **42** (2): 14-17.

Jackson, M. L. 1973. Soil chemical analysis, Prentice Hall of India Private Limited, New Delhi. Pp 183-192.

Jat, H. S. and Ahlawat, I. P. S. 2003. Response of pigeonpea (*Cajanus cajan*) + (*Arachis hypogaea*) intercropping system to planting pattern and phosphorous management. *Indian Journal of Agronomy*. **48**(3):156-159.

Jha, K. P., Moorthy, B. T. S. and Misra, A. P. 1991. Rice-based cropping system for rainfed upland of eastern India. *Indian Journal of Agronomy.* **36**(2): 218-222.

Joy, P. P., Rajaram, K. P. and James, K.I. 1987. A rice legume cropping system. Rice Abst **10** (4): 164

Jukanti, A. K., Gaur, P. M., Gowda, C. L. L. and Chibbar, R. N. 2012. Nutritional quality and health benefits of chickpea (*Cicer arietinum* L.): *A review. British Journal of Nutrition.* **108:**11-26.

Katmale, D. K., Dhadge, S. M., Satpute, N. R., Patil, S. V., Chary, G. R., Rao, C. S., Jadhav, J. D. and Kadam, J. R. 2014. Evaluation of pigeonpea (*Cajanus cajan* L.) based intercropping systems under semi-arid vertisol in scarcity zone of Maharashtra. *Indian Journal of Dryland Agricultural Research and Development.* **29:** 27-34.

Kantwa, S. R., Ahlawat, I. P. S., and Gangaiah, B. 2005. Effect of land configuration, post-monsoon irrigation and Phosphorus on performance of sole and intercropped pigeonpea. *Indian Journal of Agronomy,* **50**(4): 278-280.

Kaparwan, D., Rana, N. S., Vivek and Dhyani, B.P. 2021. Effect of Mustard on yield attributes, nutrient uptake and quality of chickpea under Different nutrient management levels and intercropping treatments in chickpea + mustard intercropping system. *International Journal of Current Microbiology and Applied Science*. **10**(3): 427-433.

Kasbe, A.B., P.N. Karanjikar, P.N., Dhoke, M.K. and Deshmukh R.B. 2010. Effect of planting pattern on soybean and pigeonpea intercropping system. *International Journal of Agricultural Sciences*. **6**(1): 330-332.

Khargkharate, V. K. Kadam, G. L. Pandagale, A. D. Awasarmal, V. B. Rathod, S. S. 2014. Studies on kharif legume intercropping with Bt cotton under rainfed conditions. Cotton Research and Development Association, Hisar, *Indian Journal of Cotton Research and Development*. **2**: 243-246.

Keerthanapriya, S., Hemalatha, M., Joseph, M. and Prabina, B. J. 2019.

Assessment of competitiveness and yield advantages of little millet based intercropping system under rainfed condition. *International Journal of Chemical Studies*. **7**(3): 4121-4124.

Kithan, L. 2012. Effect of maize (*Zea mays* L.) and soybean (*Glycine max* L. Merrill) intercropping on weed dynamics. M.Sc. (Ag.) Thesis, Nagland University, Medziphema.

Kithan. L., Sharma, M. B., Longchar, A., Sema, T. and Sumi, K. 2020. Exploring yield potential of pigeonpea and soybean intercropping systems in NEHZ. *International Journal of Plant & Soil Science*. **32**(9): 20-27.

Kotadiya, P. B., Leva, R. L., Usadadiya, V. P., Chaudhary B. J. and Shiyal, V. N. 2023. Effect of sesame based intercropping system with different levels of nitrogen on nutrient content, uptake and post-harvest soil status. *The Pharma Innovation Journal*. **12**(7): 1101-1108.

Kour, P., Kumar, A., Sharma, B. C., Kour, R. and Sharma, N. 2014. Nutrient uptake as influence by weed management in winter + potato intercropping system. *Indian Journal of Weed Science*. **46**(4): 336-341.

Kour, R., Sharma, B. C., Kumar, A., and Paramjeet Kour, P. and Nandan, B. 2016. Study of physiological growth indices of chickpea in chickpea (*Cicer arietinum*) + mustard (*Brassica juncea*) intercropping system under different weed management practices. *Legume Research*. **39**(3): 453-458.

Kujur, S. and Ahamad, S. 2018. Productivity, profitability and soil fertility in pigeonpea + fingermillet intercropping system as influenced by their row ratio and cultivars. *International Journal of Current Microbiology and Applied Sciences.* **7**:1159-1165.

Kumar, A. 2009. Evaluation of intercropping system of mustard under Agra region. Ph.D. Thesis, Dr. B. R. Ambedkar University, Agra.

Kumar, B. Bharti, C., Kumar, S., Barla, S., & Chaudhary, D. K. 2019. Productivity and economic assessment of fodder + Pigeon Pea (*Cajanus cajan*) intercropping system under upland situation of Jharkhand. *Chemical Science Review & Letters*. **8**(30): 198-201.

Kumar, N., Dhaka, A.K., Kumar, S., Singh, B., Bhatia, J. K and Gupta, G. 2020. relative advantages and economics of maize based intercropping systems. *Forage Research*. **46**(3): 254-260

Kumar, P. and Uthayakumar, B. 2006. Use of organics for crops for crop production under rainfed situation-A review. *Agricultural Reviews*. **27**: 208-215.

Kumar, P. Rathi, K.S. and Prasad, K. 2002. Effect of component crops in intercropping of linseed + mustard under increasing rates of nitrogen. *Crop Research*. **23**(2): 283-286.

Kumar, Pramod., Rana, K.S. and Rana D.S. 2012. Effect of planting system and phosphorus with bio-fertilizers on the performance of sole and intercropped pigeonpea (*Cajanus cajan*) under rain-fed conditions. *Indian journal of Agronomy*. **57**(2): 127-132.

Kumar, P., Rana, K.S., Ansari, M. A. and Om, H. 2013. Effect of planting system and phosphorus on productivity, moisture use efficiency and economics of sole and intercropped pigeonpea (*Cajanus cajan*) under rainfed conditions of northern India. *Indian Journal of Agricultural Science*. **83**:549-54.

Kumar., R. 2004. Performance of intercropping and strip cropping systems of pearl millet legume association. Thesis Submitted to Choudhary Charan Singh Haryana Agricultural university, HISAR.

Kumar, R., Paslawar, N., Singh, U. and Nagar, R. K. 2015. Effect of conservation tillage on growth, production and energetics of pigeonpea based intercropping system under rainfed area. *The Ecoscan.* **9:**153-157.

Kumar, R., Turkhede, A. B., Meena., S. and Nagar, R. K. 2016. Performance of American cotton-legumes based intercropping system on nutrient uptake and soil nutrient status. *Agricultural Science Digest.* **36**(3): 234-236.

Kumar, S., Singh, R. C. and Kadian, V. S. 2005. Compatibility of pigeonpea and green gram intercropping systems in relation to row ratio and row spacing. *Legume Research*. **28**(3): 213 – 215.

Kumar, U. and Kushwaha, H. S. 2018. Studies on nutrient management in pigeonpea [*Cajanus cajan* (L) Millsp] based intercropping system of urd bean, sesame and mung bean. *Journal of Pharmacognosy and Phytochemistry*. **7**(2): 490-494

Kumawat, N., Singh, R. P., Kumar, A. and Kumar, P. 2012. Response of intercropping and integrated nutrition on production potential and profitability on rainfed pigeonpea. *Journal of Agricultural Sciences*. **4**: 154-162.

Kumawat. N., Singh, R. P., Kumar, R., Yadav, T. P. and Om, H. 2015. Effect of integrated nutrient management on productivity, nutrient uptake and economics of rainfed pigeonpea (*Cajanus cajan*) and blackgram (*Vigna mungo*) intercropping system. *Indian Journal of Agricultural Sciences.* **85:** 171-76.

Kushwaha, A. and Mehta, C. M. 2023. Pigeon Pea (*Cajanus cajan* L.) Based Intercropping System: A Review. *International Journal of Plant & Soil Science*. **36**(5): 2320-7035.

Lavanya, Y. and Kurhade, N. G. 2018. Growth, yield attributes and yield of pigeonpea + niger intercropping system as influenced by planting pattern under rainfed condition of Marathwada region. *International Journal of Current Microbiology and Applied Sciences*. **7**(11): 2303-2309.

Lawrence, H. and Gohain, T. 2011. Intercropping of Green Gram (*Vigna radiata* L) with upland Rice (*Oryza sativa* L) under rainfed condition of Nagaland. *Indian Journal of Hill Farming*. **24**(2): 25-28.

Laxminarayana, K. and Munda, G. C. 2004. Performance of rice (*Oryza sativa*) and maize (*Zea mays*) **-** based cropping system under mid–hills of Mizoram. *Indian Journal of Agronomy*. **49**(4): 230-232.

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A. and Vlachostergios, D. N. 2011. Annual intercrops: an alternative pathway for sustainable agriculture. *Australian Journal of Crop Science.* **5:** 396 – 410.

Lingaraju, B. S., Marer, S. B. and Chandrashekar, S. S. 2008. Studies on intercropping of maize and pigeonpea under rainfed conditions in northern transitional zone of Karnataka. *Karnataka Journal of Agricultural Science*. **21**(3)1-3.

Mahapatra, P. K. 1991. Weed control in intercropping systems based on pigeonpea (*Cajanus cajan*). *Indian Journal of Agricultural Sciences*. **61**(12): 885-888.

Mahapatra, S. C. 2011. Study of grass **-**legume intercropping system in terms of competition indices and monetary advantage index under acid lateritic soil of India. *American Journal of Experimental Agriculture.* **1:**1-6.

Mahto, D. K., Ahmad, S., Singh, S. and Srivastava, G. P. 2007. Soil fertility and nutrient uptake in fingermillet (*Eleusine coracana* L.) based intercropping systems. *Journal of Research* (BAU). **19**(1): 87-90.

Maini, R. and Sandhu, K. S. 2022. Response of pigeonpea (*Cajanus cajan*) variety Pusa Arhar 16 to different row spacing and intercropping systems. *Indian Journal of Agronomy*. **67**(2): 212-215.

Mallikarjun, K., B. G., Desai, B. K., Basavanneppa, M. A., Rao, K. N. and Swamy, Mahadev. 2018. Performance of pigeonpea (*Cajanus cajan*) intercropping as influenced by row ratios and nutri cereal crops. *International Journal of Current Microbiology and Applied Sciences*. **7**(6): 2653-2658.

Mandal, B. K., Dasgupta, S. and Roy, P. K. 1986b. Yield of wheat, mustard and chickpea grown as sole crop and intercrop with four moisture regimes. *Indian Journal of Agricultural Sciences*. **56**(3): 577

Mandal, B. K., Dasgupta, S., Roy, P.K. and Mandal, Bikash K. 1987. Package of practices for improving gram yield in West Bengal. *Journal of Indian Farming*. **37**(9): 12-13.

Mandal, B. K., Dhara, M.C., Mandal, B.B., Das, S.K. and Nandy (Mrs) R. 1989. Effect of intercropping on the yield components of rice, mungbean, soybean, peanut and blackgram. *Journal of Agronomy and Crop Science.* **162:** 30-34.

Mandal, B. K. and Mahapatra, S. K. 1990. Barley and water use of barley, lentil and linseed under irrigation, mulch and intercropping system. *Indian Journal of Plant Physiology*. **36** (Accepted).

Mandal, B.K., Tapan, K. and Jana. and Sanjay, S. 1997. Yield and monetary advantage of intercropping rice in Nadia region of West Bengal. *Indian Journal of Agronomy*. **42**(2): 196-200.

Mandal, M. K., Banerjee, M., Alipatra, A. and Malik, G.C. 2014. Production of maize (*Zea mays*) based intercropping system during *kharif* season under red and lateritic tract of West Bengal. *The Bioscan*. ***9***(1): 31-35.

Manjunath, M. G., Salakinkop, S, R., Nayak, H. G. H. and Varalakhmi, A. 2023. Productivity and nutrient uptake of soybean and millets in intercropping systems. *The Pharma Innovation Journal*. **12**(3): 3633-3635.

Mazaheri, D., Madani, A. and Oveysi, M. 2006. Assessing the land equivalent ratio (LER) of two corn (*Zea mays* L.) varieties intercropping at various nitrogen levels in Karaj, Iran. *Journal of Central European Agriculture*. **7**(2):359-364.

McGilchrist, C. A. 1965. Analysis of competition experiments. *Biometrics*. **21**: 957-985.

Meena, S. L., Shamsudheen, M. and Dayal, D. 2008. Impact of row ratio and nutrient management on performance of clusterbean (*Cyamopsis tetragonoloba*) + sesame (*Sesamum indicum*) intercropping system. *Indian Journal of Agronomy*. **53**(4): 285-289

Merkeb, Fitsum. 2016. Effect of population density and spatial arrangements of pigeon pea (*Cajanus cajan* L. Millsp) on productivity of maize-pigeon pea intercropping. *World Scientific News*. **53**(3). 216-229.

Mohan, G., Gohain, T., Tzudir, L., Singh, A. P. and Nongmaithem, D. 2023a. Study on yield, nutrient content and nutrient uptake of rice- based intercropping system as influenced by integrated nutrient management. *Biological Forum – An International Journal*. **15**(7): 141- 146.

Mohan, G., Gohain, T., Yadav, R., Longkumer, L. T. and Dolie, S. 2023b. Intercropping of rice with groundnut and soybean with different nutrient management practices under rainfed upland conditions of Nagaland. **25**(3): 404-411.

Mohankumar, R., Girijesh, G. K., Krishnamurthy, N., Reddy, V. C. and Vageesh, T. S. 2012. Yield potential, biological feasibility and economic viability of maize (*Zea mays* L.) and local fieldbean (*Dolichos lablab* L.) inter cropping system in southern transitional zone of Karnataka. *World Research Journal of Agronomy*. **1**(1): 1 **-** 3.

Mousavi, S. R. and Eskandari, H. 2011. A general overview on intercropping and its advantages in sustainable agriculture. *Journal of Applied Environmental and Biological Sciences*. **1**(11): 482-486.

Nambiar, P. T. C., Rao, M. R., Reddy, M. S., Floyd, C. N., dart, P. J. and Willey, R. W. 1983. Effect of inter-cropping on nodulation and N_2- fixation by groundnut. *Experimental Agriculture*. **19**: 1979- 1986.

Nndwambi, F. H., Mariga, I. K. and Kutu R. F. 2016. Growth and yield responses of pigeonpea to variable phosphorus application rates when intercropped with maize under dryland conditions. *Journal of Agriculture and Crops*. **2**(12): 121-130.

Oad, F. C., Siddiqui, M. H. and Buriro, U. A. 2007. Agronomic and economic interference between cotton *Gossypium hirsutum* L. and pigeon pea *Cajanus cajan* L. *Journal of Agronomy*. **6**(1): 199-203.

Ogutu, M. O., Ouma, G., Ogolla, H., Okech, J. N. and Kidula, N. 2012. Rainfed rice-legume based cropping systems for sustainable food security and soil fertility improvement in western Kenya. *Journal of Agricultural and Biological Sciences*. **7**(9): 709- 720.

Omprakash and Bhushan, C. S. 2000. Productivity and economics of pigeonpea and castor based intercropping system. *Indian Journal of Soil Conservation*. **28** (2): 147-150.

Padhi, A. K. and Panigrahi, R. K. 2006. Effect of intercropping and crop geometry on productivity, economics, energetics and soil-fertility status of maize (*Zea mays*)-based intercropping systems. *Indian Journal of Agronomy*. **51**(3): 174–177.

Padhi, A. K., Panigrahi., R. K and Jena, B. K. 2010. Effect of planting geometry and duration of intercrops on performance of pigeonpea - fingermillet intercropping systems. *Indian Journal of Agricultural Research.* **44**: 43- 47.

Padhi, A. K., Sahoo, B. K., Das, K. C. 1992. Productivity of rainfed pigeonpea (*Cajanus cajan*) based intercropping systems. *Indian Journal of Agricultural Sciences*. **62**(9): 594-598.

Pal, K., Singh, R. S., Shukla, U. N. and Singh, Smita. 2016. Growth and production potential of pigeonpea (*Cajanus cajan* L.) as influenced by intercropping and integrated nutrient management. *Journal of Applied and Natural Science.***8:** 179 -83.

Pali, G. P., Patel, S.R. and Tripathi, R.S. 2000. Intercropping in linseed (*Linum usitatissimum*) with mustard (*Brassica juncea*) under rainfed condtion of Chattisgarh region. *Indian Journal of Agronomy*. **45**(3): 540-544.

Pandey, I. B., Singh, S. K. and Tiwari, S. 2013. Integrated nutrient management for sustaining the productivity of pigeonpea (*Cajanus cajan*) based intercropping systems under rainfed condition. *Indian Journal of Agronomy*. **58:** 192-97.

Pandit, S. G., Khurade, N. G., More, V. R. and Jagtap, M. P. 2020. Response of pigeon pea + bajra intercropping systems under variable crop geometry and plant population level under rainfed condition. *International Journal of Current Microbiology and Applied Sciences.* **9**(2): 1673-1679.

Papong, J. R. and Cagasan, U. A. 2020. Growth and yield performance of upland rice (*Oryza sativa* L. var. zambales) intercropped with mungbean (*Vigna radiata* L.) and peanut (*Arachis hypogaea* L.). *International Journal of Agriculture, Forestry and Life Sciences.* **4**(1): 34-41.

Patel, S. U., Maheriya, V. D. and Patel, H. F. 2013. Intercropping in rabi pigeon pea (*Cajanus cajana* L.) in south Gujarat. *Bioinfolet*. **10**: 317-19.

Patra, A. P. 2005. Studies on growth of rice and greengram in intercropping, as influenced by nitrogen levels in rice, during rainy season of West Bengal. *Journal of Crop and Weed*. **1**(1): 17-20.

Patra, B. C., Mandal., B. K. and Mandal., B. B. 1990. Profitability of maize-legume intercropping systems. *Indian Agriculturist.* 34**(4):** 227-233.

Patra, B. C. and Patra, A. P. 2010. Productivity of soybean and sesame as influenced by intercropping in entisol of West Bengal. *Environment and Ecology*. **28**(1A): 262-265

Piper, C. S. 1966. Soil and Plant analysis. Academic Press. pp 47-77.

Podder, R., Kumar, S., Pannu, R. K. and Dhaka, A. K. 2013. Evaluation of chickpea (*Cicer arietinum* L.) species based intercropping system on yield and economics. *Annals of Biology*. **29**(3): 327-370

Pragatheeswaran, M., Kalaiyarasan, C., Jawahar, S., Kanagarajan, R. and Suseendran, K. 2021. Effect of different planting geometry and sulphur fertilization on yield, quality, nutrient uptake and post-harvest soil nutrient status of sunflower in sunflower + green gram intercropping system. *Plant Archives*. **21**(1):959-962.

Prajapat, K., Shivran, A. C., Choudhary, G. L. and Choudhary, H. R. 2012. Influence of planting pattern and sulphur on mungbean (*Vigna radiata*) and sesame (Sesamum indicum) intercropping under semi-arid region of Rajasthan. *Indian Journal of Agronomy*. **57**(1): 89-91.

Prajapat, K., Shivran, A.C., Yadav, L.R., and Choudhary, G. L. 2011. Growth, production potential and economics of mung bean as influenced by intercropping systems and sulphur levels. *Journal of Food Legumes*. **24**(4):330-331.

Prasad, K. and Shrivastava, R. C. 2011. Pigeonpea (*Cajanus cajan*) and soyabean (*Glycine max*) intercropping system under rainfed situation. *Indian journal agricultural science*. **61**:243-246.

Radford, P. J. 1967. Growth analysis formulae, their use abuse. *Crop Science*. **8**:171-175

Rajashree, Dodamani, B. M., Rathod, P. S., Patil, D. H. and Amaregouda, A. 2022. Influence of different fodder crops on the growth Parameters of pigeonpea under pigeonpea based fodder intercropping system under rainfed conditions of north Karnataka. *The Pharma Innovation Journal*. **11**(2): 1436-1439.

Ram, K. and Meena, R. S. 2014. Evaluation of pearl millet and mungbean intercropping systems in arid region of Rajasthan (India). *Bangladesh Journal of Botany*. **43**(3):367-370.

Ramesh, P. and Reddy, K. S. 2004. Productivity and nutrient use efficiency of soybean (*Glycine max*) and sorghum (*Sorghum bicolor*) intercropping at different levels of nitrogen in rainfed deep vertisols. *Indian Journal of Agronomy*. 49(1): 31-33.

Rana, K. and Pal, M. 1997. Productivity and water use in pigeonpea –based on intercropping systems as affected by weed control in rainfed conditions. *Indian Journal of Agronomy*. **42**(4):576-580.

Rana, S. K., Maiti, D., Banrwal, M. K., Singh, R. K. and Variar, M. 2002. Effect of rice based intercropping system on vesicular-arbuscular mycorrhizal colonization, P uptake and yield. *Indian Journal of Agricultural Sciences*. **72**(1): 400-403.

Rani, B. P and Reddy, D. R. 2010. Performance of pigeonpea in sole and inter cropping system in vertisols of Krishna - godavari zone in Andhra Pradesh. *Indian Journal of Agricultural Research*. **44**(3): 225 – 228.

Rao, J.V, Khan, I. A. and Sujatha (Eds.). 2003. Critical Review of Research on Intercropping Systems in Rainfed Regions of India. National Agricultural Technology Project, Central Research Institute for Dryland Agriculture

(CRIDA), Hyderabad, India, pp. 1-100.

Rao, M. R. and Mathuva, M. N. 2000. Legumes for improving maize yields and income in semi-arid Kenya. *Agriculture*, *ecosystems & environment*. **78**(2): 123-137.

Rathod, P. S., Halikatti, S. I., Hiremath, S.M. and Kajjidoni, S. T. 2004. Influence of different intercrops and row proportions on yield and yield parameters of pigeonpea in vartisols of Dharwad. *Karnataka Journal of Agricultural Sciences* **17**: 652-657.

Rathiya, P. S., Lakpale, R., Shrivastava, G. K. and Bargali, S. S. 2010. Effect of nutrient blending with FYM on biomass production and economics under hybrid cotton- soybean intercropping system. *Journal of Plant Development Sciences*. **2**(1-2): 9- 18.

Ravindra, C. G., Venketeswarlu, B., Sharma, S. K., Mishra, J. S, Rana, D. S., and Ganesh, Kute. 2012. Agronomic Research in dryland farming in India: An Overview. *Indian Journal of Agronomy*, 57 (3rd IAC special issue):157-167.

Ravindra, P. G. 2019. Performance of pigeonpea (*Cajanus cajan* L.) based intercropping system under varied weather condition. M. Sc. (Ag) Thesis, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharastra.

Ray, S., De, B. and Hazari, S. 2016. Enhancing productivity potential of pigeonpea (*Cajanus Cajan* L.) based intercropping system on a lateritic red soil of Tripura. Journal of Food Legumes. **29**(1): 33-36.

Raza, M. A., Zhiqi, Wang., Hassan Shehryar Yasin, H. S., Gul, H., Qin, R., Rehman S. U., Mahmood, A., Iqbal, Z., Ahmed. Z., Luo, S., Juan, C., Liang, X., Gitari, H., Khalid, M. H. B., Feng, Y. and Zhongming, M. 2023. Effect of crop combination on yield performance, nutrient uptake, and land use advantage of cereal/legume intercropping systems. *Field Crops Research*. 304. 109144

Reddy, V., Koppalkar, B.G., Kiran. And Mallikarjun. 2015. Growth and yield advantages of pigeonpea with sesame intercropping system influenced by nutrient management. *The Ecoscan*. **7**:01-05.

Rusinamhodzi, L., Corbeels, M., Nyamangara, J., and Giller, K. E. 2012. Maize– grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field crops research*. **136**: 12-22.

Sai Ram, M., Maitra, S., Shankar, T. and Duvvada, S. K. 2020. Effect of integrated nutrient management on growth, yield, nutrient content and economics of summer rice (*Oryza sativa* L.). *Indian Journal of Pure and Applied Bioscience*. **8**(3): 421-427.

Sangtam, K., Ezung, N. K. and Jamir. T. 2019. Response on Growth and Yield of Maize as Affected by Different Intercropping Systems under Rubber Plantation in Hill Areas of Nagaland. *International Journal of Current Microbiology and Applied Sciences*. **8**(5): 632-638

Sarkar, R. K., Goswami, S. and Pal, P. K. 2003. Production potential and economic feasibility of sunflower (*Helianthus annuus*) and pigeonpea (*Cajanus cajan*) intercropping system on rainfed upland condition. *Indian Journal of Agronomy*. **48**(4): 263-266.

Sarojani. 2018. Studies on nutrient management in pigeonpea [*Cajanus cajan* (L.) Millsp.] and fieldbean [*Dolichos lablab* (L.)] intercropping system. M. Sc. (Ag). Thesis. University of Agricultural Sciences, Raichur.

Schultz, B., Phillips, C., rosset, P. and Vandermeer, J. 1982. An experiment in intercropping cucumber and tomatoes in Southern Michigon, U.S.A. *Scientia Horticulture*.**18**b: 1-8.

Sethy, A. K. 2019. Nutrient management in pigeonpea + radish intercropping system. Ph.D. Thesis, Palli Siksha Bhavana (Institute of agriculture), Visva-Bharati Sriniketan, West Bengal.

Shanwad, U. K., Rajkumar, S., Hulihalli, U. K., Mummigatti, U. V. and Arvind Kumar, B.N. 2009. Performance of maize + pigeonpea intercropping system under rainfed conditions of North Karnataka. *Current Advances in Agricultural Sciences*. **1**(1): 21-23.

Sharma, A., Rathod. P. S., and Basavaraj, K. 2010. Agronomic management of pigeonpea (*Cajanus cajana*) based intercropping systems for improving productivity under rainfed conditions. *Karnataka Journal of Agricultural*

Sciences. **23**: 570-74.

Sharma, A., Rathod. Dharmaraj., P. S. and Chavan, M. 2012. Response of pigeonpea to biofertilizers in pigeonpea based intercropping systems under rainfed conditions. *Karnataka Journal of Agricultural Sciences*. **25**: 322-25.

Sharma, B. B., Singh, N. P., Sahu, J. P. and Singh, H. P. 1988. Intercropping with early pigeonpea in tarai. *Indian Journal of Agronomy*. **33** (1): 112-114.

Sharma, P. B. and Singh, V. B. 2008. Productivity and economic viability of different intercrop combinations in Tawa command area. *Advances in Plant Sciences.* **21**(2): 441-442.

Sharmili, K. and Manoharan, S. 2018. Studies on Intercropping in Rainfed Little Millet (*Panicum sumatrense*). *International Journal of Current Microbiology and Applied Sciences*.**7**(2): 323-327.

Sharmili, K., Parasuraman, P. and Sivagamy, K. 2023. Effect of inter and sequential cropping of pulses in little millet (*Panicum sumatranse* L.) based cropping system. *Indian Journal of Agricultural Research*. **57**(1): 52-55.

Shinde, S. H. 1990. Weed control in pigeonpea + groundnut intercropping system. *Indian Journal of Weed Science*. **20**(3): 96-97.

Shivakumar, R., Vidya Sagar, G. E. Ch., Suresh, K., Sharma, S. H.K. and Naik, D. S. 2022a. Performance of chickpea under pigeonpea based sequential intercropping systems and integrated nutrient management in black soils of Telangana state, India. *Agriculture mechanization in Asia, Africa and Latin America*. **53**(03): 6405-6418.

Shivakumar, R., Vidya Sagar, G.E.Ch., Suresh, K., Sharma, S. H. K and Naik, D. S. 2022b. Effect of sequential intercropping systems and integrated nutrient management on nutrient uptake of Pigeonpea. International Journal of Environment and Climate Change. **12**(6): 65-74.

Shivran, P. L. and Ahlawat, I. P. S. 2000. Effect of cropping systems and fertilizers on pigeonpea (*Cajanus cajan*) and wheat (*Triticum aestivium*) in pigeonpea- wheat sequence. *Indian Journal of Agronomy*. **45**: 669-676.

Shivran, A. C. and Yadav, R. K. 2016. Growth, yield and nutrient uptake by sesame as influenced by intercropping systems and sulphur levels under semi-arid region of Rajasthan. *Annals of Agricultural Research*. **37**(1):107-113.

Siddique, K. H. M., Johansen, C., Turner, N. C., Jeuffroy, M. H., Hashem, A., Sakar, D., Gan, Y. and Alghamdi, S. S. 2012. Innovations in agronomy for food legumes. *A review Agronomy for sustainable development*. **32**: 45-64.

Singh, B., Kumar, S., Dhaka, A. K., and Kumar, S. 2011. Intercropping of cereals and legumes for forage production in kharif season–A review. *Forage Research*. **36**: 189-196.

Singh, C. V., Singh, R. K., Tomar, R. K., Chauhan, V. S. and Variar, M. 1990. Rice-based intercropping systems for rainfed upland conditions of chotonagpur plantae. *International Rice Research* Newsletter. **15**(3): 36.

Singh, D. 2015. Study on pigeonpea based intercropping system of soybean.M. Sc (Ag.) Thesis, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra.

Singh, D., Mathimaran, N., Boller, T. and Kahmen, A. 2020. Deep-rooted pigeon pea promotes the water relations and survival of shallow-rooted finger millet during drought—Despite strong competitive interactions at ambient water availability. *PLOS ONE*. **15**:1–22.

Singh, M. 2017. Production potential and profitability of pigeonpea [*Cajanus cajan* (L.) Millsp.] as influenced by intercropping with black gram [*Vigna mungo* (L.) Hepper] and integrated nutrient management. Ph. D. Thesis. Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

Singh, L., Tiwari, A. S., Shrivastava, M. P., Sharma, H. K. and Singh, B. R. 1978. Breeding studies in cropping systems in pigeonpea. *agris.fao.org*.

Singh, R. and Rai, R. K. 2004. Yield attributes, yield and quality of soybean (*Glycine max*) as influenced by integrated nutrient management. *Indian Journal of Agronomy*. **49**(4): 271-274.

Singh, R. S. and Rahman, A. 1999. Economics feasibility of pigeonpea (*Cajanus cajan* L.) based on intercropping systems in Chotanagpur plateau. *Journal of Research*. 11(1):27-30.

Singh, R., Malik. J. K., Thenua, O. V. S. and Jat, H. S. 2013. Effect of phosphorus and bio-fertilizer on productivity, nutrient uptake and economics of pigeonpea (*Cajanus cajan*) + mungbean (*Phaseolus radiata*) intercropping system. *Legume Research.* **36:**41-48.

Singh, S. P., Maurya, C. L. and Khan, N. 2024a. Feasibility of parallel cropping of black gram with pigeon pea in central trait of Uttar Pradesh. *Journal of Experimental Agriculture International*. **46**(5): 360-365.

Singh, S. P., Maurya, C. L. and Khan, N., Singh, B. V., Kumar, S. and Kumar,

K. 2024b. Productivity and economic feasibility of pigeonpea base companion cropping under additive series planting system. *Journal of Advances in Biology & Biotechnology*. **27**(5): 277-280.

Singh, T. and Pal, M., 2003. Growth parameter, yield attributers and yield of pigeon pea as influenced by cropping system and nitrogen, phosphorus levels. *Annals of Agricultural Research*. **24**(4): 755-759.

Singh, U, Saad, A. A. and Singh, S. R. 2008, Production potential, biological feasibility and economic viability of maize based inter cropping system under rain fed conditions of Kashmir valley. *Indian Journal of Agricultural Science*. **78**(12): 1023 - 1027.

Shri, S., Jha, A. K. and Shrivastava, A. 2014. Evaluation of different intercropping systems for productivity and economics in maize (*Zea mays* L.). *Annals of Agricutural Research.* **35**(2): 200.204.

Sonawale, D. A., Bahale, V. M. and Dalavi, N. D. 2011. Evaluation of pigeonpea based intercropping systems under scarcity conditions of Northern Maharashtra. *JNKVV Research Journal*. **45**(1): 81-84.

Subbiah, B. V. and Asija, G. L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science*. **25:** 259-260.

Subramanian, V. B. and Rao, D.G. 1988. Intercropping effects and components of dryland sorghum, pigeonpea and mungbean. *Tropical Agriculture*. **65**:145-149.

Sujatha, H. T., and Babalad. H. B. 2018. Effect of planting methods, geometry and intercrops on growth and productivity of pigeonpea in pigeonpea based cropping systems. *Journal of Pharmacognosy and Phytochemistry*.**7(6)**: 26-30

Syafruddin and Suwardi. 2020. IOP Conf. Ser.: *Earth Environment Science*.

484 012054

Thimmegowda, M. N., Ramachandrappa, B. K., Devaraja, K., Savitha, M. S., Babu, P. N., Gopinath, K. A., Chary, G. R. and Rao, C. S. 2016. Climate Resilient Intercropping Systems for Rainfed Red Soils of Karnataka. *Indian Journal of Dryland Agricultural Research and Development*. **31**(2): 39-44.

Tiwari, D. 2021. Studies on growth and yield of chickpea and mustard intercropping system in different row ratios and liquid manure. Ph.D. Thesis, Sam Higginbottom University of Agriculture, Technology and Sciences Prayagraj (U.P.).

Tiwari, K. V. 2022. Nutrient management in Pigeonpea [*Cajanus cajan* (L.) Millsp.] + Sesame (*Sesamum indicum* L.) intercropping system for Kymore Plateau of Madhya Pradesh. Ph. D. Thesis, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.).

Tripathi, A. K., and H.S. Kushwah. 2013. Performance of pearlmillet (*Pennisetum glaucum*) intercoppped with pigeonpea (*Cajanus cajan*) under varying fertility levels in the rainfed environment of Bundelkhand region. *Annals of Agricultural Research. New Series*. **34**(1):36-43.

Tripathi, A. K., Kushwaha, H. S., Singh, D. and Praharaj, C. S. 2019. Nutrient management in pigeonpea [*Cajanus cajan* (L.) Millsp.] + cereal intercropping system under rainfed environment of Bundelkhand region of India. *Journal of Food Legumes*. **32**(3): 161-169

Tripathi, H. N., Chand. S. and Tripathi, A. K. 2005. Biological and economical feasibility of chickpea (*Cicer aritinum*) + Indian mustard (*Brassica juncea*) cropping systems under varying levels of phosphorus. *Indian Journal of Agronomy*. **50**(1): 31-34

Udhaya, N. D., Vimalendran, L., Latha, K. R., Sangamithra, S. and Kalaiyarasan, V. 2015. A review on biological advantages of pigeonpea intercropping influenced by different cropping geometries. *International Journal Agricultural Science Research.* **5**: 103-12.

Vittal, K. P. R., Rao, K. V., Sharma, K. L., Victor, U. S., Ravindra, C. G. Maruti., Sankar, G. R., Samra, J. S. and Gurbachan, Singh. 2005. Agricultural Drought Zonation, cropping practices and amelioration paths for rainfed production systems. *Indian Journal of Dryland Agriculture Research and Development*. **20**(2): 155-202.

Velayutham., A. Meyyazhagan., A, N. and Krishnrajan. 2000. Response of perennial redgram to spacing and intercropping. *Madras Agricultural Journal*. **87**: 178.

Venkatesha. 2008. Studies in integrated nutrient management and intercropping in rice (*Oryza sativa* L.) cultivars under aerobic condition. Ph.D. (Agri.) Thesis, University of Agricultural Sciences Bengaluru.

Verma, S. P. and Mogdal, S. C. 1983. Use of equivalent yield in cropping systems. *Himachal Journal of Agricultural Research*. 9(2): 89-92.

Walkley, A. and Black, T. A. 1934. An estimation of soil organic matter and proposed modification of the chromic acid titration method. *Soil Science*. **37**: 29-38.

Watson, D. J. 1947. Comparative physiological studies on the growth of field crops. I: Variation in net assimilation rate and leaf area between species and varieties and within and between years. *Annals of Botany*. 11(1):41-76

Watson, D. J. 1952. The physiological basis for variation in yield. *Advances in Agronomy Journal*. **4:**101-145

Willey, B. W. 1979a. Intercropping - its importance and research needs, competition and yield advantages. *Field Crop Abstracts.* **32:** 1-10.

Willey, B. W. 1979b. Inter-cropping: its importance and research needs. *Field Crop Abstracts*. **32**: 73-85.

Willey, R. W. and Rao, M. R. 1980. A Competitive ratio for quantifying competition between intercrops. *Experimental Agriculture*. **16**(2):117-125.

Willey, R. W., Rao, M.R. and Natrajan, M. 1980. Traditional cropping systems with pigeonpea and their improvement. Proceedings of International Workshop on Pigeonpea. 15 December, ICRISAT, Patancheru (India), 11-25.

Yadav, A., Kumar, N., Ahamad, A., Singh, H. C., Kumar, R., Bahadur, R., Yadav, S. K. and Kumar, S. 2021. Nutrient management in pigeonpea [*Cajanus cajan* (L.) Millisp.] based intercropping system under rainfed condition of eastern Uttar Pradesh. *The Pharma Innovation*

Journal. **10**(6): 853-857.

Yadav, G., Shivran, A. C., Yadav, K. R., Kumavat, S. R. and Yadav, M. 2017. Effect of intercropping system and integrated nutrient management on growth, yield and nutrient uptake by sesame under semi-arid region. *Chemical Science and Review Letter*. **6**(22):1308-1311.

Yadav, P. S. and B. M. Maurya. 2012. Assessment of productivity and economics of various soybean + pigeonpea intercropping system under rainfed condition of Rewa region of Madhya Pradesh. *JNKVV Research Journal*. **46**(3): 355-359.

Yakudu, H., J. D. Kwari and M. K. Sandade. 2010. Effect of phosphorus on nitrogen fixation by some grain legume varieties in Sudan Asahelian Zone of North. *Nigerian Journal of Basic and Applied Science.* **189**: 19-26.

Yang, C., Fan, Z. and Chai, Q. 2018. Agronomic and economic benefits of pea/maize intercropping systems in relation to N fertilizer and maize density. *Agronomy*. **8**(52): 2-14.

Yenebala, L. 2017. Study on pigeonpea + niger intercropping system. M.sc. (Agri.) Thesis.V. N. M. K.V. Parbhani. Maharashtra. India.

Yokha, K. 2015. Study of soybean (*Glycine max*. L. Merill) based intercropping on weed dynamics. M.Sc. (Ag) Thesis. Nagaland University, Medziphema. Zhao, X., Qiqi Dong, Q., Han, Y., Kezhao Zhang, K., Shi, X., Yang, X., Yuan, Y., Zhou, D., Wang, K., Wang, X., Jiang, C., Liu, X., Zhang, H., Zhang,

Z. and Yu, H. 2022. Maize/peanut intercropping improves nutrient uptake of side-row maize and system microbial community diversity. *BMC Microbiology*. **22**(14): 1-14.

APPENDICES

APPENDIX - A

Calendar of agronomic management practices performed during the investigation period 2021 and 2022

Sl. No.	Field operations	Date	
		2021	2022
1	Land preparation	18-06-2021	22-06-2022
a.	tillage and ion of FYM	18-06-2021	22-06-2022
b.	Secondary tillage	28-06-2021	01-07-2022
c.	Layout of the experiment	29-06-2021	5-07-2022
2.	Application of fertilizers	2-07-2021	8-07-2022
3	Seed treatment and sowing	2-07-2021	8-07-2022
4	Weeding	28-08-2021	30-08-2022
5	Harvesting		
a.	Pigeonpea	28-12-2021	21-12-2022
b.	rice	06-10-2021	12-10-2022
c.	Sesame	08-11-2021	4-11-2022
d.	Greengram	10-09-2021 to 15-10-2021	08-09-2022 to 11-10-2022
e.	Soybean	10-10-2021	22-10-2022
6	Threshing		
a.	Pigeonpea	5-02-2022	29-02-2023
b.	rice	17-11-2021	25-11-2022
c.	Sesame	15-12-2021	20-12-2022
d.	Greengram	17-11-2021	10-11-2022
e.	Soybean	20-11-2021	27-11-2022

APPENDIX-B

Cost of cultivation (Rs. ha^{-1})

A. Fixed cost				
Sl.no	**Particulars**	**Input/Quantity**	**Rate (Rs. unit^{-1})**	**Cost (Rs. ha^{-1})**
1	Field preparation			
	a. Primary and secondary tillage	1	3500	3500
	b. FYM application and sowing	4 men days	400/men/day	1600
2	Interculture operations			
	Thinning, hand weeding and earthing up	8 men days	400/men/day	3200
3.	Plant protection			
	a. Labour charges	6 men days	400/men/day	2400
	b. Insecticide			
	Chloropyriphos	2 litre	550/500ml	2200
	Malathion	1 litre	819/litre	819
	c. Fungicide			
	a. Saaf	200 g	241/100g	482
	b. Redomil gold	200 g	233/100g	466
4.	Harvesting, threshing and winnowing	16 men days	400/men/day	6400
5.	Miscellaneous	-	-	1000
	Total			22067

B. Cost of variable inputs ha^{-1}				
Sl.No	Inputs	Inputs/Quantity	Rate (Rs. unit^{-1})	Cost (Rs, ha^{-1})
	Seed			
1	C1R1 Pigeonpea	12	₹ 60	₹ 720
	Rice	18.52	₹ 20	370.4
2	C2R1 Pigeonpea	9.6	₹ 60	576
	Rice	32	₹ 20	640
3	C3R1 Pigeonpea	7.2	₹ 60	432
	Rice	32	₹ 20	640
4	C4R1 Pigeonpea	12	₹ 60	720
	Sesame	2	₹ 80	160
5	C5R1 Pigeonpea	9.6	₹ 60	576
	Sesame	3	₹ 80	240
6	C6R1 Pigeonpea	7.2	₹ 60	432
	Sesame	3	₹ 80	240
7	C7R1 Pigeonpea	12	₹ 60	720
	Greengram	6	₹ 60	360
8	C8R1 Pigeonpea	9.6	₹ 60	576
	Greengram	9	₹ 60	540
9	C9R1 Pigeonpea	7.2	₹ 60	432
	Greengram	9	₹ 60	540
10	C10R1 Pigeonpea	12	₹ 60	720
	Soybean	34.3	₹ 40	1372
11	C11R1 Pigeonpea	9.6	₹ 60	576
	Soybean	45.7	₹ 40	1828
12	C12R1 Pigeonpea	7.2	₹ 60	432
	Soybean	45.7	₹ 40	1828
13	C13R1 Pigeonpea	12	₹ 60	720
14	C14R1 Rice	80	₹ 20	1600
15	C15R1 Sesame	5	₹ 60	300
16	C16R1 Greengram	15	₹ 60	900
17	C17R1 Soybean	60	₹ 40	2400
B.	Fertilizer			
	Nitrogen (Urea) Pigeonpea	43.4 kg	₹ 320/50 kg bag	277.26
	Phophorus (SSP) Pigeonpea	250 kg	₹ 420/50 kg bag	2100
	Potasium (MOP) Pigeonpea	50 kg	₹ 980/50 kg bag	980
				3357.26
	Nitrogen Urea Rice	130.2 kg	₹ 320/50 kg bag	833.28

	Phophorus (SSP) Rice	187.5 kg	₹ 420/50 kg bag	1575
	Potasium (MOP) Rice	33.34 kg	₹ 980/50 kg bag	653.464
				3061.744
	Nitrogen Urea Sesame	65.1 kg	₹ 320/50 kg bag	416.64
	Phophorus (SSP) Sesame	250 kg	₹ 420/50 kg bag	2100
	Potasium (MOP) Sesame	33.33 kg	₹ 980/50 kg bag	653.268
				3169.908
	Nitrogen Urea Greengram	43.4 kg	₹ 320/50 kg bag	277.26
	Phophorus (SSP) Greengram	250 kg	₹ 420/50 kg bag	2100
	Potasium (MOP) Greengram	33.33 kg	₹ 980/50 kg bag	653.268
				3030.528
	Nitrogen Urea Soybean	43.4 kg	₹ 320/50 kg bag	277.26
	Phophorus (SSP) Soybean	375 kg	₹ 420/50 kg bag	3150
	Potasium (MOP) Soybean	66.68 kg	₹ 980/50 kg bag	1306.9
				4734.16
C.	FYM			
	Pigeonpea	4.5 t	₹ 2	9000
	Rice	2.5 t	₹ 2	5000
	Sesame	5.5 t	₹ 2	11000
	Greengram	5 t	₹ 2	10000
	Soybean	5.5 t	₹ 2	11000

APPENDIX-C

ANOVA 1(a): Analysis of variance of pigeonpea plant height (cm) at 30 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.53	0.27	0.45	3.40	NS
Treatment	12	70.32	5.86	9.97	2.18	S
Error	24	14.10	0.59			
Total	38	84.96				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.27	0.14	0.71	3.40	NS
Treatment	12	52.65	4.39	22.64	2.18	S
Error	24	4.65	0.19			
Total	38	57.57				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	263.75	263.75	675.01	4.04	S
Replication	4	0.81	0.20	0.52	2.57	NS
Treatment	12	111.49	9.29	23.78	1.96	S
Years x Treatment	12	11.48	0.96	2.45	1.96	S
Error	48	18.75	0.39			
Total	77	406.28				

ANOVA 1(b): Analysis of variance of pigeonpea plant height (cm) at 60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.59	0.29	0.11	3.40	NS
Treatment	12	503.64	41.97	15.71	2.18	S
Error	24	64.13	2.67			
Total	38	568.36				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.19	1.09	0.80	3.40	NS
Treatment	12	57.68	4.81	3.52	2.18	S
Error	24	32.82	1.37			
Total	38	92.68				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	138.51	138.51	68.58	4.04	S
Replication	4	2.78	0.69	0.34	2.57	NS
Treatment	12	425.32	35.44	17.55	1.96	S
Years x Treatment	12	136.00	11.33	5.61	1.96	S
Error	48	96.95	2.02			
Total	77	799.55				

ANOVA 1(c): Analysis of variance of pigeonpea plant height (cm) at 90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.89	0.44	0.03	3.40	NS
Treatment	12	2693.92	224.49	14.38	2.18	S
Error	24	374.60	15.61			
Total	38	3069.40				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	24.39	12.20	1.49	3.40	NS
Treatment	12	762.71	63.56	7.78	2.18	S
Error	24	196.09	8.17			
Total	38	983.18				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	6847.22	6847.22	575.91	4.04	S
Replication	4	25.28	6.32	0.53	2.57	NS
Treatment	12	3080.55	256.71	21.59	1.96	S
Years x Treatment	12	376.07	31.34	2.64	1.96	S
Error	48	570.69	11.89			
Total	77	10899.81				

ANOVA 1(d): Analysis of variance of pigeonpea plant height (cm) at 120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	298.96	149.48	3.22	3.40	NS
Treatment	12	1531.22	127.60	2.75	2.18	S
Error	24	1113.55	46.40			
Total	38	2943.73				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	41.42	20.71	0.54	3.40	NS
Treatment	12	4381.70	365.14	9.52	2.18	S
Error	24	920.09	38.34			
Total	38	5343.21				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	3852.02	3852.02	90.92	4.04	S
Replication	4	340.38	85.09	2.01	2.57	NS
Treatment	12	5373.91	447.83	10.57	1.96	S
Years x Treatment	12	539.02	44.92	1.06	1.96	NS
Error	48	2033.64	42.37			
Total	77	12138.96				

ANOVA 2(a): Analysis of variance of pigeonpea plant population (m^{-2}) at 30 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.62	0.31	2.72	3.40	NS
Treatment	12	49.59	4.13	36.49	2.18	S
Error	24	2.72	0.11			
Total	38	52.92				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.67	0.33	3.00	3.40	NS
Treatment	12	49.03	4.09	36.77	2.18	S
Error	24	2.67	0.11			
Total	38	52.36				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	0.11	4.04	NS
Replication	4	1.28	0.32	2.86	2.57	S
Treatment	12	97.79	8.15	72.65	1.96	S
Years x Treatment	12	0.82	0.07	0.61	1.96	NS
Error	48	5.38	0.11			
Total	77	105.29				

ANOVA 2(b): Analysis of variance of pigeonpea plant population (m^{-2}) at 60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.08	0.54	3.60	3.40	S
Treatment	12	42.10	3.51	23.46	2.18	S
Error	24	3.59	0.15			
Total	38	46.77				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.90	0.95	8.22	3.40	S
Treatment	12	45.69	3.81	33.00	2.18	S
Error	24	2.77	0.12			
Total	38	50.36				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.05	0.05	0.39	4.04	NS
Replication	4	2.97	0.74	5.61	2.57	S
Treatment	12	86.85	7.24	54.63	1.96	S
Years x Treatment	12	0.95	0.08	0.60	1.96	NS
Error	48	6.36	0.13			
Total	77	97.18				

ANOVA 2(c): Analysis of variance of pigeonpea plant population (m^{-2}) at 90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.08	0.54	3.60	3.40	S
Treatment	12	36.10	3.01	20.11	2.18	S
Error	24	3.59	0.15			
Total	38	40.77				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.90	0.95	8.22	3.40	S
Treatment	12	39.23	3.27	28.33	2.18	S
Error	24	2.77	0.12			
Total	38	43.90				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.32	0.32	2.42	4.04	NS
Replication	4	2.97	0.74	5.61	2.57	S
Treatment	12	74.49	6.21	46.85	1.96	S
Years x Treatment	12	0.85	0.07	0.53	1.96	NS
Error	48	6.36	0.13			
Total	77	84.99				

ANOVA 2(d): Analysis of variance of plant population (m^{-2}) at 120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.85	0.92	5.33	3.40	S
Treatment	12	29.08	2.42	14.00	2.18	S
Error	24	4.15	0.17			
Total	38	35.08				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.62	0.31	1.82	3.40	NS
Treatment	12	35.33	2.94	17.44	2.18	S
Error	24	4.05	0.17			
Total	38	40.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.46	0.46	2.70	4.04	NS
Replication	4	2.46	0.62	3.60	2.57	S
Treatment	12	63.21	5.27	30.81	1.96	S
Years x Treatment	12	1.21	0.10	0.59	1.96	NS
Error	48	8.21	0.17			
Total	77	75.54				

ANOVA 3(a): Analysis of variance of pigeonpea on number of primary branches plant^{-1} at 30 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.49	0.24	2.25	3.40	NS
Treatment	12	10.60	0.88	8.19	2.18	S
Error	24	2.59	0.11			
Total	38	13.67				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.26	0.13	1.35	3.40	NS
Treatment	12	5.16	0.43	4.43	2.18	S
Error	24	2.33	0.10			
Total	38	7.76				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.58	1.58	15.42	4.04	S
Replication	4	0.75	0.19	1.83	2.57	NS
Treatment	12	15.08	1.26	12.27	1.96	S
Years x Treatment	12	0.68	0.06	0.55	1.96	NS
Error	48	4.92	0.10			
Total	77	23.01				

ANOVA 3(b): Analysis of variance of pigeonpea on number of primary branches of plant^{-1} at 60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.26	0.13	1.58	3.40	NS
Treatment	12	17.20	1.43	17.44	2.18	S
Error	24	1.97	0.08			
Total	38	19.44				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.45	0.22	1.52	3.40	NS
Treatment	12	13.12	1.09	7.46	2.18	S
Error	24	3.52	0.15			
Total	38	17.09				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	30.16	30.16	263.51	4.04	S
Replication	4	0.71	0.18	1.54	2.57	NS
Treatment	12	29.76	2.48	21.67	1.96	S
Years x Treatment	12	0.57	0.05	0.41	1.96	NS
Error	48	5.49	0.11			
Total	77	66.68				

ANOVA 3(c): Analysis of variance of pigeonpea on number of primary branches plant^{-1} at 90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.68	0.84	0.59	3.40	NS
Treatment	12	48.16	4.01	2.83	2.18	S
Error	24	34.00	1.42			
Total	38	83.84				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	5.84	2.92	2.61	3.40	NS
Treatment	12	67.62	5.63	5.03	2.18	S
Error	24	26.89	1.12			
Total	38	100.35				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	144.60	144.60	113.99	4.04	S
Replication	4	7.52	1.88	1.48	2.57	NS
Treatment	12	105.09	8.76	6.90	1.96	S
Years x Treatment	12	10.69	0.89	0.70	1.96	NS
Error	48	60.89	1.27			
Total	77	328.78				

ANOVA 3(d): Analysis of variance of pigeonpea on number of primary branches plant^{-1} at 120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.04	0.52	0.55	3.40	NS
Treatment	12	36.32	3.03	3.21	2.18	S
Error	24	22.64	0.94			
Total	38	60.00				

ANOVA Table of second year						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.92	0.46	0.45	3.40	NS
Treatment	12	37.43	3.12	3.04	2.18	S
Error	24	24.61	1.03			
Total	38	62.96				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	36.74	36.74	37.32	4.04	S
Replication	4	1.96	0.49	0.50	2.57	NS
Treatment	12	71.92	5.99	6.09	1.96	S
Years x Treatment	12	1.82	0.15	0.15	1.96	NS
Error	48	47.25	0.98			
Total	77	159.69				

ANOVA 4(a): Analysis of variance of pigeonpea on crop growth rate CGR (g m^{-2} day^{-1}) at 30-60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.89	3.40	NS
Treatment	12	11.25	0.94	333.49	2.18	S
Error	24	0.07	0.00			
Total	38	11.32				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.26	3.40	NS
Treatment	12	10.16	0.85	382.58	2.18	S
Error	24	0.05	0.00			
Total	38	10.21				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.15	0.15	59.55	4.04	S
Replication	4	0.01	0.00	0.61	2.57	NS
Treatment	12	21.21	1.77	703.44	1.96	S
Years x Treatment	12	0.20	0.02	6.78	1.96	S
Error	48	0.12	0.00			
Total	77	21.69				

ANOVA 4(b): Analysis of variance of pigeonpea on crop growth rate CGR (g m^{-2} day^{-1}) at 60-90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.28	3.40	NS
Treatment	12	33.61	2.80	485.82	2.18	S
Error	24	0.14	0.01			
Total	38	33.75				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.01	1.81	3.40	NS
Treatment	12	33.90	2.83	686.29	2.18	S
Error	24	0.10	0.00			
Total	38	34.01				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.11	4.04	NS
Replication	4	0.02	0.00	0.91	2.57	NS
Treatment	12	67.49	5.62	1138.27	1.96	S
Years x Treatment	12	0.02	0.00	0.39	1.96	NS
Error	48	0.24	0.00			
Total	77	67.77				

ANOVA 4(c): Analysis of variance of pigeonpea on crop growth rate CGR (g m^{-2} day^{-1}) at 90-120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.01	1.94	3.40	NS
Treatment	12	90.71	7.56	2149.87	2.18	S
Error	24	0.08	0.00			
Total	38	90.81				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	0.86	3.40	NS
Treatment	12	104.34	8.70	800.66	2.18	S
Error	24	0.26	0.01			
Total	38	104.62				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.03	0.03	4.41	4.04	S
Replication	4	0.03	0.01	1.12	2.57	NS
Treatment	12	194.60	16.22	2256.00	1.96	S
Years x Treatment	12	0.46	0.04	5.30	1.96	S
Error	48	0.35	0.01			
Total	77	195.46				

ANOVA 5(a): Analysis of variance of pigeonpea on relative growth rate RGR (g g^{-1} day^{-1}) at 30-60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.05	3.40	NS
Treatment	12	0.00	0.00	0.22	2.18	NS
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.35	3.40	NS
Treatment	12	0.00	0.00	3.82	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	53.96	4.04	S
Replication	4	0.00	0.00	0.66	2.57	NS
Treatment	12	0.00	0.00	2.40	1.96	S
Years x Treatment	12	0.00	0.00	2.09	1.96	S
Error	48	0.00	0.00			
Total	77	0.00				

ANOVA 5(b): Analysis of variance of pigeonpea on relative growth rate RGR (g g^{-1} day^{-1}) at 60-90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.13	3.40	NS
Treatment	12	0.00	0.00	0.60	2.18	NS
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.47	3.40	NS
Treatment	12	0.00	0.00	1.64	2.18	NS
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	5.26	4.04	S
Replication	4	0.00	0.00	0.24	2.57	NS
Treatment	12	0.00	0.00	1.38	1.96	NS
Years x Treatment	12	0.00	0.00	0.49	1.96	NS
Error	48	0.00	0.00			
Total	77	0.00				

ANOVA 5(c): Analysis of variance of pigeonpea on relative growth rate RGR ($g\ g^{-1}\ day^{-1}$) at 90-120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.56	3.40	NS
Treatment	12	0.00	0.00	1.87	2.18	NS
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.87	3.40	NS
Treatment	12	0.00	0.00	1.34	2.18	NS
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	1.48	4.04	NS
Replication	4	0.00	0.00	1.36	2.57	NS
Treatment	12	0.00	0.00	1.00	1.96	NS
Years x Treatment	12	0.00	0.00	2.09	1.96	S
Error	48	0.00	0.00			
Total	77	0.00				

ANOVA 6(a): Analysis of variance of pigeonpea on absolute growth rate AGR ($g\ d^{-1}$) at 30-60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.44	3.40	NS
Treatment	12	0.01	0.00	1.98	2.18	NS
Error	24	0.01	0.00			
Total	38	0.01				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.58	3.40	NS
Treatment	12	0.01	0.00	3.04	2.18	S
Error	24	0.00	0.00			
Total	38	0.01				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	19.87	4.04	S
Replication	4	0.00	0.00	0.50	2.57	NS
Treatment	12	0.01	0.00	3.97	1.96	S
Years x Treatment	12	0.00	0.00	0.85	1.96	NS
Error	48	0.01	0.00			
Total	77	0.03				

ANOVA 6(b): Analysis of variance of pigeonpea on absolute growth rate AGR (g d^{-1}) at 60-90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.03	3.40	NS
Treatment	12	0.01	0.00	1.30	2.18	NS
Error	24	0.01	0.00			
Total	38	0.01				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.53	3.40	NS
Treatment	12	0.00	0.00	1.39	2.18	NS
Error	24	0.01	0.00			
Total	38	0.01				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.06	4.04	NS
Replication	4	0.00	0.00	0.69	2.57	NS
Treatment	12	0.01	0.00	2.34	1.96	S
Years x Treatment	12	0.00	0.00	0.34	1.96	NS
Error	48	0.02	0.00			
Total	77	0.03				

ANOVA 6(c): Analysis of variance of pigeonpea on absolute growth rate AGR (g d^{-1}) at 90-120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.10	3.40	NS
Treatment	12	0.01	0.00	1.81	2.18	NS
Error	24	0.01	0.00			
Total	38	0.01				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.11	3.40	NS
Treatment	12	0.04	0.00	5.77	2.18	S
Error	24	0.01	0.00			
Total	38	0.05				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.68	4.04	NS
Replication	4	0.00	0.00	1.11	2.57	NS
Treatment	12	0.02	0.00	4.86	1.96	S
Years x Treatment	12	0.02	0.00	4.00	1.96	S
Error	48	0.02	0.00			
Total	77	0.07				

ANOVA 7(a): Analysis of variance of pigeonpea on net assimilation rate NAR (g m^{-2} day^{-1}) at 30-60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.06	3.40	NS
Treatment	12	0.17	0.01	1.82	2.18	NS
Error	24	0.19	0.01			
Total	38	0.37				

ANOVA Table of second year (2022)						
Source of Variance	df	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.01	0.78	3.40	NS
Treatment	12	0.18	0.02	2.09	2.18	NS
Error	24	0.17	0.01			
Total	38	0.37				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.33	4.04	NS
Replication	4	0.01	0.00	0.40	2.57	NS
Treatment	12	0.35	0.03	3.85	1.96	S
Years x Treatment	12	0.00	0.00	0.04	1.96	NS
Error	48	0.36	0.01			
Total	77	0.73				

ANOVA 7(b): Analysis of variance of pigeonpea net assimilation rate NAR (g m^{-2} day^{-1}) at 60-90 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.20	0.10	2.27	3.40	NS
Treatment	12	0.51	0.04	0.95	2.18	NS
Error	24	1.07	0.04			
Total	38	1.78				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.23	0.12	1.98	3.40	NS
Treatment	12	0.43	0.04	0.61	2.18	NS
Error	24	1.41	0.06			
Total	38	2.08				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.12	0.12	2.32	4.04	NS
Replication	4	0.44	0.11	2.10	2.57	NS
Treatment	12	0.47	0.04	0.75	1.96	NS
Years x Treatment	12	0.47	0.04	0.76	1.96	NS
Error	48	2.49	0.05			
Total	77	3.98				

ANOVA 7(c): Analysis of variance of pigeonpea net assimilation rate NAR (g m^{-2} day^{-1}) at 90-120 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.05	0.03	0.07	3.40	NS
Treatment	12	5.77	0.48	1.27	2.18	NS
Error	24	9.11	0.38			
Total	38	14.93				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.67	0.34	0.75	3.40	NS
Treatment	12	2.45	0.20	0.46	2.18	NS
Error	24	10.76	0.45			
Total	38	13.89				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.00	4.04	NS
Replication	4	0.72	0.18	0.44	2.57	NS
Treatment	12	5.92	0.49	1.19	1.96	NS
Years x Treatment	12	2.31	0.19	0.46	1.96	NS
Error	48	19.87	0.41			
Total	77	28.82				

ANOVA 8(a): Analysis of variance of pigeonpea leaf area index at 30 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	0.80	3.40	NS
Treatment	12	0.25	0.02	5.40	2.18	S
Error	24	0.09	0.00			
Total	38	0.35				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	1.12	3.40	NS
Treatment	12	0.40	0.03	4.96	2.18	S
Error	24	0.16	0.01			
Total	38	0.58				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.68	4.04	NS
Replication	4	0.02	0.01	1.00	2.57	NS
Treatment	12	0.64	0.05	10.02	1.96	S
Years x Treatment	12	0.01	0.00	0.22	1.96	NS
Error	48	0.25	0.01			
Total	77	0.93				

ANOVA 8(b): Analysis of variance of pigeonpea leaf area index at 60 DAS under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	0.06	3.40	NS
Treatment	12	7.00	0.58	8.86	2.18	S
Error	24	1.58	0.07			
Total	38	8.59				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.08	0.04	0.49	3.40	NS
Treatment	12	2.18	0.18	2.24	2.18	S
Error	24	1.95	0.08			
Total	38	4.21				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.51	1.51	20.57	4.04	S
Replication	4	0.09	0.02	0.30	2.57	NS
Treatment	12	8.08	0.67	9.16	1.96	S
Years x Treatment	12	1.11	0.09	1.25	1.96	NS
Error	48	3.53	0.07			
Total	77	14.31				

ANOVA 8(c): Analysis of variance of pigeonpea leaf area index at 90 DAS under different intercropping system

ANOVA Table of first year						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.07	0.04	1.35	3.40	NS
Treatment	12	3.45	0.29	10.42	2.18	S
Error	24	0.66	0.03			
Total	38	4.18				

ANOVA Table of second year						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.28	0.14	1.86	3.40	NS
Treatment	12	3.71	0.31	4.04	2.18	S
Error	24	1.84	0.08			
Total	38	5.83				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.04	0.04	0.72	4.04	NS
Replication	4	0.36	0.09	1.72	2.57	NS
Treatment	12	7.12	0.59	11.40	1.96	S
Years x Treatment	12	0.03	0.00	0.05	1.96	NS
Error	48	2.50	0.05			
Total	77	10.05				

ANOVA 9: Analysis of variance of pigeonpea on plant stand at harvest (m^{-2}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.21	1.10	6.97	3.40	S
Treatment	12	27.74	2.31	14.62	2.18	S
Error	24	3.79	0.16			
Total	38	33.74				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.97	0.49	3.86	3.40	S
Treatment	12	29.90	2.49	19.76	2.18	S
Error	24	3.03	0.13			
Total	38	33.90				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.32	0.32	2.26	4.04	NS
Replication	4	3.18	0.79	5.59	2.57	S
Treatment	12	56.79	4.73	33.31	1.96	S
Years x Treatment	12	0.85	0.07	0.50	1.96	NS
Error	48	6.82	0.14			
Total	77	67.96				

ANOVA 10: Analysis of variance of pigeonpea on number of pods plant^{-1} under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	44.18	22.09	0.18	3.40	NS
Treatment	12	20594.09	1716.17	14.10	2.18	S
Error	24	2921.75	121.74			
Total	38	23560.01				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	348.27	174.13	0.43	3.40	NS
Treatment	12	25770.45	2147.54	5.31	2.18	S
Error	24	9711.18	404.63			
Total	38	35829.90				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	43115.46	43115.46	163.82	4.04	S
Replication	4	392.44	98.11	0.37	2.57	NS
Treatment	12	45558.96	3796.58	14.43	1.96	S
Years x Treatment	12	805.58	67.13	0.26	1.96	NS
Error	48	12632.93	263.19			
Total	77	102505.37				

ANOVA 11: Analysis of variance of pigeonpea on number of seeds pod^{-1} under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.07	0.04	0.13	3.40	NS
Treatment	12	2.69	0.22	0.81	2.18	NS
Error	24	6.61	0.28			
Total	38	9.38				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.18	0.09	0.48	3.40	NS
Treatment	12	3.12	0.26	1.37	2.18	NS
Error	24	4.55	0.19			
Total	38	7.85				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.10	0.10	0.43	4.04	NS
Replication	4	0.25	0.06	0.27	2.57	NS
Treatment	12	5.09	0.42	1.82	1.96	NS
Years x Treatment	12	0.73	0.06	0.26	1.96	NS
Error	48	11.16	0.23			
Total	77	17.33				

ANOVA 12: Analysis of variance of pigeonpea on pod length (cm) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.08	0.54	3.31	3.40	NS
Treatment	12	1.54	0.13	0.78	2.18	NS
Error	24	3.93	0.16			
Total	38	6.55				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.06	0.03	0.60	3.40	NS
Treatment	12	0.83	0.07	1.49	2.18	NS
Error	24	1.11	0.05			
Total	38	2.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.38	1.38	13.12	4.04	S
Replication	4	1.14	0.28	2.71	2.57	S
Treatment	12	2.20	0.18	1.74	1.96	NS
Years x Treatment	12	0.17	0.01	0.13	1.96	NS
Error	48	5.04	0.11			
Total	77	9.93				

ANOVA 13: Analysis of variance of pigeonpea on weight of pod plant^{-1} (g) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	205.50	102.75	1.56	3.40	NS
Treatment	12	648.07	54.01	0.82	2.18	NS
Error	24	1581.66	65.90			
Total	38	2435.22				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	163.96	81.98	1.39	3.40	NS
Treatment	12	644.96	53.75	0.91	2.18	NS
Error	24	1419.34	59.14			
Total	38	2228.26				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	593.90	593.90	9.50	4.04	S
Replication	4	369.46	92.37	1.48	2.57	NS
Treatment	12	1240.07	103.34	1.65	1.96	NS
Years x Treatment	12	52.95	4.41	0.07	1.96	NS
Error	48	3001.00	62.52			
Total	77	5257.38				

ANOVA 14: Analysis of variance of pigeonpea on seed index (g) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.46	0.23	1.33	3.40	NS
Treatment	12	4.09	0.34	1.97	2.18	NS
Error	24	4.16	0.17			
Total	38	8.70				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.18	0.09	0.44	3.40	NS
Treatment	12	1.39	0.12	0.57	2.18	NS
Error	24	4.85	0.20			
Total	38	6.42				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	3.04	3.04	16.20	4.04	S
Replication	4	0.64	0.16	0.85	2.57	NS
Treatment	12	4.28	0.36	1.90	1.96	NS
Years x Treatment	12	1.19	0.10	0.53	1.96	NS
Error	48	9.01	0.19			
Total	77	18.17				

ANOVA 15: Analysis of variance of pigeonpea on seed yield (kg ha^{-1}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	3664.59	1832.29	0.97	3.40	NS
Treatment	12	1153323.15	96110.26	51.06	2.18	S
Error	24	45179.04	1882.46			
Total	38	1202166.77				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	4344.98	2172.49	0.93	3.40	NS
Treatment	12	1245327.35	103777.28	44.40	2.18	S
Error	24	56090.73	2337.11			
Total	38	1305763.06				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	10127.86	10127.86	4.80	4.04	S
Replication	4	8009.57	2002.39	0.95	2.57	NS
Treatment	12	2388525.72	199043.81	94.34	1.96	S
Years x Treatment	12	10124.78	843.73	0.40	1.96	NS
Error	48	101269.76	2109.79			
Total	77	2518057.69				

ANOVA 16: Analysis of variance of pigeonpea stover yield (kg ha^{-1}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	29325.14	14662.57	1.42	3.40	NS
Treatment	12	5055173.27	421264.44	40.73	2.18	S
Error	24	248222.27	10342.59			
Total	38	5332720.68				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	17920.57	8960.28	0.65	3.40	NS
Treatment	12	5382566.94	448547.25	32.50	2.18	S
Error	24	331187.51	13799.48			
Total	38	5731675.02				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	36173.42	36173.42	3.00	4.04	NS
Replication	4	47245.71	11811.43	0.98	2.57	NS
Treatment	12	#########	866092.25	71.75	1.96	S
Years x Treatment	12	44633.19	3719.43	0.31	1.96	NS
Error	48	579409.79	12071.04			
Total	77	#########				

ANOVA 17: Analysis of variance of pigeonpea on biological yield (kg ha^{-1}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	53722.72	26861.36	1.48	3.40	NS
Treatment	12	#########	917043.56	50.52	2.18	S
Error	24	435652.60	18152.19			
Total	38	#########				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	38730.38	19365.19	0.73	3.40	NS
Treatment	12	#########	982987.03	37.24	2.18	S
Error	24	633469.79	26394.57			
Total	38	#########				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	84582.32	84582.32	3.80	4.04	NS
Replication	4	92453.10	23113.27	1.04	2.57	NS
Treatment	12	#########	1893131.92	85.00	1.96	S
Years x Treatment	12	82784.06	6898.67	0.31	1.96	NS
Error	48	1069122.38	22273.38			
Total	77	#########				

ANOVA 18: Analysis of variance of pigeonpea harvest index (%) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.08	0.04	0.07	3.40	NS
Treatment	12	13.49	1.12	2.19	2.18	S
Error	24	12.30	0.51			
Total	38	25.87				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.18	0.09	0.51	3.40	NS
Treatment	12	11.69	0.97	5.64	2.18	S
Error	24	4.15	0.17			
Total	38	16.02				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.18	0.18	0.51	4.04	NS
Replication	4	0.25	0.06	0.18	2.57	NS
Treatment	12	23.19	1.93	5.64	1.96	S
Years x Treatment	12	2.00	0.17	0.49	1.96	NS
Error	48	16.45	0.34			
Total	77	42.06				

ANOVA 19: Analysis of variance of nitrogen content (%) on seed of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.54	3.40	NS
Treatment	12	0.07	0.01	19.59	2.18	S
Error	24	0.01	0.00			

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.06	3.40	NS
Treatment	12	0.12	0.01	53.61	2.18	S
Error	24	0.00	0.00			
Total	38	0.12				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.32	0.32	1288.47	4.04	S
Replication	4	0.00	0.00	0.36	2.57	NS
Treatment	12	0.19	0.02	61.70	1.96	S
Years x Treatment	12	0.01	0.00	2.61	1.96	S
Error	48	0.01	0.00			
Total	77	0.53				

ANOVA 20: Analysis of variance of nitrogen content (%) on stover of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.07	3.40	NS
Treatment	12	0.00	0.00	97.89	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.33	3.40	NS
Treatment	12	0.00	0.00	23.99	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	3521.30	4.04	S
Replication	4	0.00	0.00	0.30	2.57	NS
Treatment	12	0.00	0.00	65.43	1.96	S
Years x Treatment	12	0.00	0.00	1.69	1.96	NS
Error	48	0.00	0.00			
Total	77	0.02				

ANOVA 21: Analysis of variance of nitrogen uptake (kg ha^{-1}) on seed of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.30	1.15	0.80	3.40	NS
Treatment	12	1078.46	89.87	62.64	2.18	S
Error	24	34.43	1.43			
Total	38	1115.20				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	3.63	1.81	0.94	3.40	NS
Treatment	12	1301.36	108.45	56.37	2.18	S
Error	24	46.17	1.92			
Total	38	1351.16				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	82.15	82.15	48.92	4.04	S
Replication	4	5.93	1.48	0.88	2.57	NS
Treatment	12	2365.26	197.10	117.38	1.96	S
Years x Treatment	12	14.57	1.21	0.72	1.96	NS
Error	48	80.60	1.68			
Total	77	2548.51				

ANOVA 22: Analysis of variance of nitrogen uptake (kg ha^{-1}) on stover of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.03	0.51	1.46	3.40	NS
Treatment	12	201.22	16.77	47.42	2.18	S
Error	24	8.49	0.35			
Total	38	210.73				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.69	0.35	0.68	3.40	NS
Treatment	12	239.74	19.98	39.05	2.18	S
Error	24	12.28	0.51			
Total	38	252.71				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	18.95	18.95	43.79	4.04	S
Replication	4	1.72	0.43	0.99	2.57	NS
Treatment	12	438.45	36.54	84.46	1.96	S
Years x Treatment	12	2.51	0.21	0.48	1.96	NS
Error	48	20.77	0.43			
Total	77	482.39				

ANOVA 23: Analysis of variance of phosphorus content (%) on seed of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.11	3.40	NS
Treatment	12	0.05	0.00	2.50	2.18	S
Error	24	0.04	0.00			
Total	38	0.10				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.31	3.40	NS
Treatment	12	0.06	0.00	5.40	2.18	S
Error	24	0.02	0.00			
Total	38	0.08				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.03	0.03	23.51	4.04	S
Replication	4	0.00	0.00	0.17	2.57	NS
Treatment	12	0.11	0.01	6.88	1.96	S
Years x Treatment	12	0.00	0.00	0.02	1.96	NS
Error	48	0.06	0.00			
Total	77	0.20				

ANOVA 24: Analysis of variance of phosphorus content (%) on stover of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.07	3.40	NS
Treatment	12	0.00	0.00	97.89	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.21	3.40	NS
Treatment	12	0.00	0.00	28.18	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	1569.85	4.04	S
Replication	4	0.00	0.00	0.20	2.57	NS
Treatment	12	0.00	0.00	66.46	1.96	S
Years x Treatment	12	0.00	0.00	6.88	1.96	S
Error	48	0.00	0.00			
Total	77	0.01				

ANOVA 25: Analysis of variance on phosphorus uptake (kg ha^{-1}) of seed on pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.50	0.75	0.69	3.40	NS
Treatment	12	660.73	55.06	50.82	2.18	S
Error	24	26.00	1.08			
Total	38	688.23				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.06	1.03	0.92	3.40	NS
Treatment	12	735.25	61.27	54.94	2.18	S
Error	24	26.76	1.12			
Total	38	764.08				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	16.71	16.71	15.20	4.04	S
Replication	4	3.55	0.89	0.81	2.57	NS
Treatment	12	1390.08	115.84	105.38	1.96	S
Years x Treatment	12	5.90	0.49	0.45	1.96	NS
Error	48	52.77	1.10			
Total	77	1469.01				

ANOVA 26: Analysis of variance on phosphorus uptake (kg ha^{-1}) of stover on pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.25	0.13	1.49	3.40	NS
Treatment	12	55.39	4.62	54.81	2.18	S
Error	24	2.02	0.08			
Total	38	57.66				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.13	0.07	0.49	3.40	NS
Treatment	12	69.33	5.78	42.75	2.18	S
Error	24	3.24	0.14			
Total	38	72.71				

ANOVA Table of Pooled Final						
Source of Variance	**Df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	7.76	7.76	70.73	4.04	S
Replication	4	0.38	0.10	0.87	2.57	NS
Treatment	12	123.60	10.30	93.91	1.96	S
Years x Treatment	12	1.12	0.09	0.85	1.96	NS
Error	48	5.26	0.11			
Total	77	138.13				

ANOVA 27: Analysis of variance on potassium content (%) of seed on pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.16	3.40	NS
Treatment	12	0.00	0.00	120.04	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.79	3.40	NS
Treatment	12	0.00	0.00	185.19	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.01	0.01	9814.04	4.04	S
Replication	4	0.00	0.00	0.42	2.57	NS
Treatment	12	0.00	0.00	291.19	1.96	S
Years x Treatment	12	0.00	0.00	2.60	1.96	S
Error	48	0.00	0.00			
Total	77	0.01				

ANOVA 28: Analysis of variance on potassium content (%) of stover on pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	1.97	3.40	NS
Treatment	12	0.00	0.00	15.54	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.64	3.40	NS
Treatment	12	0.00	0.00	5.08	2.18	S
Error	24	0.00	0.00			
Total	38	0.00				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	199.11	4.04	S
Replication	4	0.00	0.00	0.77	2.57	NS
Treatment	12	0.00	0.00	11.07	1.96	S
Years x Treatment	12	0.00	0.00	1.12	1.96	NS
Error	48	0.00	0.00			
Total	77	0.00				

ANOVA 29: Analysis of variance on potassium uptake (kg ha^{-1}) of seed of pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	0.98	3.40	NS
Treatment	12	8.25	0.69	75.40	2.18	S
Error	24	0.22	0.01			
Total	38	8.48				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.03	0.01	0.96	3.40	NS
Treatment	12	10.44	0.87	61.48	2.18	S
Error	24	0.34	0.01			
Total	38	10.81				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.68	1.68	144.45	4.04	S
Replication	4	0.04	0.01	0.97	2.57	NS
Treatment	12	18.56	1.55	132.98	1.96	S
Years x Treatment	12	0.12	0.01	0.89	1.96	NS
Error	48	0.56	0.01			
Total	77	20.97				

ANOVA 30: Analysis of variance on potassium uptake (kg ha^{-1}) of stover on pigeonpea under pigeonpea based intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.61	1.31	1.26	3.40	NS
Treatment	12	517.77	43.15	41.71	2.18	S
Error	24	24.83	1.03			
Total	38	545.21				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2.25	1.12	0.80	3.40	NS
Treatment	12	583.36	48.61	34.62	2.18	S
Error	24	33.70	1.40			
Total	38	619.31				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	10.33	10.33	8.47	4.04	S
Replication	4	4.86	1.21	1.00	2.57	NS
Treatment	12	1096.23	91.35	74.92	1.96	S
Years x Treatment	12	4.90	0.41	0.33	1.96	NS
Error	48	58.53	1.22			
Total	77	1174.84				

ANOVA 31: Analysis of variance on pigeonpea equivalent yield (PEY) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	9955.52	4977.76	2.68	3.29	NS
Treatment	16	8352309.73	522019.36	281.19	1.97	S
Error	32	59407.66	1856.49			
Total	50	8421672.92				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	2387.27	1193.64	0.64	3.29	NS
Treatment	16	8606985.80	537936.61	287.32	1.97	S
Error	32	59912.77	1872.27			
Total	50	8669285.84				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	489.24	489.24	0.26	3.99	NS
Replication	4	12342.79	3085.70	1.66	2.52	NS
Treatment	16	#########	1058524.70	567.76	1.80	S
Years x Treatment	16	22900.37	1431.27	0.77	1.80	NS
Error	64	119320.44	1864.38			
Total	101	#########				

ANOVA 32: Analysis of variance on land equivalent ratio LER under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	1.98	3.29	NS
Treatment	16	3.98	0.25	48.03	1.97	S
Error	32	0.17	0.01			
Total	50	4.16				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.94	3.29	NS
Treatment	16	3.81	0.24	93.10	1.97	S
Error	32	0.08	0.00			
Total	50	3.90				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.00	0.00	0.10	3.99	NS
Replication	4	0.03	0.01	1.64	2.52	NS
Treatment	16	7.78	0.49	125.65	1.80	S
Years x Treatment	16	0.01	0.00	0.23	1.80	NS
Error	64	0.25	0.00			
Total	101	8.06				

ANOVA 33: Analysis of variance on area time equivalent ratio ATER under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	1.17	3.29	NS
Treatment	16	0.92	0.06	24.97	1.97	S
Error	32	0.07	0.00			
Total	50	1.00				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.00	0.00	0.32	3.29	NS
Treatment	16	0.51	0.03	18.28	1.97	S
Error	32	0.06	0.00			
Total	50	0.56				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.07	0.07	34.34	3.99	S
Replication	4	0.01	0.00	0.81	2.52	NS
Treatment	16	1.39	0.09	42.90	1.80	S
Years x Treatment	16	0.04	0.00	1.29	1.80	NS
Error	64	0.13	0.00			
Total	101	1.64				

ANOVA 34: Analysis of variance on pigeonpea aggressivity under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.09	0.05	2.61	3.29	NS
Treatment	16	18.43	1.15	66.46	1.97	S
Error	32	0.55	0.02			
Total	50	19.07				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.04	0.02	0.83	3.29	NS
Treatment	16	17.13	1.07	45.79	1.97	S
Error	32	0.75	0.02			
Total	50	17.91				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.09	0.09	4.31	3.99	S
Replication	4	0.13	0.03	1.58	2.52	NS
Treatment	16	35.34	2.21	108.52	1.80	S
Years x Treatment	16	0.22	0.01	0.67	1.80	NS
Error	64	1.30	0.02			
Total	101	37.08				

ANOVA 35: Analysis of variance on intercrop aggressivity under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.09	0.05	2.61	3.29	NS
Treatment	16	18.43	1.15	66.46	1.97	S
Error	32	0.55	0.02			
Total	50	19.07				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.04	0.02	0.83	3.29	NS
Treatment	16	17.13	1.07	45.79	1.97	S
Error	32	0.75	0.02			
Total	50	17.91				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.09	0.09	4.31	3.99	S
Replication	4	0.13	0.03	1.58	2.52	NS
Treatment	16	35.34	2.21	108.52	1.80	S
Years x Treatment	16	0.22	0.01	0.67	1.80	NS
Error	64	1.30	0.02			
Total	101	37.08				

ANOVA 36: Analysis of variance on pigeonpea competition ratio under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.18	0.09	2.82	3.29	NS
Treatment	16	40.01	2.50	77.20	1.97	S
Error	32	1.04	0.03			
Total	50	41.23				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.07	0.04	0.91	3.29	NS
Treatment	16	41.04	2.56	66.43	1.97	S
Error	32	1.24	0.04			
Total	50	42.34				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.06	0.06	1.63	3.99	NS
Replication	4	0.25	0.06	1.78	2.52	NS
Treatment	16	80.88	5.06	142.40	1.80	S
Years x Treatment	16	0.16	0.01	0.28	1.80	NS
Error	64	2.27	0.04			
Total	101	83.63				

ANOVA 37: Analysis of variance on intercrop competition ratio under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	3.38	3.29	**S**
Treatment	16	6.35	0.40	159.49	1.97	**S**
Error	32	0.08	0.00			
Total	50	6.44				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.01	0.00	1.08	3.29	NS
Treatment	16	5.16	0.32	123.02	1.97	S
Error	32	0.08	0.00			
Total	50	5.25				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.02	0.02	8.19	3.99	S
Replication	4	0.02	0.01	2.20	2.52	NS
Treatment	16	11.45	0.72	280.02	1.80	S
Years x Treatment	16	0.06	0.00	1.53	1.80	NS
Error	64	0.16	0.00			
Total	101	11.72				

ANOVA 38: Analysis of variance on pigeonpea relative crowding coefficient under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.52	0.76	1.17	3.29	NS
Treatment	16	1562.75	97.67	149.81	1.97	S
Error	32	20.86	0.65			
Total	50	1585.14				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	10.14	5.07	2.41	3.29	NS
Treatment	16	1881.64	117.60	56.01	1.97	S
Error	32	67.18	2.10			
Total	50	1958.97				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	10.91	10.91	7.93	3.99	S
Replication	4	11.66	2.92	2.12	2.52	NS
Treatment	16	3421.22	213.83	155.43	1.80	S
Years x Treatment	16	23.17	1.45	1.05	1.80	NS
Error	64	88.05	1.38			
Total	101	3555.01				

ANOVA 39: Analysis of variance on intercrop relative crowding coefficient under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	23.13	11.56	3.44	3.29	S
Treatment	16	306.82	19.18	5.71	1.97	S
Error	32	107.54	3.36			
Total	50	437.49				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	8.09	4.05	2.76	3.29	NS
Treatment	16	125.05	7.82	5.33	1.97	S
Error	32	46.95	1.47			
Total	50	180.09				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	16.51	16.51	6.84	3.99	S
Replication	4	31.22	7.81	3.23	2.52	S
Treatment	16	392.80	24.55	10.17	1.80	S
Years x Treatment	16	39.08	2.44	1.01	1.80	NS
Error	64	154.49	2.41			
Total	101	634.10				

ANOVA 40: Analysis of variance on relative crowding coefficient system under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	13.58	6.79	1.35	3.29	NS
Treatment	16	2754.22	172.14	34.15	1.97	S
Error	32	161.30	5.04			
Total	50	2929.10				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.34	0.17	0.05	3.29	NS
Treatment	16	2551.39	159.46	47.52	1.97	S
Error	32	107.37	3.36			
Total	50	2659.10				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.58	0.58	0.14	3.99	NS
Replication	4	13.92	3.48	0.83	2.52	NS
Treatment	16	5292.58	330.79	78.80	1.80	S
Years x Treatment	16	13.03	0.81	0.19	1.80	NS
Error	64	268.67	4.20			
Total	101	5588.78				

ANOVA 41: Analysis of variance on soil pH under intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.88	0.44	49.67	3.29	S
Treatment	16	0.24	0.02	1.71	1.97	NS
Error	32	0.28	0.01			
Total	50	1.40				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.14	0.07	1.32	3.29	NS
Treatment	16	0.66	0.04	0.78	1.97	NS
Error	32	1.70	0.05			
Total	50	2.50				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.29	0.29	9.39	3.99	S
Replication	4	1.02	0.25	8.22	2.52	S
Treatment	16	0.84	0.05	1.69	1.80	NS
Years x Treatment	16	0.07	0.00	0.14	1.80	NS
Error	64	1.98	0.03			
Total	101	4.19				

ANOVA 42: Analysis of variance on soil organic carbon (%) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.42	0.21	24.85	3.29	S
Treatment	16	0.24	0.02	1.79	1.97	NS
Error	32	0.27	0.01			
Total	50	0.94				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	0.02	0.01	1.77	3.29	NS
Treatment	16	0.29	0.02	3.96	1.97	S
Error	32	0.14	0.00			
Total	50	0.45				

ANOVA Table of Pooled Final						
Source of Variance	**Df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	0.02	0.02	3.20	3.99	NS
Replication	4	0.44	0.11	16.86	2.52	S
Treatment	16	0.52	0.03	5.02	1.80	S
Years x Treatment	16	0.01	0.00	0.06	1.80	NS
Error	64	0.42	0.01			
Total	101	1.41				

ANOVA 43: Analysis of variance on soil available nitrogen (kg ha^{-1}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	11.58	5.79	0.06	3.29	NS
Treatment	16	5258.84	328.68	3.40	1.97	S
Error	32	3097.31	96.79			
Total	50	8367.74				

ANOVA Table of second year (2022)						
Source of Variance	**Df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	20.88	10.44	0.04	3.29	NS
Treatment	16	8447.43	527.96	2.11	1.97	S
Error	32	8002.70	250.08			
Total	50	16471.01				

ANOVA Table of Pooled Final						
Source of Variance	**Df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	3388.07	3388.07	19.53	3.99	S
Replication	4	32.46	8.12	0.05	2.52	NS
Treatment	16	13346.08	834.13	4.81	1.80	S
Years x Treatment	16	360.20	22.51	0.13	1.80	NS
Error	64	11100.01	173.44			
Total	101	28226.82				

ANOVA 44: Analysis of variance on soil available phosphorus (kg ha^{-1}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	3.41	1.71	1.43	3.29	NS
Treatment	16	28.92	1.81	1.51	1.97	NS
Error	32	38.23	1.19			
Total	50	70.56				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	1.38	0.69	0.87	3.29	NS
Treatment	16	18.13	1.13	1.44	1.97	NS
Error	32	25.23	0.79			
Total	50	44.73				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	1.25	1.25	1.26	3.99	NS
Replication	4	4.79	1.20	1.21	2.52	NS
Treatment	16	42.33	2.65	2.67	1.80	S
Years x Treatment	16	4.71	0.29	0.30	1.80	NS
Error	64	63.46	0.99			
Total	101	116.54				

ANOVA 45: Analysis of variance on soil available nitrogen (kg ha^{-1}) under different intercropping system

ANOVA Table of first year (2021)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	3537.64	1768.82	1.98	3.29	NS
Treatment	16	2362.75	147.67	0.17	1.97	NS
Error	32	28523.50	891.36			
Total	50	34423.89				

ANOVA Table of second year (2022)						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Replication	2	3519.25	1759.62	3.02	3.29	NS
Treatment	16	3508.21	219.26	0.38	1.97	NS
Error	32	18620.77	581.90			
Total	50	25648.23				

ANOVA Table of Pooled Final						
Source of Variance	**df**	**SS**	**MSS**	**F Cal**	**F Tab at 5%**	**S/NS**
Years	1	495.79	495.79	0.67	3.99	NS
Replication	4	7056.89	1764.22	2.39	2.52	NS
Treatment	16	5568.65	348.04	0.47	1.80	NS
Years x Treatment	16	302.30	18.89	0.03	1.80	NS
Error	64	47144.27	736.63			
Total	101	60567.91				