# EVALUATION OF SOIL PHYSICO-CHEMICAL PROPERTIES, GROWTH AND YIELD OF PIGEONPEA AS INFLUENCED BY METHOD OF PLANTING AND INTEGRATED NUTRIENT MANAGEMENT IN *Vertisols* OF KARNATAKA

**M.Sc. (Ag.) Thesis**

**by**


**SOMASHEKAR T N**

**DEPARTMENT OF SOIL SCIENCE AND**

**AGRICULTURAL CHEMISTRY**

**COLLEGE OF AGRICULTURE**

**INDIRA GANDHI KRISHI VISHWAVIDYALAYA**

**RAIPUR (CHHATTISGARH)**


**2017**

# EVALUATION OF SOIL PHYSICO-CHEMICAL PROPERTIES, GROWTH AND YIELD OF PIGEONPEA AS INFLUENCED BY METHOD OF PLANTING AND INTEGRATED NUTRIENT MANAGEMENT IN *Vertisols* OF KARNATAKA

**Thesis**

**Submitted to the**

**Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)**

**by**

**SOMASHEKAR T N**

**IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF**

**Master of Science**

**in**

**Agriculture**

**(Soil Science and Agricultural Chemistry)**

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**JUNE, 2017**

## CERTIFICATE – I

This is to certify that the thesis entitled **"Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka"** submitted in partial fulfilment of the requirements for the degree of "**Master of Science in Agriculture**" of the Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) is a record of the bonafide research work carried out by **Somashekar T N** under my guidance and supervision. The subject of the thesis has been approved by Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by him.

**Co-Chairman** **Chairman**

**Date:** 04/07/2017

**THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE**

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| Chairman | : | **Dr. Alok Tiwari** |
| Co-Chairman | : | **Dr. S. P. Wani** |
| Member | : | **Dr. K. Tedia** |
| Member | : | **Dr. Srikant Chitale** |
| Member | : | **Dr. R.R. Saxena** |

## CERTIFICATE - II

This is to certify that the thesis entitled **"Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka"** submitted by **Somashekar T N** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the Departmentof **Soil Science and Agricultural Chemistry** has been approved by the external examiner and Student's Advisory Committee after an oral examination.

**Date:** 01/07/2017

**Signature External Examiner**

(Name: Dr. L. N. Verma

**Major Advisor** ____________

**Head of the Department** ____________

**Approved/ ~~Not Approved~~** ____________

**Dean/ Dean Faculty** ____________

**Director of Instructions** ____________

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*Somashekar T N*

*Department of Soil Science*
*and Agricultural Chemistry*
*College of Agriculture*
*I.G.K.V. Raipur (C.G.)*
*Date:* 04/07/17

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| | |
|---|---|
| % | Per cent |
| @ | At the rate |
| ₹ | Rupees |
| °C | Degree Celsius |
| B:C | Benefit cost ratio |
| CD | Critical difference |
| cm | Centimetre |
| $day^{-1}$ | per day |
| $dm^{-2}$ | Deci-centimetre square |
| *et al.* | And others/ co-worker |
| Fig. | Figure |
| g | Gram |
| $ha^{-1}$ | Per hectare |
| *i.e.* | That is |
| kg | Kilogram |
| m | Meter |
| $m^{-2}$ | Per meter square |
| No. | Number |
| NS | Non-Significant |
| P= 0.05 | Probability at 5% |
| q | Quintal |
| S | Significant |
| SEm± | Standard error of mean |
| *viz.* | For example |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| B | Boron |
| Ca | Calcium |
| Cu | Copper |
| DAP | Days after planting |
| EC | Electrical conductivity |
| Fe | Iron |
| HI | Harvest index |
| K | Potassium |
| max. | Maximum |
| Mg | Magnesium |
| min. | Minimum |
| Mn | Manganese |
| N | Nitrogen |
| OC | Organic carbon |
| P | Phosphorus |
| RDF | Recommended Dose of Fertilizer |
| S | Sulphur |
| Zn | Zinc |

## THESIS ABSTRACT

| | | | |
|---|---|---|---|
| a) | Title of the Thesis | : | "Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka". |
| b) | Full Name of the Student | : | Somashekar T N |
| c) | Major Subject | : | Soil Science and Agricultural Chemistry |
| d) | Name and Address of the Major Advisor | : | Dr. Alok Tiwari<br>Senior Scientist, Department of Soil Science and Agricultural Chemistry, College of Agriculture, IGKV, Raipur (C.G.) |
| e) | Degree to be awarded | : | Master of Science in Agriculture (Soil Science and Agricultural Chemistry) |

Signature of the Student

30/6/17

Signature of the Major Advisor

Date: 30/06/2017

Signature of Head of the Department

## ABSTRACT

The present investigation entitled **"Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka"** was conducted at farmer's field *i.e.*in three location of the same village Kasbe camp, District: Raichur (Karnataka), under the project of 'Bhoo Samruddhi', ICRISAT (International Crop Research Institute for Semi-Arid Tropics Agriculture), Patancheru, Hyderabad during *kharif* season 2016. The soil of the experiment plots was clayey. Low available nitrogen in all the three farmers plot, phosphorus was

high in two plots except one plot, while potassium was high in all plots. The experiment was laid out in factorial randomized block design (FRBD) with three replications comprising ten treatment combination. Treatment combination consisting of two factor, factor-1 at two levels *viz.,* methods of planting (dibbling and transplanting), and factor-2 at five levels *viz.,* $N_1$-control (Farmers practice) $N_2$-FYM @ 5 t $ha^{-1}$, $N_3$-vermicompost @ 5 t $ha^{-1}$, $N_4$-neem cake @ 250 kg $ha^{-1}$, $N_5$-green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. Sowing was done on July 14, 2016 harvesting was done on January 28, 2017.

The transplanted pigeonpea ($M_2$) recorded the maximum growth parameters *viz.,* plant height, number of leaves, number of primary and secondary branches $plant^{-1}$, leaf area $plant^{-1}$, leaf area index, total dry matter $plant^{-1}$ as well as yield and yield attributing characters *viz.,* number of pods $plant^{-1}$, weight of pods $plant^{-1}$, seed yield $plant^{-1}$, grain yield $ha^{-1}$, stalk yield $ha^{-1}$ and quality attributes of pigeonpea crop *viz.,* protein yield $ha^{-1}$. The nutrient content and uptake by seed and stalk, N in seed, content of P, K, and S in seed and stalk were found higher. In case of micronutrients Fe and Cu in seed, B and Zn in stalk and Mn in both was recorded higher nutrient content. Whereas concerned to uptake all the nutrients *i.e.* primary (N, P, K), secondary (Ca, Mg, S) and micronutrients (Fe, Zn, Cu, Mn and B) were recorded higher uptake in the transplanted pigeonpea. However, there was no effect on physico-chemical properties due to the method of planting.

The $N_3$-vermicompost along with gypsum and micronutrients have recorded the maximum growth parameters as well as yield and quality attributes of pigeonpea crop. The nutrient content was not affected due to any of the nutrient combinations and uptake was concern by seed and stalk, all the nutrients *i.e.* primary (N, P, K), secondary (Ca, Mg, S) and micronutrients (Fe, Zn, Cu, Mn and B) were recorded higher uptake at harvest. Marginal improvement in physico-chemical properties were recorded *viz.* lower bulk density, more moisture content at field capacity ($\Theta w$ and $\Theta v$), higher percent pore-space, higher content of organic carbon and higher available nitrogen.

The $N_2$ (FYM application along with gypsum and micronutrients) also showed better results than all treatments except $N_3$. The application of FYM recorded higher growth and yield parameters, along with the higher nutrient uptake and better physico-chemical properties (more moisture content, percent pore-space, organic carbon and available nitrogen). The $N_4$ (green leaf manure) and $N_5$ (neem cake) along with gypsum and micronutrients, recorded higher growth and yield parameters over $N_1$ (Control) farmer's practice, where it recorded lowest yields than other treatments.

Regarding economics, higher gross and net returns with high B:C ratio was recorded with the transplanted pigeonpea and found to be feasible for gaining higher profits by transplanting technology when compared to dibbling. Application of vernicompost, gypsum and micronutrients also recorded higher net returns and high B:C ratio, followed by FYM along with application of gypsum and micronutrients. The lowest cost of cultivation and net returns were recorded in control (farmer's practice).

## शोध सारांश

| | | | |
|---|---|---|---|
| अ) | शोध शिर्षक | : | "कर्नाटक की कन्हार मृदा में अरहर की बुवाई विधि एवं एकीकृत पोषक प्रबंधन में मृदा की भौतिक–रासायनिक गुणों, उपज व आर्थिक लाभ का मुल्यांकन" |
| ब) | छात्र का पूरा नाम | : | सोमशेखर टी एन |
| स) | मुख्य विषय | : | मृदा विज्ञान एवं कृषि रसायन |
| द) | मुख्य सलाहकार का नाम व पूरा पता | : | डॉ. आलोक तिवारी<br>वरिष्ठ वैज्ञानिक, मृदा विज्ञान एवं कृषि रसायन विभाग, कृषि महाविद्यालय रायपुर (छ.ग.) |
| इ) | उपाधि का नाम | : | एम.एस.सी (कृषि) मृदा विज्ञान एवं कृषि रसायन |

छात्र का हस्ताक्षर

मुख्य सलाहकार का हस्ताक्षर
दिनांक 30/6/2017

विभागाध्यक्ष का हस्ताक्षर

## शोध सारांश

वर्तमान में अध्ययन का विषय "कर्नाटक की कन्हार मृदा में अरहर की बुवाई विधि एवं एकीकृत पोषक प्रबंधन में मृदा की भौतिक–रासायनिक गुणों, उपज व आर्थिक लाभ का मुल्यांकन" का आयोजन कृषक के क्षेत्र में खरीफ 2016 के दौरान किया गया, उसी गांव कस्बे केम्प, जिला–रायचूर (कर्नाटक) के तीन स्थान 'भोजसमृद्धि' की परियोजना के अंतर्गत् (आई सी आर आई एस ए टी) (इंटरनेशनल क्राप रिसर्च इंस्टीट्यूट फॉर सेमीएरिड ट्रापिक्स) पाटनचेरू, हैदराबाद खरीफ 2016 में किया गया। प्रयोग भूखण्डों की मृदा कन्हार थी। सभी तीन भूखण्डों में नत्रजन की उपलब्धता कम, फास्फोरस एक भूखण्ड को छोड़कर शेष दो भूखण्डों में अधिक था, जबकी पोटेश्यिम सभी भूखण्डों में उच्च था। इस प्रयोग को क्रमबद्ध यादृच्छिक ब्लॉक डिजाइन (आरबीडी) में तीन उपचार के साथ रखा गया था, जिसमें दस उपचार संयोजन शामिल थे। दो कारकों से यूक्त संयोजन कारक–1 के दो स्तर (डिब्लींग और प्रत्यारोपण) पर तथा कारक–2 के पाच स्तर क्रमशः एन$_1$ (नियंत्रण) किसान अभ्यास, एन$_2$ (एफवायएम 5 टन / हेक्टेयर), एन$_3$ (वर्मीकम्पोस्ट 5 टन / हेक्टेयर), एन$_4$ (नीम की खली 250 किग्रा. / हेक्टेयर), एन$_5$ (ग्लाइरीसीडिया हरी पत्ती खाद 5 टन / हेक्टेयर), नियंत्रण को छोडकर सभी उपचार में सुक्ष्मपोषक तत्व (जिंकसल्फेट @ 25 किग्रा. / हेक्टेयर) और (बोरेक्स @ 5 किग्रा. / हेक्टेयर), जैव उर्वरक (राइजोबियम बीज उपचार के रूप में) और जिप्सम @100 किग्रा. / हेक्टयर को किया गया। फसल की बुवाई 14 जुलाई 2016 को तथा कटाई 28 जनवरी 2017 को किया गया।

मापदण्ड के अनुसार एम$_2$ (प्रत्यारोपित अरहर) अधिकतम वृद्धि किया जैसे–पौधे की उंचाई, पत्तियों की संख्या, प्राथमिक और द्वितीयक शाखाओं की संख्या प्रति पौध, पत्ती क्षेत्र सूचकांक, कुल सूखे पदार्थ प्रति पौध साथ ही साथ उपज एवं उपज के लक्षण जैसे–फलीयों की संख्या प्रति पौध, फली का वजन प्रति पौध,

बीज उपज प्रति हेक्टेयर, डंठल उपज प्रति हेक्टेयर एवं उपज गुणवत्ता एवं विशेषता सार्थक प्राप्त की गई। बीज एवं तना के द्वारा पोषक तत्व की मात्रा ग्रहण की गई जिसमें बीज में नत्रजन तथा फास्फोरस, पोटाश और सल्फर की मात्रा तना और बीज में अधिक पाया गया।

सुक्ष्मपोषक तत्वों में आयरन तथा कॉपर बीज में, बोरॉन और जिंक तना में तथा मैंगनीज तना एवं बीज दोनों में अधिक पोषक तत्व दर्ज की गई। सभी पोषक तत्वों एनपीके (प्राथमिक), कैल्शियम, मैग्नीशियम , सल्फर (द्वितीयक) तथा सूक्ष्म (आयरन, जिंक, कॉपर, मैंगनीज और बोरॉन) को प्रत्यारोपित अरहर में अधिक मात्रा में शोषित करते पाया गया। हालांकी रोपण के विधि के कारण भौतिक–रासायनिक गुणों पर कोई प्रभाव नही पाया गया।

एन$_3$ (जिप्सम और सूक्ष्म पोषक तत्वों के साथ वर्मीकम्पोस्ट) ने अधिकतम वृद्धि मापदण्डों के साथ ही अरहर फसल की उपज और गुणवत्ता को दर्ज किया गया। पोषक तत्वों के किसी भी संयोजन के कारण पोषक तत्व की गुणवत्ता प्रभावित नही हूई तथा बीज एवं डंठल के द्वारा सभी पोषक तत्वों अर्थात् प्राथमिक, द्वितीयक, और सूक्ष्मपोषक तत्वों का उच्चतम अवशोषण दर्ज किया गया।

भौतिक रासायनिक गुणों में सीमान्त सुधार दर्ज किया गया था, अर्थात् कम बल्क घनत्व, अधिक नमी की मात्रा, उच्च सारंध्रता, उच्च कार्बनिक कार्बन तथा उच्चतर उपलब्ध नत्रजन।

एन$_2$ (एफवायएम के साथ जिप्सम एवं सूक्ष्म पोषक भी डाला गया) में एन$_3$ को छोड़कर सभी उपचारों से बेहतर परिणाम देखा गया है, एफवायएम के प्रयोग करने से अधिक वृद्धि एव अधिक उपज दर्ज की गई, साथ ही पोषक तत्व अवशोषण में वृद्धि और भौतिक–रासायनिक गुण (नमी मात्रा, मृदा सारंध्रता, कार्बनिक कार्बन और नत्रजन) की उपलब्धता बेहतर पायी गई।

एन$_4$ और एन$_5$ (जिप्सम और पोषक तत्वों के साथ हरी पत्ती खाद एवं नीम की खली) को एन$_1$ (नियंत्रण) कृषक अभ्यास से अधिक वृद्धि एवं अधिक उपज के मापदण्डो को दर्ज किया गया जो कि यह अन्य उपचारो की तुलना में सबसे कम उत्पादन दर्ज किया गया।

अर्थशास्त्र की दृष्टि से, प्रत्यारोपित अरहर में अधिक सकल एवं शुद्ध रिटर्न के साथ अधिक लाभःलागत दर्ज किया गया। साथ ही साथ यह पाया गया की प्रत्यारोपित तकनीक अपनाकर डीब्लींग की तुलना में आर्थिक लाभ पाने की संभावना है। वर्मीकम्पोस्ट, जिप्सम और सूक्ष्मपोषक तत्व के प्रयोग से भी उच्च शुद्ध लाभ और उच्च लाभःलागत दर्ज किया गया। खेती की सबसे कम लागत और शुद्ध रिटर्न (नियंत्रण) किसान अभ्यास में दर्ज किया गया।

# CHAPTER - I

# INTRODUCTION

Pulses, together with cereals, have been fundamental to the development of modern agriculture. They are second only to cereals in importance for human and animal dietary needs. They play a vital role in human nutrition and occupy unique position in the Indian diet. They are important source of protein also rich in iron, iodine and essential amino acids. Deep rooting characteristics, ability to fix atmospheric nitrogen and huge leaf fall makes pulses an important component in cropping systems.

India is a largest producer and consumer of pulses accounting for 24.7 % of production in the world. The total area under pulses cultivation is 24.52 m ha with annual production of 17.52 m t (73 m t at the world level) at a productivity level of 714 kg $ha^{-1}$ in the country. Where, Madhya Pradesh with 4.70 m t stands first in the country followed by Maharashtra and Rajasthan with 1.95 and 1.74 m t respectively, (Agriculture statistics at a glance, 2015).

Among pulses, pigeonpea [*Cajanus cajana* (L.) Millsp.] is the most important rainy season crop in India. It is traditionally cultivated as annual crop in Asia, Africa, Caribbean region and Latin America. This crop is grown for multipurpose uses as a source of food, feed, fuel and fertilizer. Pigeonpea is nutritionally high in protein (19 - 22%) crop with high digestible protein (68%), low in fat and sodium with no cholesterol and has high dietary fiber, vitamins (thiamine, riboflavin, niacin and choline) and minerals (iron, iodine, calcium, phosphorous, Sulphur, and potassium). Besides its main use as *dhal* (de-hulled split peas), its immature green seeds and pods were also consumed as vegetable. The dry stems of pigeonpea are used as fuel wood. Being the pulse it enriches the soil through symbiotic nitrogen fixation; release soil bound phosphorous, recycles the soil nutrients and adds organic matter and other nutrients that make pigeonpea ideal crop for sustainable agriculture (Saxena, 2008).

The production of pigeonpea has increased over the years, from 1.72 m t in 1950-51 to around 2.78 m t in 2014-15. The increase in production is a result of increase in area from 2.18 m ha in 1950-51 to around 3.71 m ha in 2014-15. However, the overall productivity of pigeonpea has remained between 637 to 750 kg/ha (813kg $ha^{-1}$ in 2014) for last several decades (Agriculture statistics at a glance, 2015).

However, in Karnataka, the yield of pigeonpea remained with a range of 450 to 720 kg $ha^{-1}$ (658 kg $ha^{-1}$ in 2014-15) with an area of 0.73 m ha and contributes 19.64 % share at all India level with 0.48 m t of production (Agriculture statistics at a glance, 2015).

The low yield of pigeonpea is not only due to its cultivation in sub marginal lands but also due to poor nutrient management. It is generally due to soil moisture deficit during critical growth stages, such as flowering and pod development which results in significant reduction in grain yield (Sharma *et al.*, 2012). Water stress (drought and water logging), non availability of suitable varieties, inadequate transfer of technology, problems of weeds, insects pests and diseases are the major constraints for reduction of yield in pigeonpea (Anonymous, 2010).

The history of agriculture is very old. In earlier years, Indian farming was practiced in very simple way on natural resources (manures) with less energy. In last 35 to 40 years, steps were initiated towards the ‘Green revolution’ technology which is known as ‘Exploit Agriculture’ characterized by the use of high yielding varieties, chemical and biofertilizers and pesticides, ultimately resulted in self-sufficient in food grains. ‘Green revolution’ has resulted in deterioration of soil health which ultimately resulted in lower response to applied fertilizers. Unfortunately, in present day agriculture, due to continuous use of inorganics fertilizers with minimum or no organic manures, the cultivable lands are depleted in organic C content and becoming unfertile and exerting multiple nutrient deficiencies (Katyal,2000). In recent years, the awareness increases among the farmers about the adverse effect of excess use of inorganic fertilizers and other chemicals which lead to environmental pollution, residual effect and higher pest infestation. The management of soil fertility and maintaining of soil health plays an important role in increasing the production and sustaining the productivity of crops.

Sustainable farming depends upon the successful management of resources (inputs) for agriculture production and to satisfy the human need. No system of farming will be sustainable unless it does not care the health of soil, which plays a pivotal role in crop production. Sustainable production strategies often involve in application of organic inputs. The use of organic manures is known to promote soil health and better plant nutrition. But organic manures alone cannot meet the nutrient requirement of crops since their availability is limited. Use of biofertilizers such as biological nitrogen fixing and phosphate solubilizing micro-organisms is also gaining importance since biofertilizers are cost effective, eco-friendly and renewable source of plant nutrient to supplement chemical fertilizers. Organic manures and bio fertilizers (*Rhizobium* + phosphate solubilizing bacteria) which have been reported to be beneficial in augmenting the yield of grain legumes and this cannot meet the total nutrients need of the modern agriculture. One such approach is use of different integrated nutrient management systems which can save the soil, environment and farmer's limited resource. Integrating inorganic, organic and bio-fertilizers are essential in realizing the higher pigeonpea yield and reducing cost of production was reported by Reddy *et al.* (2011). The work of various research workers indicated that integrated nutrient management practice may play significant role to promote growth and productivity of pigeonpea in a sustainable basis as well as soil health.

Farmyard manure (FYM), though not useful as a sole source of nutrients, has a good complementary and supplementary effect with mineral fertilizer **(**Chaudhary *et al.,* 2004). Orozco *et al.* (1996) reported that compost increased the availability of nutrients such as phosphorus, calcium and magnesium, after processing by *Eisenia fetida.* Vermicompost could be a definitive source of plant growth regulators produced by interactions between microorganisms and earthworms, which could contribute significantly to enhancement of plant growth and yields. Vermicompost have been reported to contain large amounts of humic substances, which increase the yield of crop and fertility of soil**.** Green manuring is an age old concept of soil fertility management and being practiced to incorporate the succulent green portion of plants such as leaves, twigs and lopping's of trees into soil. Green manuring crops are known to fix atmospheric nitrogen, improves soil structure and recycle the nutrients. On decomposition of organic manures resulting in the liberation of $CO_2$ which influences on weathering of minerals and ultimate release of plant nutrients. Neem cake (*Azardirachita indica*) virtually as possible alternative to synthetic fertilizer and as a pesticide as it is an evergreen tree native to India sub-continent. It is considered to hold a great potential as slow nutrient release concentrated manure, pest control, cattle fed and energy etc. For centuries it has held high esteem by Indian folk for its manural, medicinal and insecticidal properties. Neem contains a large number of chemically diverse and structurally complex azadirachtnoids, which will serve as nutrient supply to crops as well as repellent/antifeedent to insect pest. Neem cake contains 7.1 % N and Azadirachtin content ranged from 0.14 to 2.02 %( w/w, kernel basis).

Sulphur as a plant nutrient is becoming increasingly important in dry land agriculture as it is the master nutrient of all oilseed crops and pulses and is rightly being called the “Forth Major Nutrient”. Among the field crops, oilseeds and pulses are more responsive to sulphur. The sulphur is one of the essential nutrient elements plays an important role in carbohydrate metabolism and formation of chlorophyll, glycosides, oils and many other compounds that are involved in N-fixation and photosynthesis of plants. Its nutrition to crops is vital both from quality and quantity point of view. It lowers the HCN content of certain crops, promotes nodulation in legumes.

Boron deficiency is a common problem for pulse production, especially on highly weathered soils. When grown in such soils it is highly advisable to apply. Boron deficiency in pigeonpea is often associated quality of the grains and the crop. Severe boron deficiency can result in split stems and roots, shortened internodes, terminal death, and extensive secondary branching.

Now days zinc deficiency is virtually an all India problem. The crop yield is reduced by about half when the zinc level in the level in the soil is lower than 1.2 mg $kg^{-1}$. So, trace elements should be included with recommended dose of fertilizers for providing balanced nutrition to the plants which not only helps to augment the production but also to sustain the productivity of pulse crop.

In the Karnataka state, the Government of Karnataka initiated a novel project under Rashtriya Krishi Vikas Yojana (RKVY) called 'Bhoochetana' to improve the livelihoods of dry-land farmers in the State by increasing the agricultural productivity of rain-fed agriculture. The primary strategy of ‘Bhoochetana’ is soil testing based nutrient management with a major thrust on micronutrients, gypsum, micronutrients (Zn & B) and bio-fertilizers at subsidized rates at village/cluster village, hence, the use of these inputs in system of integrated nutrient management also plays an important role for increasing the production and maintain the soil productivity of pigeonpea in the farmer’s field.

Another constraint in pigeonpea productivity is delayed sowing due to late onset of rains. Time of sowing has a prominent influence on both vegetative and reproductive growth phases of pigeonpea, as it determine the time available for vegetative growth before the onset of flowering which is mainly influenced by photoperiod. Thus, appropriate and proper time of sowing is one of the basic requirement for obtaining maximum yield and high returns of any crop. Pigeonpea suffers more when sowing is delayed (Padhi, 1995). Early sowing of pigeonpea *i.e.* in the month of May, ensures higher yield (Shankaralingappa and hedge, 1989). But in semi-arid regions like Karnataka, farmers are unable to sow pigeonpea in the month of May – June regularly because of non-receipt of sufficient rains and there is a stray cattle menace in the field damage the early sown pigeonpea crop, as no other crop is available in the field. Because of these constraints, the benefit of early sowing (May) of pigeonpea could not be realized.

In order to ensure timely sowing on account of delayed onset of monsoon, the transplanting of pigeonpea seedlings will be one of the best alternative measures to overcome delayed sowing. This technique involves raising of seedlings in the polythene bags or plastic trays in the nursery for a period of one month and then transplanting those seedlings in the main field, immediately after soil wetting rains. The transplanted hybrid pigeonpea recorded significantly higher yield attributes, grain and stalk yield as compared to dibbled pigeonpea in Karnataka (Mallikarjun et al. 2014). An established seedlings can picks up growth quickly under field conditions being more competitive.

The productivity of pigeonpea is controlled by many factors, of which the mineral nutrition plays an important factor, but the heavy and imbalance use of chemical fertilizers has led to think about the use of organic manures in intensively growing areas for sustainable production. To compare the two method of planting (transplanted and dibbled) pigeonpea with different integrated nutrient management practices to sustain the land productivity and to achieve production of pigeonpea with respect to black soils (*Vertisols*) of Karnataka, a field trail entitled **"Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka",** was conducted at Farmer's field in Raichur district of Karnataka under the project 'Bhoo-Samruddhi', ICRISAT (International Crop Research Institute for Semi-Arid Tropics), Patancheru, Hyderabad, during 2016-17 with the following objectives.

1. To assess effect of method of planting and integrated nutrient management on soil physico-chemical properties.
2. To study the effect of planting methods and integrated management on growth and yield of pigeonpea.
3. To work out the economics of different management practices.

# CHAPTER - II

# REVIEW OF LITERATURE

This literature pertinent to the present investigation entitled, "Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka" have been reviewed in this chapter under the following heads:

2.1 Effect of integrated nutrient management on soil physico-chemical properties.

2.2 Effect of integrated nutrient management practices on growth and yield of Pigeonpea.

2.3 Effect of planting methods on growth and yield of pigeonpea.

2.4 Economics of integrated nutrient management and method of planting on cultivation of pigeonpea.

## 2.1 Effect of integrated nutrient management on soil physico-chemical properties

Application of FYM alone or in combination with chemical fertilizers significantly increased the residual status of available nitrogen and phosphorus in soil (Dudhat *et al.*, 1997).

Integrated application of recommended fertilizer with FYM recorded significantly higher available soil nitrogen and improving soil fertility status over rest of the treatment (Babalad, 2000).

Sharma *et al.* (2003) reported that addition of FYM or vermicompost enhanced the yield of turmeric by 7-10% over the preceding year. Application of 50% RDF + 10 t vermicompost $ha^{-1}$ improved porosity, reduced soil bulk density and increased organic carbon content (from 0.44 to 0.72%).

Gholve *et al*. (2005) reported that maximum productivity, net returns in addition to improvement in soil fertility status and chemical properties from pigeonpea + pearl millet intercropping system (2:2) under dry land condition with application of 50% RDF of the respective crops on the basis of area proportion + vermicompost @ 3 t $ha^{-1}$ or FYM @ 5 $ha^{-1}$.

Bajpai *et al*. (2006) reported that in a long-term permanent plot field experiment which conducted from 1991-92 to 2002-03 in *Inceptisol* at the Raipur, C.G, showed significant reduction in bulk density (1.43 Mg $m^{-3}$), which was recorded in 50% N through green-manure (Sesbania *aculeata),* FYM + 50% N through fertilizer treatment as compared to other treatments in Rice-Wheat system of cropping pattern

Dubey and Vyas (2010) reported that application of 50% RDF + FYM @ 5 t $ha^{-1}$ + bio-fertilizers proved conducive to sustain the soil health by enhancing the organic carbon, available nutrient status, nutrient uptake by both crop (pigeonpea and soybean) by reducing the bulk density of soil.

Reddy *et al*. (2011) reported that application of 50% RDF through inorganic fertilizer + seed treatment with *Rhizobium* culture and PSB improves nutrient status of soil and ultimately increased the nutrient uptake which enhanced the yield of pigeonpea.

Nandapure *et al*. (2011) reported that the effect of long term fertilization and manuring with continuous cropping system. The bulk density was found to be significant. The values of bulk density ranged from 1.22 to 1.38 Mg $m^{-3}$ under different treatments. Significantly lowest bulk density (1.22 Mg $m^{-3}$) was observed with the application of 100% NPK + 10 t FYM $ha^{-1}$ followed by 10 t FYM $ha^{-1}$ alone (1.24 Mg $m^{-3}$) and 150% NPK (1.24 Mg $m^{-3}$). Significant reduction of bulk density in FYM treated plots along with 100% NPK may be due to better soil aggregation (Singh *et al*., 2000), higher organic carbon, more pore space (Selvi et al., 2005). Similar reduction in bulk density of soil due to application of FYM with 100% NPK were also observed by Bellakki et al. (1998) and Bhattacharya et al. (2004). Increasing levels of NPK from 50 to 150% significantly reduced bulk density from 1.36 to 1.24 Mg $m^{-3}$. Highest bulk density (1.38 Mg $m^{-3}$) was recorded in control plot. Reduction in bulk density in treatments receiving only NPK could be attributed to the biomass production with consequent increase in organic matter content of soil (Bharadwaj and Omanwar, 1992).

Meena *et al.* (2012) reported that the soil-test based NPK resulted in significantly higher grain yield of pigeonpea and wheat compared to sole manure treatment. Integration of fertilizer with FYM and induced defoliation appeared superior to sole fertilizer or manures. Conjunctive use of fertilizer NPK and FYM improved soil health as revealed by lower bulk density and higher water holding capacity over sole fertilizer treatment.

Pandey *et al*. (2013) reported that pigeonpea + urdbean intercropping system with application of FYM @ 5.0 t $ha^{-1}$ or vermicompost @ 2.5 t $ha^{-1}$ and RDF improved bulk density, organic carbon and increased available N, P and K content of the soil over initial soil value.

Pandey *et al*. (2015) found that application of RDF, FYM 5.0 tonnes $ha^{-1}$ and seed inoculation with biofertilizers, increased organic carbon, available N, P and K contents and reduced the bulk density of the soil over compared with initial soil value.

Hajari *et al*. **(**2015) the field experiment for seven years was conducted at Agricultural Research Station, Anand Agricultural University, Gujarat during *kharif* eason from 2006-07 to 2012-13 to study the varietal response of pigeon pea to organic manures under rainfed condition, showed that application vermicompost @ 1t/ha resulted in highest available $P_2O_5$ (31.28 kg $ha^{-1}$) after the crop harvest and lowest was recorded in control (17.98 kg $ha^{-1}$).

Meena *et al*. (2016) the field experiment was conducted during *Kharif* season on green gram in sandy loam soil, containing sand 62.71%, silt 23.10% and clay 14.19% (*Inceptisols*). It was observed that for post-harvest soil properties in treatment NPK of (20:40:40 kg $ha^{-1}$) + FYM @ 10 t $ha^{-1}$ and *Rhizobium* were improved significantly due to integrated use of inputs. Organic carbon 0.75%, available nitrogen 333.23 kg $ha^{-1}$, phosphorus 34.58 kg $ha^{-1}$, potassium 205.83 kg $ha^{-1}$, pore space 50.80%, pH 6.80 were found to be significant and bulk density 1.07 $Mgm^{-3}$, particle density 2.62 $Mgm^{-3}$, EC at $27^0$ C 0.24 $dSm^{-1}$ were found to be non-significantly improved in this treatment.

## 2.2 Effect of integrated nutrient management practices on growth and yield of Pigeonpea

The influence of integrated nutrient management practices on growth and yield is reviewed under following sub headings.

### 2.2.1 FYM

Patil *et al*. (2007) the crop responded favorably to application of FYM 5 t $ha^{-1}$ and gave significantly higher grain yield, protein yield and net returns over no manuring.

Anonymous (2008) reported that pigeonpea + soybean intercropping with application of 100% RDF, FYM @ 5.0 t $ha^{-1}$ and bio-fertilizer seed treatment produced higher pigeonpea yield (957 kg $ha^{-1}$ and PEY of (1558 kg $ha^{-1}$) over other treatment combinations.

Anonymous (2008) opined that pigeonpea yield was significantly influenced by fertilizers levels, organic manures as well as bio-fertilizer. Application of recommended dose of fertilizer gave significantly higher seed yield of pigeonpea (1574 kg $ha^{-1}$) than 50% RDF. Similarly application of FYM @ 5.0 t $ha^{-1}$ gave higher yield (1558 kg $ha^{-1}$) than no FYM at Bengaluru.

Application of 50 per cent RDF + FYM @ 5 t $ha^{-1}$ + bio- fertilizers was the suitable integrated plant nutrient management system for economizing inorganic fertilizer use, sustaining the soil health and productivity in pigeonpea + pearl millet intercropping system (2:2) reported by Patil and Shete (2008).

Roddannavar (2008) reported that, pigeonpea + soybean (1:1) and pigeonpea + finger millet (2:1) with the application of recommended dose of fertilizer based on area basis and FYM @ 5.0 t $ha^{-1}$ along with seed inoculation of PSB recorded significantly higher pigeonpea equivalent yield (1878 and 1869 kg $ha^{-1}$, respectively) as compared to sole crop of pigeonpea with INM practices (1680 kg $ha^{-1}$).

Sharma *et al*. (2009) revealed that application of FYM @ 5 t $ha^{-1}$ + seed inoculation with *Rhizobium* + micronutrient ($ZnSO_4$ @ 15 kg $ha^{-1}$) and crop residue @ 5 t $ha^{-1}$ recorded significantly higher plant height, primary and secondary branches plant$^{-1}$ and seed yield (184 cm, 12.34, 7.86 and 15.81 q ha$^{-1}$, respectively) of pigeonpea as compared to all other treatments.

Koushal and Singh (2011) reported that application of 50 % recommended N applied through urea + 50% N through FYM + PSB recorded the maximum plant height of 16.8, 65.78 and 73.77 cm at 30, 60, and 90 DAS, higher number of pods plant$^{-1}$, and higher test weight of soybean as compared to control treatment.

Sharma *et al*. (2012) found that among the integrated fertilizer levels, application of FYM @ 5 t ha$^{-1}$ + 100% RDF (Pigeonpea- 25:50:0, Green gram-25:50:0, and peralmillet - 50:25:0 NPK kg ha$^{-1}$) + seed inoculation of biofertilizers recorded significantly higher pigeonpea yield (15.74 q ha$^{-1}$), pigeonpea equivalent yield (18.29 q ha$^{-1}$), gross returns (` 43,930 ha$^{-1}$) , net returns (` 34,650 ha$^{-1}$) and B:C ratio(3.72) over other INM practices but it was found to be on par with application of FYM @ 5 t ha$^{-1}$ + 50% RDF + seed inoculation of biofertilizers (15.38 q ha$^{-1}$, 17.83 q ha$^{-1}$, 42,847 ha$^{-1}$, 34,032 ha$^{-1}$ and B:C ratio 3.85, respectively).

Anonymous (2012) reported that application of 25:50:25:20 kg N: $P_2O_5$: $K_2O$: S ha$^{-1}$ and $ZnSO_4$:15 kg ha$^{-1}$ with FYM or compost @ 7.5 tones ha$^{-1}$ as basal application at the time of sowing is found optimum for pigeonpea. Further they also reported that application of 100% recommended fertilizers with FYM @ 5.0 t ha$^{-1}$ gave significantly higher seed yield than 50% recommended fertilizer without FYM.

Sharma *et al.* (2012) opined that, interaction effect of 100% RDF, FYM @ 5 t ha$^{-1}$ and *Rhizobium* + PSB + PGPR application significantly increased seed yield of pigeonpea (23.3 q ha$^{-1}$) compared to 100% RDF with FYM @ 5 t ha$^{-1}$ and treatment without inoculation recorded lower seed yield (18.70 q ha$^{-1}$).

Pandey *et al.* (2013) reported that application of FYM @ 5.0 t ha$^{-1}$ or vermicompost @ 2.5 t ha$^{-1}$ with 100% RDF proved equally effective for enhancing the grain yield of pigeonpea and both produced significantly higher grain yield than RDF alone.

Pandey *et al*. (2015) the field experiment was carried out during rainy (*kharif*) season for 4 consecutive years 2008 to 2012 at Dholi, Bihar to assess the effect of integrated nutrient management on productivity and profitability of pigeonpea [*Cajanus cajan* (L.) Millsp.], under rainfed condition and reported that Protein content in grain was significantly influenced by fertilizer levels. Where application of FYM @5 t $ha^{-1}$ got higher protein content (19.7%) and biofertilizers (19.2%). Similarly application of RDF (20 kg N + 40 kg P + 20 kg K $ha^{-1}$) resulted in significantly higher protein (19.4%) content than 50% RDF (18.8%). Similarly, use of 5.0 tonnes FYM $ha^{-1}$ (19.7%) significantly enhanced protein content over no-FYM (18.6%).

Nitin *et al*. (2015) reported that Chickpea registered significantly higher seed yield with application of 10 t FYM $ha^{-1}$ + RDF and it was at par with 100% RDN through vermicompost. 100% RDF registered significantly superior chickpea seed yield and cotton equivalent yield in cotton-chickpea cropping sequence

Hajari (2015) found that application of vermicompost 1 t $ha^{-1}$ has recorded significantly highest plant height (91.3 cm) than control (78.9 cm) in pigeon pea crop.

Hajari (2015) noticed that the test weight of pigeonpea was significantly increased due to different manures. On an average, FYM recorded highest test weight (10.18 g) over control (9.66 g).

Meena *et al*. (2015) revealed that the hybrid pigeonpea ICPH 2671 recorded significantly higher grain yield (2.40 t $ha^{-1}$) as compared to cv. Maruti (1.68 t $ha^{-1}$) and the magnitude of increase was 41.7% higher.

**2.2.2 Vermicompost**

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

Sharma *et al*. (2010) reported that application of 50% RDF + vermicompost @ 2.5 t $ha^{-1}$ recorded significantly higher pigeonpea yield, pigeonpea grain equivalent yield (15.72 q ha$^{-1}$ and 19.36 q ha$^{-1}$, respectively) as compared to other INM practices and was found to be on par with application of phosphocompost @ 2.5 t ha$^{-1}$ + 50% RDF.

Kumawat *et al*. (2013) found that among the integrated nutrient management treatments, application of 100% RDF + 50% N through vermicompost + 5 kg Zn ha$^{-1}$ and 50% RDF + 100% N through vermicmopst + 5 kg Zn ha$^{-1}$ were equally effective and significantly superior to the rest of the treatments with respect to growth (plant height and branches plant$^{-1}$) and yield attributes (pods plant$^{-1}$, test weight and grain yield) of pigeonpea.

Pandey *et al.* (2013) reported that application of FYM @ 5.0 t ha$^{-1}$ or vermicompost @ 2.5 t ha$^{-1}$ with 100% RDF proved equally effective for enhancing the grain yield of pigeonpea and both produced significantly higher grain yield than RDF alone.

Kumawat *et al*. (2015) reported that application of 100% recommended dose of N, P, K, and S (20-40-20-20 kg ha$^{-1}$) + 50% recommended dose of nitrogen (through vermicompost) + 5 kg Zn ha$^{-1}$ gave significantly higher grain yield (21.05 and 5.23 q ha$^{-1}$), stover yield (82.19 and 14.47 q ha$^{-1}$), biological yield (103.24 and 18.85 q ha$^{-1}$) and harvest index (20.23 and 26.40%) of pigeonpea and blackgram, respectively.

Hajari *et al*. **(**2015) the field experiment for seven years was conducted at Agricultural Research Station, Anand Agricultural University, Gujarat during *kharif* eason from 2006-07 to 2012-13 to study the varietal response of pigeon pea to organic manures under rainfed condition, showed that, vermicompost @ 5t ha$^{-1}$ (1565 kg ha$^{-1}$) produced highest grain yield than other organic manures [pressmud 5t ha$^{-1}$, FYM 5t ha$^{-1}$, poultry manure 2t ha$^{-1}$ and recommended dose of fertilizer (20-40-0 kg NPK ha$^{-1}$)] and control (1276 kg ha$^{-1}$). Also among them vermicompost (91.3 cm) recorded significantly highest plant height. Other three manures were also proved significantly superior to control (78.9 cm).

Pal *et al*. (2016) the field experiment was conducted during the *kharif* season at Varanasi, where application of 100% recommended dose of fertilizer (30:60:20 NPK kg ha$^{-1}$) + 2.5 t (vermicompost), the fertility level recorded its superiority by recording higher growth attribute i.e. plant height (232.42 cm plant $^{-1}$), no. of branch (19.07 plant$^{-1}$), dry matter accumulation (214.65 g plant$^{-1}$), LAI (3.62) and yield attributes i.e. no. of pods (141.42 plant$^{-1}$), no. of grain (4.13 pod$^{-1}$) and test weight (108.22 g) and yield i.e. grain yield (1831.82 kg ha$^{-1}$), and stalk yield (8221.61 kg ha$^{-1}$) over all fertility levels.

### 2.2.3 Neem cake

Shivakumar *et al*. (2011) found that application of neem cake equivalent to 100% N, along with the recommended FYM, increased finger millet yield (12.8%) and available NPK in soil compared to the addition of inorganic NPK fertilizer + FYM alone . However, the experiment was conducted for only one season, whereas long term trials are needed in order to evaluate the organic fertilizer effect on soil. Subbiah *et al*. (1982), also claimed that neem cake treated with $(NH_4)_2$ $SO_4$ and urea significantly increased grain yield and NP uptake of finger millet.

### 2.2.4 Green manure (*Gliricidia*)

Incorporation of green manures resulted in increase in tillers and productive tillers of rice (Kumar and Mathew, 1994) and dry matter production (Yamada *et al*., 1986; Halepyati and sheelavanthsr, 1992 and Matiwade and Sheelvarantar, 1994). In contrast, Watannabe (1984) reported reducing in tillering with green manuring alone due to production of toxins and organic acids besides slow release of nutrients while undergoing anaerobic decomposition.

Long term fertilizer experiments at Madurai received significantly superior grain and straw yield with *Gliricidia* @12.5 t ha$^{-1}$ over prilled urea application (Udayasooriyan, 1988). Shinde (1995) reported that green manuring with gliricidia @10 t ha$^{-1}$ alone gave similar grain yield as with green manure + 50 kg N ha$^{-1}$.

Incorporation of glyricidia green leaves @ 5 t ha$^{-1}$ produced significantly higher grain yield (2297 kg ha$^{-1}$ ) of pearl millet + cowpea (1269 kg ha$^{-1}$) and pearl millet + sunhemp (1324 kg ha$^{-1}$) green manuring systems. Application of 50 kg N ha$^{-1}$ through subabul recorded highest grain yield and stover yield (1180 and 3196 kg $ha^{-1}$) and was on par with that of 50 kg N $ha^{-1}$ (904 and 2740kg $ha^{-1}$ through glyricidia (Durgude *et al*., 1996).

Haravade *et al*. (1996) reported that grain yield with application of gliricidia @ 5 t $ha^{-1}$ was higher when compaired to no fertilizer application.

Incorporation of gliricidia leaves as a green manuring @5 t $ha^{-1}$ at transplanting gave significant higher grain and straw yield and soil available NPK over no green manuring in rice at 20 cm X 15cm (Turkhede *et al*., 1998).

At Solapur, significantly higher sorghum grain yield (2370 kg $ha^{-1}$) was obtained with the combined application of FYM 4t $ha^{-1}$ + 20 kg N through urea and gliricidia @ 2 t $ha^{-1}$ + 20 kg through urea respectively under reduced tillage and it has also recorded maximum organic carbon content 0.80% and 0.76% respectively , (CRIDA, 2002).

Application of *Gliricidia* green leaf manure @ 5 t $ha^{-1}$ has recorded significantly higher maize yield (2272 kg $ha^{-1}$) compared to manuring (2333 kg $ha^{-1}$) at the same time it also recorded highest sustainability index (CRIDA, 2003).

Sharma *et al*. (2004) reported that the higher grain yield (1774 kg grain $ha^{-1}$) of sorghum was recorded with the application of gliricidia looping @ 2 t $ha^{-1}$ +20kg N through urea followed by compost @ 4t $ha^{-1}$ + 20 kg N through urea (1708 kg $ha^{-1}$). These treatments resulted in 84.62% and77.7% increase in grain yield respectively over control.

Dass *et al*. (2013) reported that based on a three year field study at Odisha, India, found that finger millet supplied with 50% of the recommended inorganic fertilizers, *Gliricidia* green leaf manure (2.5 t $ha^{-1}$), and *Azotobacter* and PSB, produced the highest grain yield (3.95 t $ha^{-1}$) compared to 1.76 t $ha^{-1}$ using the farmers' traditional practice (2 t $ha^{-1}$ FYM + 17 kg $ha^{-1}$ $P_2O_5$ + 12 kg $ha^{-1}$ $K_2O$), the combined organic treatment also increased soil moisture, organic C, and NPK content. Furthermore, the study found that treatments with *Gliricidia* (5 t $ha^{-1}$) combined with the above farmers' practice increased the available P and K in the soil, compared to the farmers' traditional practice alone.

Dass *et al*. (2013) reported that green manures and bio-fertilizers are also becoming valuable organic sources in finger millet production. Research conducted on green manure is mainly focused on *Gliricidia* (a leguminous tree fodder) [Vijaymahantesh et al., (2013).] which is rich in nutrients and decomposes rapidly.

Lakshmi (2014) reported that application of 125% Recommended dose of N + Sub soiling + TNAU micronutrient mixture @ 12.5 kg $ha^{-1}$ + Daincha recorded higher biometric characters, yield attributes (number of pods $plant^{-1}$, number of seeds $pod^{-1}$ , test weight) and yield (456 kg $ha^{-1}$) with higher soil organic carbon content (0.24 per cent) and available N (282.5 kg $ha^{-1}$). The B: C ratio (1.63) was also recorded higher under the same treatment.

### 2.2.5 Farmer's practice

Dass *et al*. (2013) reported that based on a three year field study at Odisha, India, found that finger millet supplied with 50% of the recommended inorganic fertilizers, *Gliricidia* green leaf manure (2.5 t $ha^{-1}$), and *Azotobacter* and PSB, produced the highest grain yield (3.95 t $ha^{-1}$) compared to 1.76 t $ha^{-1}$ using the farmers' traditional practice (2 t $ha^{-1}$ FYM + 17 kg $ha^{-1}$ $P_2O_5$ + 12 kg $ha^{-1}$ $K_2O$); the combined organic treatment also increased soil moisture, organic C, and NPK content. Furthermore, the study found that treatments with *Gliricidia* (5 t $ha^{-1}$) combined with the above farmers' practice increased the available P and K in the soil, compared to the farmers' traditional practice alone.

Saxena (2016) reported that among several location-specific hybrids were bred, ICPH 2740 gave out-standing performance in farmers' fields and later released in Telangana for cultivation in 2015 as *"Mannem Konda Kandi*". This wilt and sterility mosaic resistant hybrid was tested in 31 locations over five years exhibited 40.7% superiority over the ruling variety "Asha". In the on-farm trials also, this hybrid recorded yield advantage of 36.2% in four provinces.

Rao *et al*. (2013) revealed that in comparison to farmers' practice, farmer practice + Zn, B, S (10:0.5:30 kg Zn: B: S $ha^{-1}$) increased finger millet grain yield (3354 *vs*. 2142 kg $ha^{-1}$), stover biomass (6654 *vs*. 4630 kg $ha^{-1}$), total biomass

(10008 *vs*. 6772 kg $ha^{-1}$), and plant uptake of Zn (322 *vs*. 193 g $ha^{-1}$), B (21 *vs*. 17 g $ha^{-1}$), and S (16 *vs*. 10 kg $ha^{-1}$).

**2.2.6 Biofertilizer and Recommended dose of fertilizer (RDF)**

Patil *et al*. (2007) revealed that seed inoculation with biofertilizers significantly increased the growth, yield, protein content and monetary returns of pigeonpea crop.

Patil *et al*. (2007) reported that a significant increasing in yield, protein content and protein yield was noted with each increment of fertilizer dose up to 100% recommended dose. Fertilizing the crop with 100% RDF $ha^{-1}$ (25:50:0 kg N: P: K $ha^{-1}$) gave the highest net realization of Rs. 14854 $ha_{-1}$, however the highest net ICBR of 1:3.2 was secured with 75% RDF $ha^{-1}$.

Pandey and Kushwaha (2009) reported that interaction effect of *Rhizobium* + PSB with 100% RDF produced the maximum seed yield (2150 kg $ha^{-1}$) of pigeonpea followed by *Rhizobium* + PSB inoculation with 50% RDF (1909 kg $ha^{-1}$).

Reddy *et al.* (2011) reported that application of 50% RDF + seed treatment with *Rhizobium* @ 200 g $kg^{-1}$ seeds recorded significantly higher number of branches $plant^{-1}$, pods and higher grain yield of pigeonpea (16.3, 151.3 and 1358 kg $ha^{-1}$, respectively) as compared to seed treatment with *Rhizobium* @ 200 g $kg^{-1}$ seeds + 100% RDF + FYM @ 5 t $ha^{-1}$ (14, 142 and 1325 kg $ha^{-1}$, respectively).

Nagaraju and Mohankumar (2009) revealed that application of recommended nitrogen and potassium along with 100% $P_2O_5$ through activated mussorie rock phosphate (cow dung + urine + silt) recorded higher plant height, pods $plant^{-1}$ and yield (185 cm, 193 and 1949 kg $ha^{-1}$, respectively) of pigeonpea.

Tiwari *et al.* (2011) reported that seed inoculation with PSB recorded higher number of trifoliate leaves $plant^{-1}$ of pigeonpea as well as intercrops (urdbean and maize) over control. Balanced application of nutrient is essential to increase the yield of pigeonpea.

Goud *et al.* (2012) reported that sowing at 90 x 30 cm with application of 30:60:30:20:15 kg N: $P_2O_5$: $K_2O$: S: $ZnSO_4$ $ha^{-1}$ are essential for obtaining higher plant height, number of branches $plant^{-1}$ and number of pods $plant^{-1}$ (180 cm, 4.6 and 163, respectively) as compared to sowing at 75 x 25 cm with application of 20:45:20:20:15 kg N: $P_2O_5$: $K_2O$: S: $ZnSO_4$ $ha^{-1}$ recorded lower values (175 cm, 4.5 and 138, respectively) on pigeonpea.

Reddy *et al*. (2011) revealed that the results of pigeonpea crop with 50% RDF (20 kg N and 50 kg $P_20_5$ $ha^{-1}$) + seed treatment with Rhizobium@200 g $kg^{-1}$ seed recorded significantly more number of branches (16.3 $Pl^{-1}$.), pods (151.3 $Pl^{-1}$.), higher grain yield (1358 kg $ha^{-1}$) and net returns (Rs. 15541/-) followed by RDF + FYM (5 t $ha^{-1}$) and Rhizobium inoculation (14 $Pl^{-1}$., 142 $Pl^{-1}$.,1325 kg $ha_{-1}$ and Rs. 13304/-) and 50%RDF + dual inoculation with Rhizobium and PSB (14 $Pl^{-1}$, 133 $Pl^{-1}$., 1305 kg $ha^{-1}$ and Rs. 14462/-) respectively.

Meena *et al.* (2012) found that application of fertilizer (NPK) at soil-test based recommended rates produced 1.44 t $ha^{-1}$ of grain yield of pigeonpea which was significantly higher as compared to unfertilized control (0.94 t $ha^{-1}$).

Singh and Singh (2012) found that interaction between phosphorus levels and bio inoculants was significant. Higher grain yield was recorded with combined application of 75 kg $P_2O_5$ $ha^{-1}$ + PSB + PGPR, being on par with application of 50 kg $P_2O_5$ $ha^{-1}$ + PSB + PGPR and significantly superior over 25 kg $P_2O_5$ $ha^{-1}$ + PSB + PGPR.

Lakshmi (2014) reported that application of 125% recommended dose of N + Sub soiling + TNAU micronutrient mixture @ 12.5 kg $ha^{-1}$ + Daincha recorded higher biometric characters, yield attributes (number of pods $plant^{-1}$, number of seeds $pod^{-1}$ , test weight) and yield (456 kg $ha^{-1}$) with higher soil organic carbon content (0.24 per cent) and available N (282.5 kg $ha^{-1}$). The B: C ratio (1.63) was also recorded higher under the same treatment.

Ahirwar (2016 a) reported that the application of phosphorous up to 90 kg $P_2O_5$ $ha^{-1}$ gave maximum grain yield (16.06 q $ha^{-1}$). The dual biofertilizer (Rhizobium and PSB) also gave maximum yield up to $15.56qha^{-1}$. The biological nitrogen fixation was highest in these treatments. Hence the N-balance in soil was maximum (230 kg $ha^{-1}$)

Ahirwar *et al*. (2016 b) reported that the field experiment for two years was conducted during rainy seasons at Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidyalaya, Chitrakoot - Satna, (M.P), to study the effect of phosphorus and bio-fertilizers on nutrient content and uptake by pigeon pea and residual soil constituent. The application of Phosphorous up to 90 kg $ha^{-1}$ gave maximum grain yield (16.06 q $ha^{-1}$), than P 60 kg $ha^{-1}$ (15.81 q $ha^{-1}$), and P 30 kg $ha^{-1}$ (13.45 q $ha^{-1}$) and control of (10.33 kg $ha^{-1}$). Similarly the dual application of biofertilizers (PSB and *Rhizobium*) as seed treatment gave highest Yield (15.56 kg $ha^{-1}$).

### 2.2.7 Micronutrients

Srinivasarao *et al*. (2008) reported that most of the micronutrient studies related to finger millet have concentrated on zinc (Zn) and boron (B). Based on soil tests with 1617 farmers in the semi-arid tropics of India, found that Zn and B deficiency ranged from 2%–100% and 0%–100% respectively in farmers' fields, depending on the geographic region. The authors considered the following minimum levels to be critical for available Zn and B in farmers' fields, respectively: 0.75 mg Zn $kg^{-1}$ soil (DTPA extractable), 0.58 mg B $kg^{-1}$ soil (hot water extractable).

Rao *et al*. (2013) reported that based on surface soil testing (802 soil samples) found that farmers' fields were deficient in Zn (34%–88% of fields tested) and B (53%–96%) in the semi-arid regions of Karnataka, India.

Srinivasarao *et al.*, (2008) found that application of Zn, B and S along with N and P enhanced finger millet grain yield (56%), stover biomass (44%), total biomass (48%), and plant uptake of Zn (66%) and B (22%) compared to the addition of N and P alone.

Rao *et al*. (2013) revealed that when compared to farmers practice, farmer practice + Zn, B, S (10:0.5:30 kg Zn: B: S $ha^{-1}$) increased finger millet grain yield (3354 *vs*. 2142 kg $ha^{-1}$), stover biomass (6654 *vs*. 4630 kg $ha^{-1}$), total biomass (10008 *vs*. 6772 kg $ha^{-1}$), and plant uptake of Zn (322 *vs*. 193 g $ha^{-1}$), B (21 *vs*. 17 g $ha^{-1}$), and S (16 *vs*. 10 kg $ha^{-1}$).

Wani *et al*. (2015) revealed that the farmer's field of Raichur, Karnataka. The application of gypsum (200 kg ha$^{-1}$), zinc sulfate (10 kg ha$^{-1}$), borax (5 kg ha$^{-1}$) and Trichoderma (200 g kg$^{-1}$ seed) along with recommend dose of fertilizer. Resulted in remarkable growth and good pods in red gram. The pod failure rate was also lower with the practice of balanced nutrition that he had adopted through the Bhoochetana initiative (ICRISAT, Hyderabad.). The farmer obtained a yield of 4.2 q per acre as against an average yield of 2.5-3 q per acre that he had been getting over the last five years. As per his opinion, adoption of balanced nutrition has proved to be a viable practice which has given him a 39 per cent increase in crop yield that corresponds to a benefit of about `3,700 per acre.

Ahirwar *et al*. (2016 b) reported that field experiment for two years was conducted during rainy seasons at Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidyalaya, Chitrakoot - Satna, (M.P), reported that the nutrient contents of pigeonpea in grain and straw *viz.* N, P and K deviated almost significantly due to phosphorus levels and bio-fertilizers but not due to their interaction. The highest phosphorus level (90 kg ha$^{-1}$) and dual bio-fertilizers (*Rhizobium* +PSB) resulted in almost significantly higher N, P and K contents and their uptake of Pigeon pea (*Cajanus cajan* L.). The highest uptake of nutrients by pigeon pea producing a total biomass up to 68.68 q/ha with highest P 90 level was 81.15 kg N, 16.01 kg P and 48.84 kg K ha$^{-1}$ similarly under dual bio-fertilizers, the corresponding uptake values were 78.75 kg N, 15.18 kg P and 47.14 kg K ha$^{-1}$ significantly up to 90 kg $P_2O_5$ ha$^{-1}$ and dual bio-fertilizers.

**2.2.8 Hybrids performance.**

Saxena and Nadarajan (2010) reported that the new hybrid pigeonpea breeding technology, developed jointly by the ICRISAT and ICAR is capable of substantially increasing the productivity of red gram, and thus offering hope of pulse revolution in the country. In the on-farm trials conducted in the states of Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, and Jharkhand during 2007, 2008 and 2009 have demonstrated 30% yield advantage over local check varieties. So far the progress in the mission of enhancing the productivity of pigeonpea has been encouraging and the reality of commercial hybrids is just around the corner. The new hybrid pigeonpea will serve as the platform for the tremendous growth of pulse production in India.

Meena *et al*. (2015) reported that the field experiment was conducted during *Kharif* season 2009 to study the response of hybrid pigeonpea to planting geometry and fertility levels. The results revealed that the hybrid pigeonpea ICPH-2671 recorded significantly higher grain yield (2.40 $tha^{-1}$) as compared to cv. Maruti (1.68 t $ha^{-1}$) and the magnitude of increase was 41.7% higher. The yield parameters like grain weight $plant^{-1}$, number of pods $plant^{-1}$ and growth parameters like number of primary and secondary branches plant+, LAI and dry matter production and its distribution were higher with hybrid pigeonpea ICPH-2671 compared to variety Maruti.

Mula *at al*. (2015) conducted the research at Parbhani, Maharashtra, India during *kharif 2011and* 2012 to evaluate hybrid and varieties of pigeonpea for early seedling vigour and its related traits under greenhouse condition. For the experimental purpose they used three medium duration hybrids (ICPH 2671, ICPH 2740, and ICPH 3762) and three medium maturing varieties (BDN 711, BSMR 736, and Asha). The results revealed that hybrids recorded significantly higher rate of germination (97.58%), longer radicle length (16.75 cm), wider leaf area (177.70 cm2), more chlorophyll content (37.35), higher seedling dry weight (4.6 g) and greater seedling vigour index (4139.08) as compared to varieties (91.9%, 11.85 cm, 106.27 cm2, 32.81, 3.67 g and 3937.28, respectively).

Saxena *et al*. (2016) reported that a hybrid technology in pigeonpea [*Cajanus cajana* (L.) Millsp.], based on cytoplasmic nuclear male-sterility (CMS) and natural cross-pollination was evolved at ICRISAT. Among several location-specific hybrids were bred, ICPH 2740 gave out-standing performance in farmers' fields and later released in Telangana for cultivation in 2015 as "*Mannem Konda Kandi*". This wilt and sterility mosaic resistant hybrid was tested in 31 locations over five years exhibited 40.7% superiority over the ruling variety "Asha". In the on-farm trials also, this hybrid recorded yield advantage of 36.2% in four provinces.

Saxena *et al*. (2016) reported that the on-farm trials conducted by ICRISAT and other agricultural departments in Maharashtra (782 trials), Andhra Pradesh (399 trials), Karnataka (184 trials), Madhya Pradesh (360 trials), and Jharkhand (288 trials) with ICPH 2671 and recorded mean yield of 969, 1411, 1201, 1940 and 1460 kg ha$^{-1}$ respectively, which is 30% - 60% superiority over the best local cultivar. Overall, in all five states, ICPH 2671 was 46.6% better than the check in its productivity. Recently, two hybrids, ICPH 3762 (8) and ICPH 2740 (10), have also been released in India and these have also recorded > 30% yield advantages over the control in farmers' fields. The performance data of the three hybrids have shown that high yields can be achieved and the persistent yield plateau in pigeonpea can be smashed.

## 2.3 Effect of planting methods on growth and yield of pigeonpea

Anonymous (2009) reported that significantly higher seed yield per hectare was recorded with direct sown pigeonpea at 90 cm x 20 cm spacing (1577 kg ha$^{-1}$) as compared to transplanted pigeonpea with different row spacing. This is due to higher number of plants in the net plot (331.33), even though the yield attributes were significantly lower as compared to the yield attributes recorded under wider row spacing. These results are in accordance with the earlier findings of Ahalawat *et al.* (1975); Patel *et al.* (1984); Goyal *et al.* (1989); Shaik Mohammad (1997) and Parameswari *et al*. (2003).

Anonymous (2009) reported, direct sown pigeonpea with a spacing of 90 cm x 20 cm recorded higher grain yield, net returns and B: C ratio over different spacing of transplanted pigeonpea evaluated at Raichur in the North Eastern Dry Zone of Karnataka during kharif season.

Anonymous (2009) reported, significant increase in seed yield per plant with 150 cm x 90 cm spacing of transplanted pigeonpea as compared to direct sown pigeonpea and other row (90 x 20 cm) spacing of transplanted pigeonpea was attributed to the higher number of pods per plant (368.7), higher number of seeds per pods (3.53), 100 seed weight (10.33 g plant$^{-1}$) and higher seed yield per plant (154.87 g plant$^{-1}$).

Mallikarjun (2012) reported that the experimental research results in pigeonpea revealed that the transplanted hybrid pigeonpea produced significantly higher plant height (201.1 cm) as compared to dibbled hybrid pigeonpea (189.3 cm). The yield of transplanted hybrid pigeonpea recorded significantly higher seed yield (1189 kg ha-$^{1}$) and net returns (Rs. 36,005 ha$^{-1}$) as compared to dibbled hybrid pigeonpea (1376 kg ha$^{-1}$, Rs. 23,531 ha$^{-1}$). Similarly other growth and yield parameters were significantly higher in transplanted hybrid pigeonpea as compared to dibbled hybrid pigeonpea.

## 2.4 Economics of integrated nutrient management on cultivation of pigeonpea

Pigeonpea + pearl millet intercropping (2:2) under integrated nutrient management system revealed that gross monetary returns were significantly higher due to application of 50% RDF + vermicompost @ 3 t ha$^{-1}$ + bio fertilizer recorded maximum gross returns (Rs. 36,236 ha$^{-1}$) and B: C ratio (1.92) than those recorded in remaining treatments except 50% RDF + FYM @ 5 t ha$^{-1}$ + bio-fertilizer which was on par with it is observed by Gholve *et al*. (2005).

Patil *et al*. (2007) reported that a significant increasing in yield, protein content and protein yield was noted with each increment of fertilizer dose up to 100% recommended dose. Fertilizing the crop with 100% RDF ha$^{-1}$ (25:50:0 kg N: P: k ha$^{-1}$) gave the highest net realization of Rs. 14854 ha$^{-1}$, however the highest net ICBR of 1:3.2 was secured with 75% RDF ha$^{-1}$.

In a study Pandey and Kushwaha (2009) reported that combined inoculation of *Rhizobium* + PSB with 100% RDF recorded significantly higher net return (Rs. 38,233 ha$^{-1}$) followed by *Rhizobium* + PSB inoculation with 50% RDF (Rs. 32,437 ha$^{-1}$) of pigeonpea.

Sharma *et al*. (2010) reported that pigeonpea + green gram intercropping system with RDF + 2% urea spray at 15 and 30 days after harvest of intercrops recorded significantly higher pigeonpea equivalent yield (19.53 and 18.99 q ha$^{-1}$), gross returns (Rs. 31,439 and 30,576 ha$^{-1}$), net returns (Rs. 23,984 and 22,928 ha$^{-1}$) and B: C ratio (3.81 and 3.63, respectively) over other intercropping systems.

Sharma *et al.* (2010 a) concluded that use of vermicompost or phosphocompost @ 2.5 t $ha^{-1}$ or FYM @ 5 t $ha^{-1}$ along with 50% recommended fertilizer is economically beneficial for realizing the higher productivity of pigeonpea, pearl millet and green gram in pigeonpea + pearl millet (1:2) and pigeonpea + green gram(1:2) intercropping systems.

Reddy *et al.* (2011) concluded that 50% RDF + *Rhizobium* was the best combination for getting higher productivity with maximum net returns of pigeonpea compared to others.

Tiwari *et al.* (2011) reported that pigeonpea + urdbean cropping system with the application of PSB + FYM @ 2.5 t $ha^{-1}$ recorded higher net returns (Rs. 27,911 $ha^{-1}$) and B:C ratio (1.58) compared to pigeonpea + maize cropping system (Rs. 14,293 $ha^{-1}$) with the B:C ratio of 0.70.

Mallikarjun (2012) reported that the experimental research results in pigeonpea revealed that the transplanted hybrid pigeonpea produced significantly higher net returns (Rs. 36,005 $ha^{-1}$) as compared to dibbled hybrid pigeonpea (Rs. 23,531 $ha^{-1}$).

Meena *et al.* (2012) revealed that adoption of induced defoliation in pigeonpea along with NPK + FYM gave the highest system productivity whereas significantly higher net returns (Rs. 32,400 $ha^{-1}$) was found under NPK + induced defoliation over the other treatments.

Sharma *et al*. (2012) reported, on the basis of 3 years results, pigeonpea + green gram intercropping systems recorded significantly higher pigeonpea seed yield (14.43 q $ha^{-1}$), pigeonpea equivalent yield (17.13 q $ha^{-1}$), gross returns (` 40,983 $ha^{-1}$), net returns (32,499 $ha^{-1}$) and B: C ratio (3.81) over pigeonpea + pearl millet intercropping system (13.23 q/ha, 14.78 q/ha, ` 35,483/ha, ` 27,230/ha and 3.29, respectively).

Sharma *et al.* (2012) reported that 100% RDF, FYM @ 5 t $ha^{-1}$ and *Rhizobium* + PSB + PGPR gave significantly higher net returns, of 27,608, 29,764, and 27,330 Rs. $ha^{-1}$, respectively. Similar, results were obtained in case of benefit cost ratio also (1.49, 1.59 and 1.52, respectively).

Pandit *et al.* (2015) reported that the three years pooled data revealed significantly higher seed yield (1239 kg $ha^{-1}$), net return (INR 35466 $ha^{-1}$) and BCR (2.37) following application of 100% RDF over that in 50% RDF (999 kg $ha^{-1}$, INR 25931 and 1.75, respectively). Addition of FYM at 5 t $ha^{-1}$ also significantly increased seed yield (1183 kg $ha^{-1}$), net return (INR 31924 $ha^{-1}$) and BCR (2.16) over that in control (1056 kg $ha^{-1}$, INR 29472 $ha^{-1}$ and 1.95, respectively).

Pandey *et al.* (2015) observed that on application of farmyard manure (FYM) 5.0 tonnes $ha^{-1}$ has increased the Plant height, yield indices, *viz*. branches $plant^{-1}$, pods $plant^{-1}$, 100-seed weight, leaf area index, fruiting efficiency (15.6%), grain (2.01 tonnes $ha^{-1}$) and stalk yields, harvest index, protein content, water-use-efficiency (2.9 kg grain $ha^{-1}$ $mm^{-1}$), production efficiency (8.3 kg $ha^{-1}$ $day^{-1}$), NPK uptake, net returns ($67.55 \times 10^3$ $ha^{-1}$) and benefit: cost ratio (2.9) were significantly higher at recommended dose of fertilizer (RDF) than 50% RDF.

# CHAPTER - III

# MATERIALS AND METHODS

Field experiment (in farmer's field) for "Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka" was conducted during *kharif* season of 2016 at Kasbe camp (village), Raichur (district) Karnataka under the project 'Bhoo-Samruddhi', ICRISAT (International Crop Research Institute for Semi-Arid Tropics), Patancheru, Hyderabad. The details of experimental techniques adopted, material used for treatment evaluation and methods followed during entire course of investigation are presented in this chapter.

## 3.1 Location of the experimental site

The experimental site was at Farmer's field, Kasbe camp village, Raichur district, Karnataka, during *Kharif* season, 2016. The crop fields were located in Kasbe camp village which was 15 km Southward from University of Agricultural Sciences, Raichur. Geographically, the field was situated at $16^0$ 15' N latitude, $77^0$ 25' E longitude of 389 meter above mean sea level.

## 3.2 Climate and weather condition

Raichur falls under *North Eastern dry zone* (Zone II) of Karnataka, with the annual rainfall varies from 633 to 807 mm. The climate of the district is characterized by dryness for the major part of the year and a very hot summer. The low and highly variable rainfall renders the district liable to drought. The year may be divided broadly into four seasons. The hot season begins by about the middle of February and extends to the end of May. The South-west monsoon is from June to end of September. October and November are the post monsoon or retreating monsoon months and the period from December to the middle of February is the cold season. The weather parameters like maximum and minimum temperatures, relative humidity, rainfall and sunshine hours during the period of the experimentation was recorded at the meteorological observatory of the Main

**Table 3.1: Monthly meteorological data during the crop growth period (From June 2016 to Jan 2017) recorded at Main Agricultural Research Station, University of Agricultural Sciences, Raichur.**

| Month | Maximum temperature | Minimum temperature | Rainfall | Rainy day | Relative humidity | | Evaporation | Sun shine | Wind speed |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | RH I | RH II | | | |
| | (°c) | (°c) | (mm) | (mm) | (%) | (%) | (mm) | (hours) | (Km $h^{-1}$) |
| **Jun-16** | 33.79 | 24.19 | 194.10 | 7.00 | 84.00 | 53.00 | 5.78 | 2.30 | 13.00 |
| **Jul-16** | 31.85 | 23.50 | 143.20 | 12.00 | 86.00 | 61.00 | 4.38 | 0.80 | 13.50 |
| **Aug-16** | 32.39 | 23.05 | 78.00 | 4.00 | 86.00 | 54.00 | 4.52 | 4.90 | 12.70 |
| **Sep-16** | 29.19 | 22.57 | 292.50 | 15.00 | 92.00 | 72.00 | 2.81 | 2.70 | 7.70 |
| **Oct-16** | 31.24 | 19.67 | 39.20 | 2.00 | 84.00 | 49.00 | 4.24 | 7.20 | 5.00 |
| **Nov-16** | 34.21 | 22.27 | 0.00 | 0.00 | 82.00 | 36.00 | 6.32 | 7.00 | 4.50 |
| **Dec-16** | 30.20 | 15.60 | 8.20 | 1.00 | 81.00 | 35.00 | 6.60 | 6.50 | 5.10 |
| **Jan-17** | 33.96 | 21.97 | 92.87 | 3.67 | 76.77 | 41.81 | 6.22 | 5.79 | 8.49 |
| **Average** | 32.10 | 21.60 | 106.01 | 5.58 | 83.97 | 50.23 | 5.11 | 4.65 | 8.75 |
| **Total** | | | 848.07 | | | | | 37.19 | |

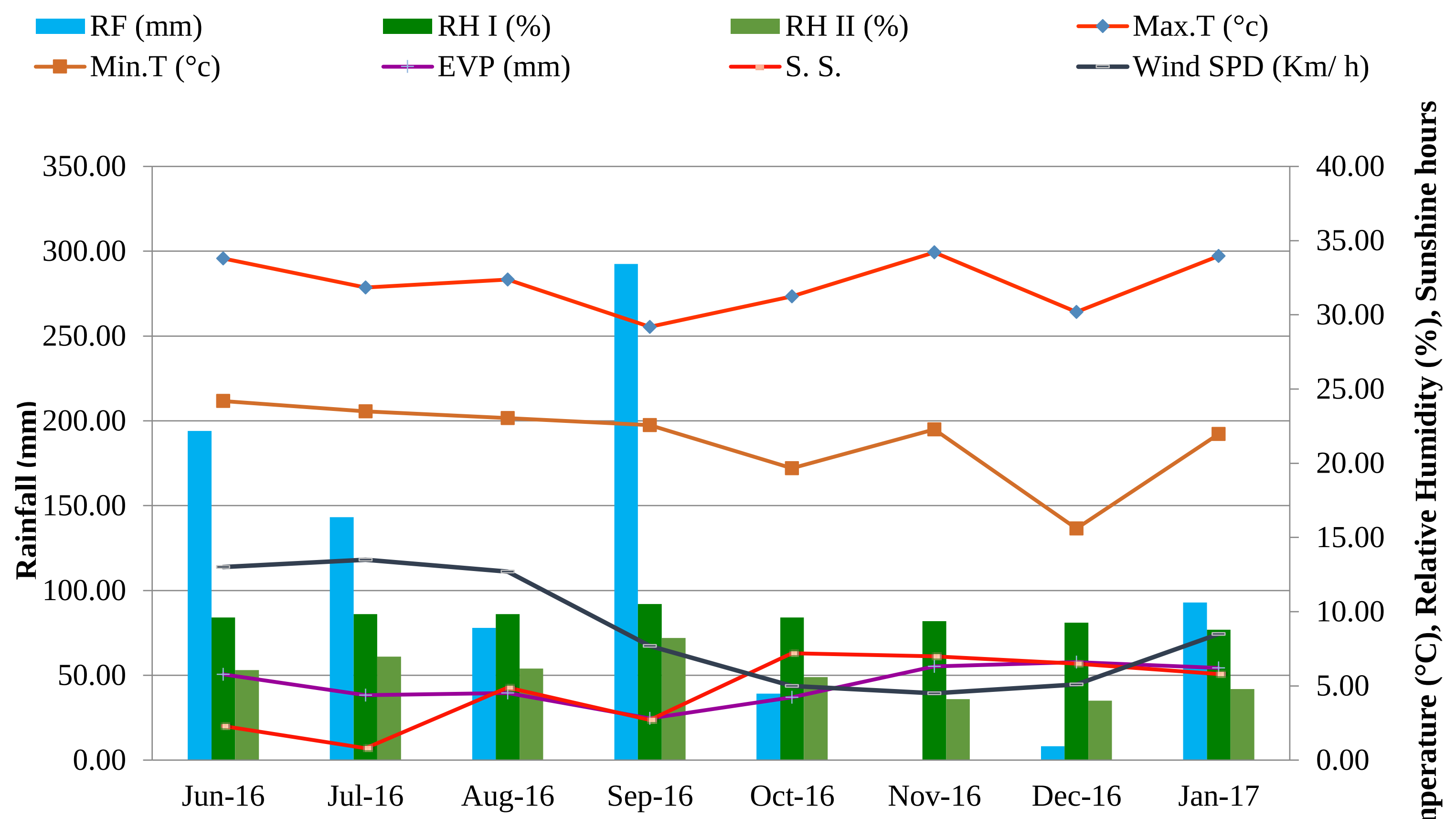



Fig.3.1 Monthly meteorological data prevailing during crop growth period, Kharif (2016-17)

Agricultural Research Station, University of Agricultural Sciences, Raichur. The details of meteorological data has been presented in Table 3.1 and depicted in fig. 3.1.

Minimum and maximum temperature during *kharif* season of 2016 was ranged from 29.19 to 34.21 $^{0}$C. The total rainfall received during *kharif* was 848.07 mm, which was slightly higher than the normal rainfall of the year. The maximum amount of rainfall (292.5 mm) was received in month of September. The maximum and minimum sunshine hours per day were 7.20 and 0.8 during first week of October and fourth week of July. The range of relative humidity at 7.12 a.m. was 92 to 76.77 per cent during the month of September and January, respectively. Whereas, the value of RH recorded at 2.14 p.m. ranged from 72 to 35 per cent during the month of September and December, respectively.

## 3.3 Soil characteristics of experimental site

The soils of Raichur region were *Vertisols*, fine textured materials with moderate drainage conditions. The soil of the experimental site belonged to

Order: *Vertisols*

Suborder: Usterts

Great group: Pellusterts

Sub group: Typic Pellusterts

Family: Very fine clayey isohyperthermic

Series: Raichur series

The topography of the experimental site was uniform and leveled. It was quite suitable for pigeonpea crop. Before ploughing, a composite soil sample from a depth of 0-15 cm was taken and analyzed for important physico-chemical properties of the soil (Table 3.2). All the three plots were having the character of good drainage, moisture holding capacity and infiltration rate.

**Table 3.2: Physico-chemical properties of soil at initial stage of three farmer's field**

| Properties | Farmer:1 | Farmer:2 | Farmer:3 | Method |
|---|---|---|---|---|
| **I. Physical properties** | | | | |
| 1. Particle size analysis | | | | |
| Sand (%) | 21.79 | 22.37 | 21.98 | International pipette method (Piper, 1967) |
| Silt (%) | 26.22 | 27.19 | 26.84 | International pipette method (Piper, 1967) |
| Clay (%) | 51.99 | 50.44 | 51.18 | International pipette method (Piper, 1967) |
| Textural class | Clayey | Clayey | Clayey | |
| 2. Bulk density (Mg $m^{-3}$) | 1.33 | 1.36 | 1.34 | Core sampler method (Dastane, 1967) |
| **II. Chemical properties** | | | | |
| Soil pH | 7.96 | 8.00 | 7.73 | pH meter (Thomas, 1996) |
| Electrical Conductivity (dS $m^{-1}$) | 0.17 | 0.12 | 0.26 | Conductivity meter (Rhoades, 1996) |
| Organic carbon (%) | 0.51 | 0.36 | 0.49 | Walkely and Black's wet oxidation method (Nelson and Sommers,1996) |
| Available nitrogen (kg $ha^{-1}$) | 213.25 | 175.62 | 200.7 | Alkaline permanganate method (Subbaiah and Asija, 1956) |
| Available phosphorus (kg $ha^{-1}$) | 33.28 | 15.07 | 39.69 | Olsen's method (Olsen. and Sommers, 1982) |
| Available potassium (kg $ha^{-1}$) | 611.52 | 589.12 | 638.2 | 1N Ammonium acetate method (Okalebo ,1993) |

**Plate I: A View of all the three farmer's field at flowering stage (*Kharif*, 2016-17)**

## 3.4 Cropping history of the experimental fields

Prior to the selection of field and putting up the experiment, the cropping history of the Farmer's field for last two years was recorded to ascertain its suitability for the trial (Table 3.3).

**Table 3.3: Cropping history of the experimental field**

| | **Farmer: 1** | | **Farmer: 2** | | **Farmer: 3** | |
|---|---|---|---|---|---|---|
| **Year** | ***Kharif*** | ***Rabi*** | ***Kharif*** | ***Rabi*** | ***Kharif*** | ***Rabi*** |
| 2014-15 | Paddy | - | Cotton | - | Cotton | - |
| 2015-16 | Paddy | - | Cotton | - | Cotton | - |
| 2016-17 | Pigeonpea (ICPH 2740) | - | Pigeonpea (ICPH 2740) | - | Pigeonpea (ICPH 2740) | - |

## 3.5 Experimental details

| | | |
|---|---|---|
| 1. Crop | : | Pigeonpea [*Cajanus cajan* (L.) Millsp.], Var. ICPH 2740 |
| 2. Experimental Design | : | Factorial Randomized Block Design (FRBD) |
| 3. Replications | : | 3 (Each replication in individual farmer field) |
| 4. Total no. of treatments | : | 10 |
| 5. Season | : | *Kharif*, 2016. |
| 6. Spacing | : | 1.5m x 0.6m (R-R x P-P) |
| 7. Plot size (gross) | : | 7.5 m X 5.4 m |
| 8. Total number of plots | : | 30 |
| 9. Gross plot area | : | 40.5 $m^2$ |
| 10. Soil type | : | Deep black clay soil |
| 11. Location | : | Kasbe camp (village), Raichur, Karnataka. |
| 12. Date of Sowing | : | 14/July/2016 |
| 13. Date of Harvesting | : | 28/January/2017 |

### 3.5.1 Layout plan

Ten treatments combinations comprising of two methods of planting (dibbling and transplanting), one control (Farmers practice) and four different integrated nutrient combinations with organic source ( FYM, vermicompost, neem cake, green leaf manure) are allocated randomly in each replication (Fig 3.2).

### 3.5.2 Treatments

**Factor- I [Method of establishment- M]**

**$M_1$**- Dibbling (direct sown)

**$M_2$**- Transplanted (seedling planted)

**Factor- II [Nutrient combinations- N]**

**$N_1$** - RDF control (Farmer's practice)

**$N_2$** - RDF + FYM

**$N_3$** - RDF + Vermicompost

**$N_4$** - RDF + Neem cake

**$N_5$** - RDF + Green leaf manure

### 3.5.3 Details of treatment combinations

**$T_1$** - $M_1N_1$ [Dibbling + control (Farmer's practice)]

**$T_2$** - $M_1N_2$ [Dibbling + FYM]

**$T_3$** - $M_1N_3$ [Dibbling + vermicompost]

**$T_4$** - $M_1N_4$ [Dibbling + Neem cake]

**$T_5$** - $M_1N_5$ [Dibbling + Green leaf manure]

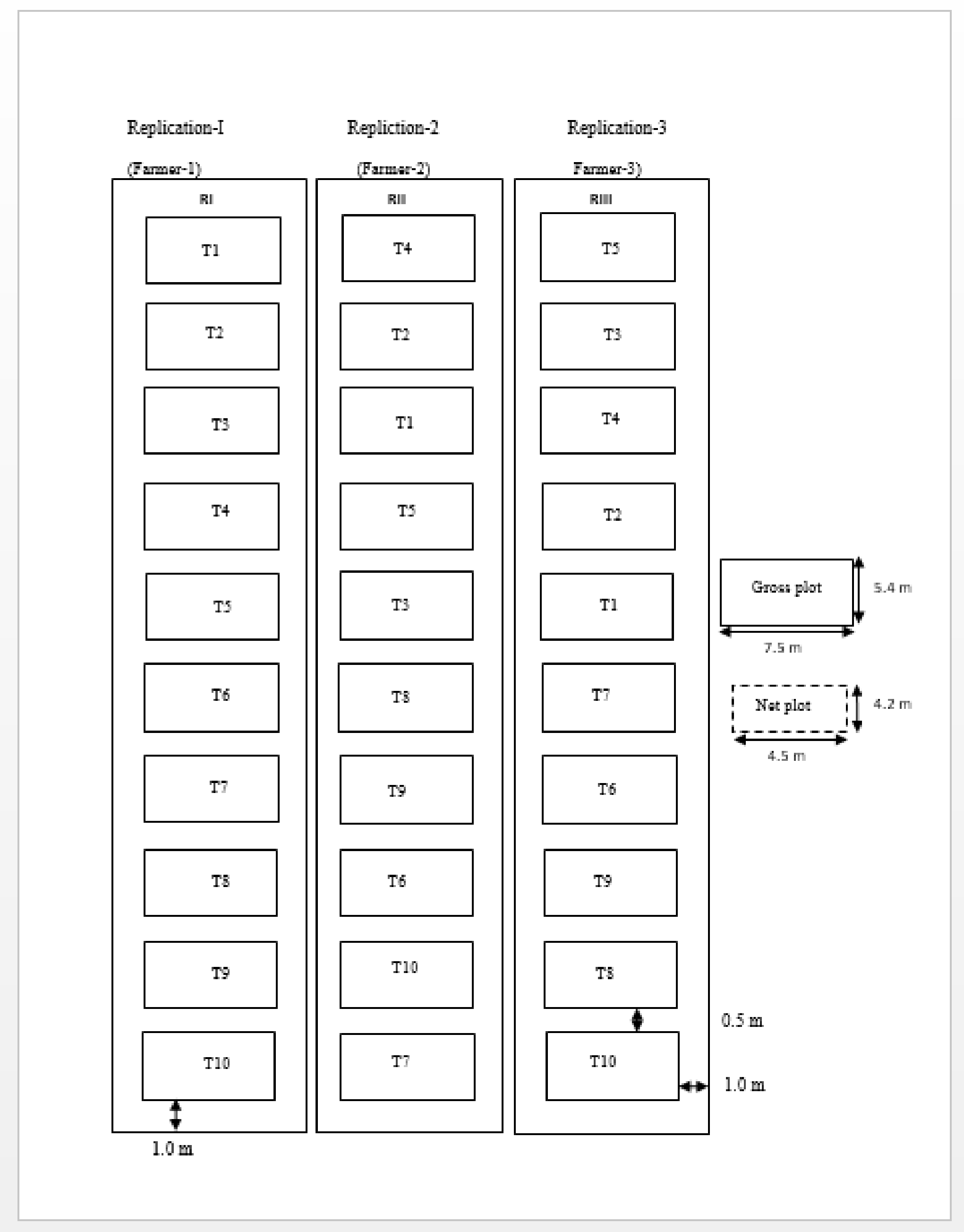
**$T_6$** - $M_2N_1$ [Transplanted + control (Farmer's practice)]

**$T_7$** - $M_2N_2$ [Transplanted + FYM]

**$T_8$** - $M_2N_3$ [Transplanted + vermicompost]

**$T_9$** - $M_2N_4$ [Transplanted + Neem cake]

**$T_{10}$** - $M_2N_5$ [Transplanted + Green leaf manure]




1. Number of treatment combination – 10

2. Number of replication - 3

3. Gross length of plot – 7.5 m

4. Net length of plot – 4.5 m

5. Gross width of plot – 5.4 m

6. Net width of plot – 4.2 m

7. Gross plot size – 40.5 sq. m

8. Net plot size – 18.9 sq. m

9. Inter row spacing – 1.5 m

10. Intra row spacing – 0.6 m

11. Between treatments - 0.5 m

12. Plot alley – 1.0 m

**Fig 3.2: Layout plan of the experiment, each replication in individual farmer's fields of Kasbe camp, Raichur, Karnataka.**

**Note:**

RDF: 20:50 kg ha$^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t ha$^{-1}$, Vermicompost @ 5 t ha$^{-1}$, Neem cake @ 0.25 t ha$^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t ha$^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg ha$^{-1}$ and Borax @ 5kg ha$^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg ha$^{-1}$).

## 3.6 Experimental crop details

Pigeonpea hybrid ICPH-2740 which was developed by ICRISAT, Hyderabad was chosen for the experimentation. **The state varietal release committee of Telangana released a pigeonpea hybrid developed by ICRISAT specifically suited for different agro ecologies across the state. ICPH 2740** – released under the name *Mannem Konda Kandi* – was the **first pigeonpea hybrid for the state of Telangana**. It was released from the Regional Agricultural Research Station (RARS), Palem, Mahabubnagar district. The hybrid possess resistance to wilt and sterility mosaic diseases and is suitable for deep black soils of the state. With a yield potential of 3.5 t ha$^{-1}$, it registered a 40% yield increase over the local cultivars.

Hybrid ICPH 2740 was developed by crossing a medium maturing cytoplasmic-nuclear male-sterile (CMS) line ICPA 2047 with a fertility restoring (R-) genotype ICPR 2740 of the same maturity (Kulbhushan Saxena *et al.*, 2016). The female parent (ICPA 2047) of this hybrid was bred by crossing the original CMS line 'ICPA 2039' carrying A4 cytoplasm of *Cajanus cajanifolius,* a wild relative of pigeonpea (Saxena *et al.*, 2005) with a disease resistant advanced breeding line ICPL 99050.

## 3.7 Cultural operations

Details of various cultural operations carried out in all the three farmer's field during the experimentations from field preparation to harvesting are given in appendix-I.

### 3.7.1 Land preparation

The experimental fields were prepared in the month of June. One deep ploughing with MB-plough followed by two cross harrowing was given. The plots


**Plate II: A view of different treatment plots (*Kharif*, 2016-17)**




Plate III: A view of experimental field from pre-flowering to maturity stage (*Kharif*, 2016-17) was then leveled to give a gentle slope for smooth surface drainage with the help of tractor drawn leveler.

### 3.7.2 Fertilizer application

Nitrogenous and phosphatic fertilizers (20 N and 50 $P_2O_5$ kg $ha^{-1}$) were applied just before the sowing using urea and di-ammonium phosphate (DAP) as source of nitrogen and phosphorus. Well-decomposed farmyard manure (FYM) was used according to treatments, similarly, vermicompost, neem-cake, gliricidia was procured from good source and applied as per the treatments. The microbial cultures of *Rhizobium* was used as a biofertilizer (seed treatment). Micronutrients - Zn ($ZnSO_4$ @ 25 kg $ha^{-1}$) and B (borax @ 5 kg $ha^{-1}$). Gypsum (100 kg ha $^{-1}$).

### 3.7.3 Techniques of fertilizer application

FYM, Neem cake, vermcompost, and gliricidia lopping's were uniformly spread to respective plots and well mixed into the soil at ten days before sowing and the chemical fertilizers, micronutrients and gypsum was placed in furrows opened at 5 cm away from the seed line (crop row) and covered with soil as basal dressing just before sowing. *Rhizobium* culture was used as a seed treatment.

### 3.7.4 Seeds sowing (Dibbling and Transplanting)

The furrows were opened manually at 1.5 m apart with the help of furrow opener. In case of dibbled plots, seeds of pigeonpea was dibbled at 4-5 cm depth in the furrows. Where as in transplanted plots, the seedlings were planted in the small opened pits with recommended spacing between plants.

### 3.7.5 Gap filling and thinning

To obtain optimum plant population, gap filling and thinning was done 10 days after sowing (DAS) in case of dibbled plots. Gap filling was also done in transplanted plots by planting the seedling.

### 3.7.6 Weed control

Hand weeding was done at 25 and 52 days after planting (DAP) to avoid crop weed competition.

### 3.7.7 Insect control

The Pigeonpea crop was protected against insects and sclerotium wilt with the sprays of Acephate and Vitavax powder each @ 2.0 g $litre^{-1}$ of water. *Helicoverpa armigera* (pod borer) was controlled with the sprays of Coragen @ 0.2 ml $litre^{-1}$ and Emamectine benzoate @ 0.5 ml $litre^{-1}$ of water during flowering and pod filling stages respectively and protected against leaf webber with sprays of DDVP and Chlorpyrifos @ 1.5 ml and 2.0 ml $litre^{-1}$ of water, respectively during flowering stage.

### 3.7.8 Nipping

At 60 DAP the nipping of main stem apical bud is carried out in order to maintain the excessive growth of plant height and to increase the number of secondary branches in successive growth stages of crop.

### 3.7.9 Irrigation

Being hybrid crop, maintenance of soil moisture is must and crop was given one protective irrigation (11/11/2016) to avoid moisture stress.

### 3.7.10 Harvesting and threshing

The border row pigeonpea plants were harvested followed by the net plot area as per the treatment. The plants were harvested by cutting close to the ground. After harvesting, the plants were bundled and allowed for sun drying. After complete sun drying, the crop was threshed by beating with wooden sticks. The seeds were winnowed, cleaned and seed weight per net plot was recorded.

## 3.8 Details of collection of experimental data

### 3.8.1 Growth parameters of pigeonpea

Five randomly selected plants in the net plot area were tagged and used for making observations on various growth parameters at 30, 60, 90, 120 DAP and also at harvest.

**3.8.1.1 Plant height**

The height from ground level to the growing tip of the shoots was recorded from five plants and mean plant height was worked out and expressed in centimeters.

**3.8.1.2 Number of leaves per plant**

The total number of fully opened leaves produced per plant were counted from five plants and their mean was taken as the number of leaves per plant.

**3.8.1.3 Number of primary branches per plant**

The total number of branches arising from the main stem were counted from five plants and the mean was taken as the number of primary branches per plant.

**3.8.1.4 Number of secondary branches per plant**

The total number of branches arising from the primary were counted number of branches from five plants and the mean was taken number of secondary branches per plant

**3.8.1.5 Leaf area per plant**

The leaf area per plant was worked out by disc method the dry weight basis at 30, 60, 90, 120 DAS and at harvest as the procedure suggested *by Vivekandan et al.,* (1972).

$$LA = \frac{Wa \times A}{Wd}$$

Where,

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

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

Wd = Oven dry weight of 10 discs in gram

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

### 3.8.1.6 Leaf area index

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

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

Where,

A= Leaf area per plant ($dm^2$)

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

### 3.8.1.7 Dry matter production

For this purpose at each sampling three plants were selected randomly and were cut close to the ground and plant parts were separated into stem, leave's and reproductive parts at 30, 60, 90, 120 DAP and at harvest. These samples were completely dried at 70°C in hot air oven for 72 hours till a constant weight. The samples were weighed and the dry weight of different plant parts was expressed in g per plant.

### 3.8.2 Yield attributes

Five tagged plants from the net plot area which were used for recording growth parameters were harvested separately at physiological maturity and were used for recording various yield components and seed yield as listed below.

### 3.8.2.1 Number of pods per plant

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

### 3.8.2.2 Number of seeds per pod

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

**3.8.2.3 Seed weight**

The seeds from the pods of five plants were separated by threshing and their mean weight was taken as a seed weight (g plant$^{-1}$).

**3.8.2.4 Test weight**

Seed samples from the produce of each plot were taken and 100 seeds from these samples were counted and weighed (g).

**3.8.2.5 Seed yield**

Pods from the net plot were threshed, cleaned and seed weight (kg) was recorded on per plot basis and later converted into per hectare basis

**3.8.2.6 Stalk yield**

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

**3.8.2.7 Husk yield**

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

**3.8.2.8 Harvest index**

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

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

**3.8.3 Quality parameters**

**3.8.3.1 Protein content**

The seed sample is treated with a mixture of sulfuric acid, selenium and salicylic acid. The salicylic acid forms a compound with the nitrates present to prevent losses of nitrate nitrogen. The actual digestion is then started with hydrogen peroxide, and in this step the larger part of the organic matter is oxidized. After decomposition of the excess of hydrogen peroxide, the digestion is completed by concentrated sulfuric acid at elevated temperature with selenium as a catalyst.

The automated procedure for the determination of total nitrogen is based on the modified Berthelot reaction; ammonia is buffered and chlorinated to on chloramine, which reacts with salicylate to 5- amino salicylate. After oxidation and oxidative coupling a green colored complex is formed. The absorption of the formed complex is measured at 660 nm. (Millsand Jones, 1996).

The protein percent in the seed was calculated by multiplying the nitrogen content by a factor 6.25.

**3.8.3.2 Protein yield**

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

**3.8.4 Physico-chemical properties of soil**

**3.8.4.1 Soil pH**

Soil pH was determined by digital automatic pH meter in soil water suspension 1:2 (Thomas, 1996).

**3.8.4.2 Organic carbon**

Organic carbon was estimated by Walkley and Black rapid titration method (Nelson and Sommers, 1996).

**3.8.4.3 Electrical conductivity**

Electrical conductivity was estimated by EC meter in soil water suspension 1:2 (Rhoades, 1996).

**3.8.4.4 Bulk density**

The BD of soil was determined by the core sampler method (Dastane, 1967).

**3.8.4.5 Gravimetric moisture at field capacity**

Gravimetric moisture at field capacity (ϴw) was estimated by collecting the soil sample at saturation with pressure plate apparatus at 0.33 bar and expressed in percentage (Laryea *et al*.1997).

**3.8.4.6 Volumetric moisture at field capacity**

Volumetric moisture at field capacity (ϴv) was determined by multiplying gravimetric moisture content with the respective soil bulk density and expressed in percentage

**3.8.4.7 Available nitrogen**

Available nitrogen content in soil (kg $ha^{-1}$) after harvest of crop was determined by alkaline permanganate method as described by Subbiah and Asija (1956).

**3.8.4.8 Available phosphorous**

Available phosphorus content in soil (kg $ha^{-1}$) after harvest of crop was analyzed by the method as suggested by Olsen (1954).

**3.8.4.9 Available potassium**

Available potassium content in soil (kg $ha^{-1}$) after harvest of crop was analyzed by the ICP-OES, by extracting with 1 N ammonium acetate (Okalebo, 1993).

**3.8.4.10 Available sulphur**

The available (heat soluble) S (kg $ha^{-1}$) was extracted with 0.15% $CaCl_2$ determined as per the method adopted by Williams and Steinbergs (1959).

**3.8.4.11 Exchangeable Calcium and Magnesium**

The exchangeable Ca and Mg is extracted with I N ammonium acetate (Okalebo, 1993). Determined with ICP-OES.

**3.8.4.12 Available boron**

The extracted B in the filtered extract is determined by the azo methane -H colorimetric method and expressed in (mg $kg^{-1}$). (Keren. R., 1996).

### 3.8.4.13 Available micronutrients zinc, copper, iron and manganese

The DTPA extracted micronutrients with use of inductively coupled plasma emission spectroscopy (ICP-OES) for the estimation of available micronutrients (mg $kg^{-1}$). (Lindsay and Norvell, 1978).

### 3.8.5 Plant analysis

### 3.8.5.1 Total nitrogen content

The plant sample is treated with a mixture of sulfuric acid, selenium and salicylic acid. The salicylic acid forms a compound with the nitrates present to prevent losses of nitrate nitrogen. The actual digestion is then started with hydrogen peroxide, and in this step the larger part of the organic matter is oxidized. After decomposition of the excess of hydrogen peroxide, the digestion is completed by concentrated sulfuric acid at elevated temperature with selenium as a catalyst.

The automated procedure for the determination of total nitrogen is based on the modified Berthelot reaction; ammonia is buffered and chlorinated to on chloramine, which reacts with salicylate to 5- amino salicylate. After oxidation and oxidative coupling a green colored complex is formed. The absorption of the formed complex is measured at 660 nm. (Millsand Jones, 1996).

$$\text{N uptake (kg ha}^{-1}\text{)} = \frac{\text{N content (\%)} \times \text{Yield (kg ha}^{1}\text{)}}{100}$$

### 3.8.5.2 Total phosphorus content

Digested samples with nitric acid in the presence of an oxidizing agent such as Hydrogen Peroxide. The above digest can be used for the estimation of total nutrients by inductively coupled plasma optical emission spectrometry (ICP-OES). (Matthew *et al*. 2011).

$$\text{P uptake (kg ha}^{-1}\text{)} = \frac{\text{P content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

**3.8.5.3 Total Potassium content**

Digested samples with nitric acid in the presence of an oxidizing agent such as Hydrogen Peroxide. The above digest can be used for the estimation of total nutrients by inductively coupled plasma optical emission spectrometry (ICP-OES). (Matthew *et al*. 2011).

$$\text{K uptake (kg ha}^{-1}) = \frac{\text{K content (\%)} \times \text{Yield (kg ha}^{-1})}{100}$$

**3.8.5.4 Sulphur, Calcium and Magnesium content**

Digested samples with nitric acid in the presence of an oxidizing agent such as Hydrogen Peroxide. The above digest can be used for the estimation of total nutrients by inductively coupled plasma optical emission spectrometry (ICP-OES). (Matthew *et al.* 2011).

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (mg kg}^{-1}) \times \text{Yield (kg ha}^{-1}) \text{ x } 10^{3}}{100}$$

**3.8.5.5 Micronutrients-zinc, copper, iron and manganese content**

Digested samples with nitric acid in the presence of an oxidizing agent such as Hydrogen Peroxide. The above digest can be used for the estimation of total nutrients by inductively coupled plasma optical emission spectrometry (ICP-OES). (Matthew *et al.* 2011).

$$\text{Nutrient uptake (g ha}^{-1}) = \frac{\text{Nutrient content (mg kg}^{-1}) \times \text{Yield (kg ha}^{-1}) \times 10^{3}}{100}$$

**3.8.5.6 Boron content**

Digested samples with Nitric acid in the presence of an oxidizing agent such as Hydrogen Peroxide. The above digest can be used for the estimation of total nutrients by inductively coupled plasma optical emission spectrometry (ICP-OES). (Matthew *et al.* 2011).

$$\text{B uptake (g ha}^{-1}) = \frac{\text{B content (mg kg}^{-1}) \times \text{Yield (kg ha}^{-1}) \times 10^{3}}{100}$$

## 3.9 Economic analysis

### 3.9.1 Cost of cultivation

The expense incurred (₹ $ha^{-1}$) for all the cultivation operations from preparatory tillage to harvesting including threshing, cleaning as well as the cost of inputs *viz.*, seeds, fertilizers, pesticides, *etc.* applied to each treatment were calculated on the basis of prevailing local charges.

### 3.9.2 Gross income

The gross realization in terms of rupees per hectare was worked out taking into consideration the grain and stalk yields from each treatment and local market prices.

### 3.9.3 Net income

Net returns (₹ $ha^{-1}$) of each treatment were calculated by deducting the total cost of cultivation from the gross returns.

### 3.9.4 Benefit: Cost ratio (%)

The B: C ratio worked out by the following formula.

$$\text{B: C ratio} = \frac{\text{Gross income (₹ ha}^{-1})}{\text{Cost of cultivation (₹ ha}^{-1})}$$

## 3.10 Statistical analysis

Data collected in respect of various parameters were analyzed statistically as described by Gomez, K. A. and Gomez, A. A. (1984). The factorial randomized completely block design was adopted in the experiment. The data was subjected to the test of significance (‘F’ test) by analysis of variance method. In the tables, critical difference values are for the observation significant at five percent level and for non-significant (NS) values the S.Em ± values are given.

# CHAPTER - IV

# RESULTS AND DISCUSSION

The results of the field experiment entitled “Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka” at farmer’s field of Raichur district, Karnataka under the project ‘Bhoo-Samruddhi’, ICRISAT (International Crop Research Institute for Semi-Arid Tropics), Patancheru, Hyderabad during *Kharif* season 2016-17 are presented in this chapter. It includes the experimental data on various growth parameters, yield attributes, various soil physico-chemical properties and economics are presented in tables and as well as in figures and discussed with appropriate reasons.

## 4.1 Growth parameters of pigeonpea

### 4.1.1 Plant height

The data pertaining to plant height of pigeonpea at different stages of crop growth (30, 60, 90, 120 DAP and at harvest) are presented in table 4.1 and depicted in fig. 4.1. The results revealed that the plant height of pigeonpea increased progressively increase with increase in the age of the crop. Both method of planting and integrated nutrient management practices had a significant impact on plant height of pigeonpea.

With regard to impact of method of planting, the plant height at 30 DAP in transplanted pigeonpea ($M_2$) recorded the plant height of 51.87 cm which was significantly higher than the plant height of 47.42 cm recorded under dibbling ($M_1$) method, Similar trend was followed at 60, 90 120 DAP and harvest with plant height of 95.14 cm, 136.90 cm, 200.02 cm and 213.28 cm respectively. Mallikarjun *et al.* (2012) similarly revealed that the transplanted hybrid pigeonpea produced significantly higher plant height as compared to dibbled hybrid pigeonpea. This may due to the early establishment in the seedling stages of crop which favors the better nutrient absorption and utilization of natural resources.

The integrated nutrient management treatments revealed non-significant difference with respect to plant height at 30 DAP stage of crop growth. Whereas at 60 DAP and further growth stages the plant height of pigeonpea revealed significant difference among the INM treatments, At 60 DAP the integrated nutrient combination treatment $N_3$-vermicompost, recorded highest plant height (98.64 cm) compared to $N_4$-neem cake (90.08 cm), $N_1$-farmer's practice (86.70 cm) and was on par with N2-FYM (94.14 cm), $N_5$-green leaf manure (91.97 cm). The $N_2$-FYM treatment recorded significant higher plant height as compared to $N_1$-farmer's practice (86.70 cm) and was on par with $N_5$-green leaf manure (91.97 cm) and $N_4$-neem cake (90.08 cm) treatments. The lowest plant height was found in $N_1$-farmer's practice (86.70 cm) treatment. Similar trend was followed at 90, 120 DAP and harvest (141.18 cm, 201.77 cm, and 221.17 cm, respectively) in case of $N_3$ recording highest plant height, the possible growth in plant height is due to increased enzymatic activity and presence of beneficial microorganisms or biologically active plant growth influencing substances, might have involved (Singh *et al.*2008), Sharma *et al*. (2009), Kumawat *et al*., (2013), Gholve *et al.* (2005), Hajari et al.**, (**2015) and Pal *et al*., (2016) also reported similar results.

Interaction among the method of planting and integrated nutrient management on plant height found non-significant during all stages of plant growth.

### 4.1.2 Number of leaves per plant

The data related to the number of leaves per plant of pigeonpea at different growth stages (30, 60, 90, 120 DAP and at harvest) are presented in table 4.2. The results indicated that number of leaves was significantly influenced due to method of planting and different INM treatments at all the stages of crop growth.

In case of method of planting at 30 DAP, the transplanted ($M_2$) pigeonpea found significantly higher number of leaves per plant (58.55) as compared to dibbled ($M_1$) pigonpea (50.73). Similar trend was followed at 60, 90 120 DAP and harvest. Lower

**Table 4.1: Effect of method of planting and integrated nutrient management on plant height at different stages of crop growth**

| Treatments | Plant height (cm) | | | | |
|---|---|---|---|---|---|
| | 30 DAP | 60 DAP | 90 DAP | 120 DAP | At harvest |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 47.42 | 89.47 | 129.32 | 186.20 | 201.83 |
| **M2 : Transplanted** | 51.87 | 95.14 | 136.90 | 200.02 | 213.28 |
| **Mean** | 49.65 | 92.30 | 133.11 | 193.11 | 207.55 |
| **S. Em.±** | 0.93 | 1.58 | 2.24 | 2.52 | 2.74 |
| **C.D.(P=0.05)** | 2.76 | 4.70 | 6.65 | 7.48 | 8.15 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 47.83 | 86.70 | 124.06 | 183.11 | 194.15 |
| **N2 : FYM** | 50.40 | 94.14 | 136.04 | 196.74 | 211.47 |
| **N3 : Vermicompost** | 50.86 | 98.64 | 141.18 | 201.77 | 221.17 |
| **N4 : Neem cake** | 49.48 | 90.08 | 130.52 | 190.13 | 204.28 |
| **N5 : Green leaf manure** | 49.67 | 91.97 | 133.75 | 193.79 | 206.69 |
| **Mean** | 49.65 | 92.30 | 133.11 | 193.11 | 207.55 |
| **S. Em.±** | 1.47 | 2.50 | 3.54 | 3.98 | 4.34 |
| **C.D.(P=0.05)** | NS | 7.44 | 10.51 | 11.83 | 12.89 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**Table 4.2: Effect of method of planting and integrated nutrient management on number of leaves per plant at different stages of crop growth**

| Treatments | Number of leaves per plant | | | | |
|---|---|---|---|---|---|
| | **30 DAP** | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 50.73 | 319.74 | 683.29 | 1008.15 | 579.49 |
| **M2 : Transplanted** | 58.55 | 346.55 | 753.17 | 1074.21 | 627.95 |
| **Mean** | 54.64 | 333.14 | 718.23 | 1041.18 | 603.72 |
| **S. Em.±** | 1.05 | 6.38 | 13.99 | 16.78 | 10.63 |
| **C.D.(P=0.05)** | 3.12 | 18.96 | 41.55 | 49.85 | 31.57 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 49.93 | 288.10 | 633.24 | 939.77 | 543.21 |
| **N2 : FYM** | 56.20 | 346.02 | 755.90 | 1073.01 | 621.23 |
| **N3 : Vermicompost** | 57.30 | 368.88 | 802.67 | 1138.76 | 661.31 |
| **N3 : Neem cake** | 54.57 | 321.80 | 681.72 | 1010.07 | 586.58 |
| **N5 : Green leaf manure** | 55.20 | 340.92 | 717.62 | 1044.30 | 606.27 |
| **Mean** | 54.64 | 333.14 | 718.23 | 1041.18 | 603.72 |
| **S. Em.±** | 1.66 | 10.09 | 22.11 | 26.53 | 16.80 |
| **C.D.(P=0.05)** | NS | 29.98 | 65.70 | 78.82 | 49.91 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

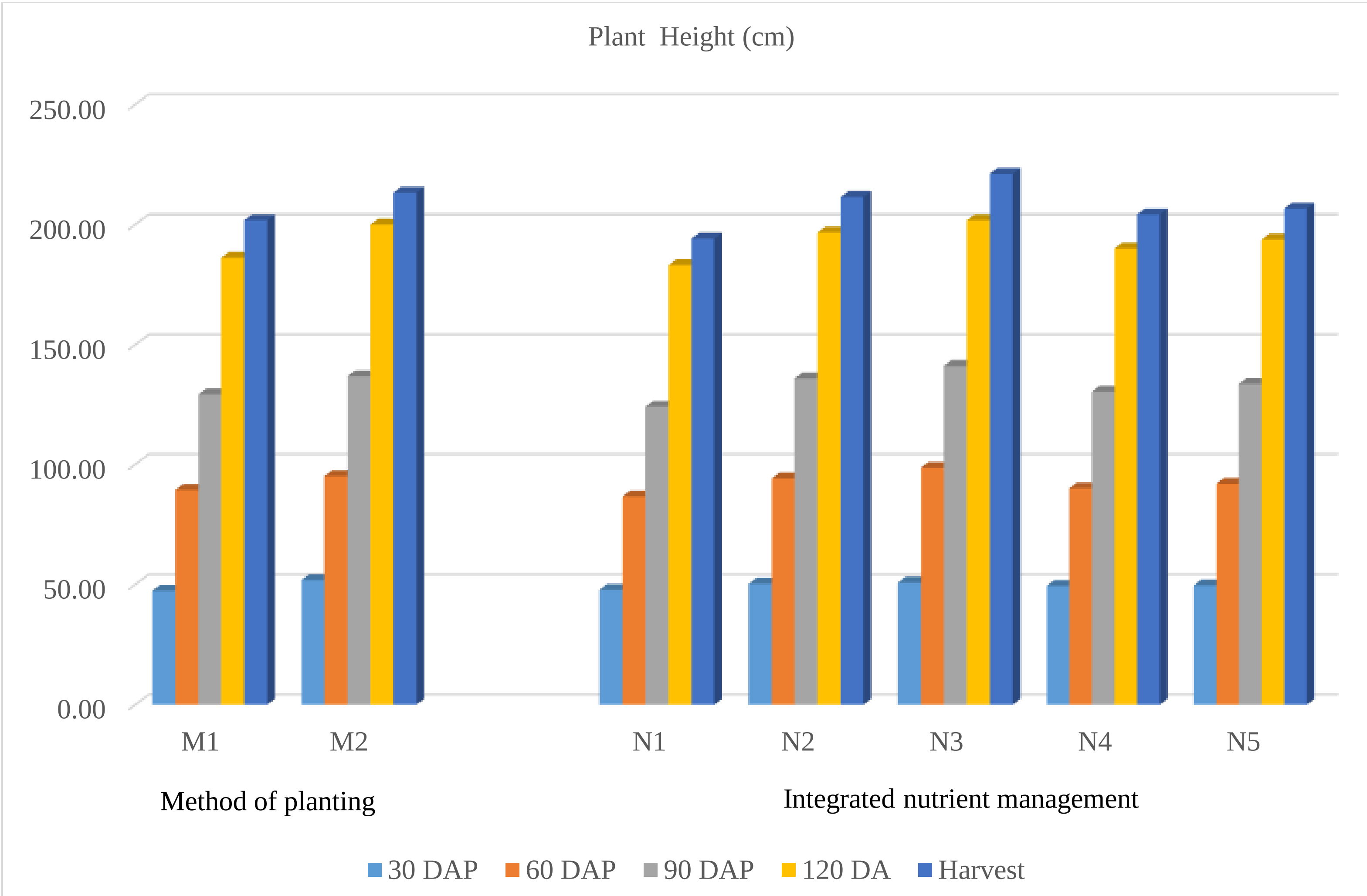



**Fig 4.1: Plant Height of pigeonpea at different growth stages (cm) as influenced by method of planting and integrated nutrient management**

number of leaves was noticed at harvest as compared to leaves at 120 DAP is due to complete maturity and drying stage of crop resulted in reduction in total number of leaves at this stage.

The integrated nutrient management treatments at 30 DAP found no significance in total number of leaves per plant, where at 60 DAP and further the treatment $N_3$-vermicompost (368.88) found significantly higher number of leaves per plant than $N_4$-neem cake (321.80), $N_1$ -farmer's practice (288.10) and on par with $N_2$-FYM (346.02) and $N_5$-green leaf manure (340.92) treatment. The treatment $N_5$-green leaf manure (340.92) found significant over $N_1$-farmer's practice (288.10) treatment and on par with $N_4$-neem cake (321.80) treatment. Similar trend was followed at 90, 120 DAP and harvest with highest number of leaves (802.67, 1138 and 661.31, respectively) in case of $N_3$ treatment. The drastic reduction in leaves was noticed at harvesting stage in all treatments than the preceding growth stage (120 DAP).

The interaction effect among the method of planting and integrated nutrient management on number of leaves per plant found non-significant during all stages of plant growth.

**4.1.3 Number of primary branches per plant**

The data regarding number of primary branches per plant of pigeonpea at different stages of crop growth (30, 60, 90,120 DAP and at harvest) are presented in table 4.3**.** The results revealed that the number of primary branches per plant of pigeonpea was significantly influenced due to method of planting and different INM treatments at all the stages of crop growth.

At 30 DAP, the transplanted ($M_2$) pigeonpea recorded significantly higher number of primary branches per plant (6.04) compared to dibbled ($M_1$) treatment (4.79). Similar trend was followed at 60, 90 120 DAP and harvest. Mallikarjun *et al.* (2012) also reported higher number of branches in transplanted pigeonpea than dibbled crop.

Among the integrated nutrient management treatments no significance difference between the treatments was recorded at 30 DAP. Whereas at 60 DAP, $N_3$-

vermicompost treatment recorded significantly higher number of primary branches per plant (11.48) when compared to that observed under $N_2$-FYM (10.37), $N_4$-neem cake (9.73), $N_5$ -green leaf manure (10.13) and $N_1$-farmer's practice (8.56). Further, $N_2$, $N_4$, and $N_5$ were on par with each other. Similar trend was followed at 90, 120 DAP and at harvest. When compared to 120 DAP and harvest stage slight reduction in the number of primary branches was notice at harvesting stage, because of drying of lower primary branches due to smothering or shade effect of upper branches on lower branches of the same crop, that made the lower branches to dry drastically. Sharma *et al*. (2009) also found the higher number of primary branches per plant with application of FYM @ 5 t $ha^{-1}$.

The interaction effect among the method of planting and integrated nutrient management on number of primary branches per plant found non-significant during all stages of plant growth.

**4.1.4 Number of secondary branches per plant**

The data concerned to number of secondary branches per plant of pigeonpea at different stages of crop growth (60, 90,120 DAP and at harvest) are presented in table 4.4. The results indicated that the number of secondary branches per plant of pigeonpea was significantly influenced due to integrated nutrient management and method of planting at all the stages of crop growth.

At 60 DAP the method of planting in pigeonpea with the transplanted ($M_2$) recorded higher number of secondary branches per plant (17.42) which is significantly higher than the number of secondary branches recorded under dibbled method ($M_1$) of planting (15.16). Similar trend was followed at 90, 120 DAP and harvest. The increase in the secondary branches in $M_2$ was due to higher number of primary branches per plant and rapid and healthy growth of the plant with better establishment by transplanting from planting onwards.

Among the integrated nutrient management treatments, at 60 DAP $N_3$-vermicompost have recorded significantly higher number of secondary branches per

**Table 4.3: Effect of method of planting and integrated nutrient management on number of primary branches per plant at different stages of crop growth**

| Treatments | Number of primary branches per plant | | | | |
|---|---|---|---|---|---|
| | **30 DAP** | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 4.79 | 9.42 | 11.72 | 12.75 | 12.72 |
| **M2 : Transplanted** | 6.04 | 10.69 | 13.05 | 14.39 | 14.35 |
| **Mean** | 5.42 | 10.06 | 12.39 | 13.57 | 13.53 |
| **S. Em.±** | 0.17 | 0.21 | 0.27 | 0.28 | 0.27 |
| **C.D.(P=0.05)** | 0.50 | 0.64 | 0.81 | 0.82 | 0.80 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 4.90 | 8.56 | 10.84 | 11.99 | 11.97 |
| **N2 : FYM** | 5.63 | 10.37 | 12.48 | 13.78 | 13.74 |
| **N3 : Vermicompost** | 5.80 | 11.48 | 13.93 | 15.12 | 15.04 |
| **N4 : Neem cake** | 5.22 | 9.73 | 12.26 | 13.33 | 13.32 |
| **N5 : Green leaf manure** | 5.53 | 10.13 | 12.41 | 13.62 | 13.59 |
| **Mean** | 5.42 | 10.06 | 12.39 | 13.57 | 13.53 |
| **S. Em.±** | 0.27 | 0.34 | 0.43 | 0.44 | 0.43 |
| **C.D.(P=0.05)** | NS | 1.01 | 1.29 | 1.29 | 1.26 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**Table 4.4: Effect of method of planting and integrated nutrient management on number of secondary branches per plant at different stages of crop growth**

| Treatments | Number of secondary branches per plant | | | |
|---|---|---|---|---|
| | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | |
| **M1 : Dibbled** | 15.16 | 23.63 | 27.59 | 30.96 |
| **M2 : Transplanted** | 17.42 | 26.98 | 31.29 | 37.29 |
| **Mean** | 16.29 | 25.31 | 29.44 | 34.13 |
| **S. Em.±** | 0.30 | 0.46 | 0.67 | 0.81 |
| **C.D.(P=0.05)** | 0.89 | 1.38 | 2.00 | 2.41 |
| **Nutrient ( N )** | | | | |
| **N1 : Control** | 14.05 | 22.14 | 25.66 | 29.15 |
| **N2 : FYM** | 16.79 | 26.18 | 30.28 | 34.83 |
| **N3 : Vermicompost** | 18.56 | 28.03 | 33.04 | 38.79 |
| **N4 : Neem cake** | 15.85 | 24.66 | 28.95 | 33.64 |
| **N5 : Green leaf manure** | 16.20 | 25.52 | 29.29 | 34.22 |
| **Mean** | 16.29 | 25.31 | 29.44 | 34.13 |
| **S. Em.±** | 0.47 | 0.73 | 1.06 | 1.28 |
| **C.D.(P=0.05)** | NS | 2.17 | 3.16 | 3.81 |
| **Interaction (M X N)** | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

plant (18.56) compared to $N_2$-FYM (16.79), $N_4$ -neem cake (15.85), $N_5$-green leaf manure (16.20) and $N_1$-farmer's practice (14.05). Further, $N_4$ and $N_5$ were on par with each other. Similar trend was followed at 90, 120 DAP and harvest with more number of branches (28.03, 33.04, and 38.79 branches per plant, respectively) in $N_3$. The number of secondary branches were increased among all the treatments throughout crop growth period. Sharma *et al*. (2009) also found similar results with application of FYM @ 5 t $ha^{-1}$.

The interaction effect among the method of planting and integrated nutrient management on number of secondary branches per plant found non-significant during all stages of plant growth.

**4.1.5 Leaf area**

The data pertaining to leaf area ($dm^2$ $plant^{-1}$) of pigeonpea at different growth stages (30, 60, 90, 120 DAP and at harvest) are presented in table 4.5**.** The results revealed that the leaf area of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting at all the stages of crop growth.

At 30 DAP, the transplanted ($M_2$) pigeonpea recorded leaf area of 6.17 $dm^2$ $plant^{-1}$ which is significantly higher than the leaf area (5.93) recorded under dibbled ($M_1$). Similar trend was followed at 60, 90, 120 DAP and harvest.

Among the integrated nutrient management treatments, at 30 DAP no significance difference of leaf area per plant was found between the INM treatments, whereas at 60 DAP, $N_3$-vermicompost recorded significantly higher leaf area (43.12 $dm^2$ $plant^{-1}$) compared to $N_4$-neem cake ( 38.05 $dm^2$ $plant^{-1}$), $N_5$-green leaf manure (39.54 $dm^2$ $plant^{-1}$) and $N_1$-farmer's practice (34.42 $dm^2$ $plant^{-1}$) and was on par with $N_2$ -FYM ( 40.72 $dm^2$ $plant^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other. Similar trend was followed at 60, 90 120 DAP and harvest, among all stages the $N_3$ found significantly higher leaf area (100.42, 161.56, 90.77 $dm^2$ $plant^{-1}$, respectively). The leaf area per plant at harvest stage recorded lower than leaf area per plant at 120 DAP, this is due to reduction of total number of leaves per plant at harvest stage.

The interaction effect among the method of planting and integrated nutrient management on leaf area per plant found non-significant during all stages of plant growth.

**4.1.6 Leaf area index**

The data related to leaf area index of pigeonpea at different stages of crop growth (30, 60, 90, 120 DAP and at harvest) are presented in table 4.6 and depicted in fig. 4.2. The results indicated that the leaf area index of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting system at all the stages of crop growth.

At 30 DAP, the transplanted ($M_2$) pigeonpea recorded significantly higher leaf area index (0.069) compared to that recorded by dibbling ($M_1$) method of planting (0.060). Similar trend (0.470, 1.103, 1.683 and 0.881 respectively in Transplanted) was followed at 60, 90, 120 DAP and harvest. The leaf area index is directly depend on the leaf area and dry matter accumulation in leaf and thus higher value of LAI in transplanted crop.

Among the integrated nutrient management treatments at 30 DAP no significance difference of leaf area index was found between the INM treatments, whereas at 60 DAP, $N_3$-vermicompost recorded significantly higher leaf area index (0.479) compared to $N_4$ -neem cake) (0.423), $N_5$-green leaf manure (0.439) and $N_1$-farmer's practice (0.382) and was on par with $N_2$-FYM (0.452). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other. Similar trend was followed at 60, 90 120 DAP and at harvest. Where the $N_3$ found higher (1.116, 1.795, and 1.009) in all the growth stages of crop, this was attributed to the better utilization of available growth resources like moisture, nutrients, and solar radiation due to well developed root system. The LAI at harvest stage recorded lower than LAI at 120 DAP, this is due to reduction of total number of leaves per plant at harvest stage.

The interaction effect among the method of planting and integrated nutrient management on leaf area index found non-significant during all stages of plant growth.

**Table 4.5: Effect of method of planting and integrated nutrient management on leaf area per plant at different stages of crop growth**

| Treatments | Leaf area ($dm^2$ $plant^{-1}$) | | | | |
|---|---|---|---|---|---|
| | **30 DAP** | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 5.39 | 36.04 | 90.74 | 137.46 | 76.81 |
| **M2 : Transplanted** | 6.17 | 42.30 | 99.24 | 151.49 | 81.85 |
| **Mean** | 5.78 | 39.17 | 94.99 | 144.48 | 79.33 |
| **S. Em.±** | 0.11 | 0.70 | 1.28 | 2.01 | 1.35 |
| **C.D.(P=0.05)** | 0.32 | 2.08 | 3.82 | 5.96 | 4.02 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 5.46 | 34.42 | 88.99 | 128.88 | 68.25 |
| **N2 : FYM** | 5.87 | 40.72 | 96.98 | 148.45 | 83.76 |
| **N3 : Vermicompost** | 5.98 | 43.12 | 100.42 | 161.56 | 90.77 |
| **N4 : Neem cake** | 5.75 | 38.05 | 93.22 | 138.37 | 74.95 |
| **N5 : Green leaf manure** | 5.82 | 39.54 | 95.35 | 145.11 | 78.92 |
| **Mean** | 5.78 | 39.17 | 94.99 | 144.48 | 79.33 |
| **S. Em.±** | 0.17 | 1.11 | 2.03 | 3.17 | 2.14 |
| **C.D.(P=0.05)** | NS | 3.28 | 6.03 | 9.42 | 6.36 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**Table 4.6: Effect of method of planting and integrated nutrient management on leaf area index at different stages of crop growth**

| Treatments | Leaf area index | | | | |
|---|---|---|---|---|---|
| | 30 DAP | 60 DAP | 90 DAP | 120 DAP | At harvest |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 0.060 | 0.400 | 1.008 | 1.527 | 0.853 |
| **M2 : Transplanted** | 0.069 | 0.470 | 1.103 | 1.683 | 0.909 |
| **Mean** | 0.064 | 0.435 | 1.055 | 1.605 | 0.881 |
| **S. Em.±** | 0.001 | 0.008 | 0.014 | 0.022 | 0.015 |
| **C.D.(P=0.05)** | 0.004 | 0.023 | 0.042 | 0.066 | 0.045 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 0.061 | 0.382 | 0.989 | 1.432 | 0.758 |
| **N2 : FYM** | 0.065 | 0.452 | 1.078 | 1.649 | 0.931 |
| **N3 : Vermicompost** | 0.066 | 0.479 | 1.116 | 1.795 | 1.009 |
| **N4 : Neem cake** | 0.064 | 0.423 | 1.036 | 1.537 | 0.833 |
| **N5 : Green leaf manure** | 0.065 | 0.439 | 1.059 | 1.612 | 0.877 |
| **Mean** | 0.064 | 0.435 | 1.055 | 1.605 | 0.881 |
| **S. Em.±** | 0.002 | 0.012 | 0.023 | 0.035 | 0.024 |
| **C.D.(P=0.05)** | NS | 0.036 | 0.067 | 0.105 | 0.071 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

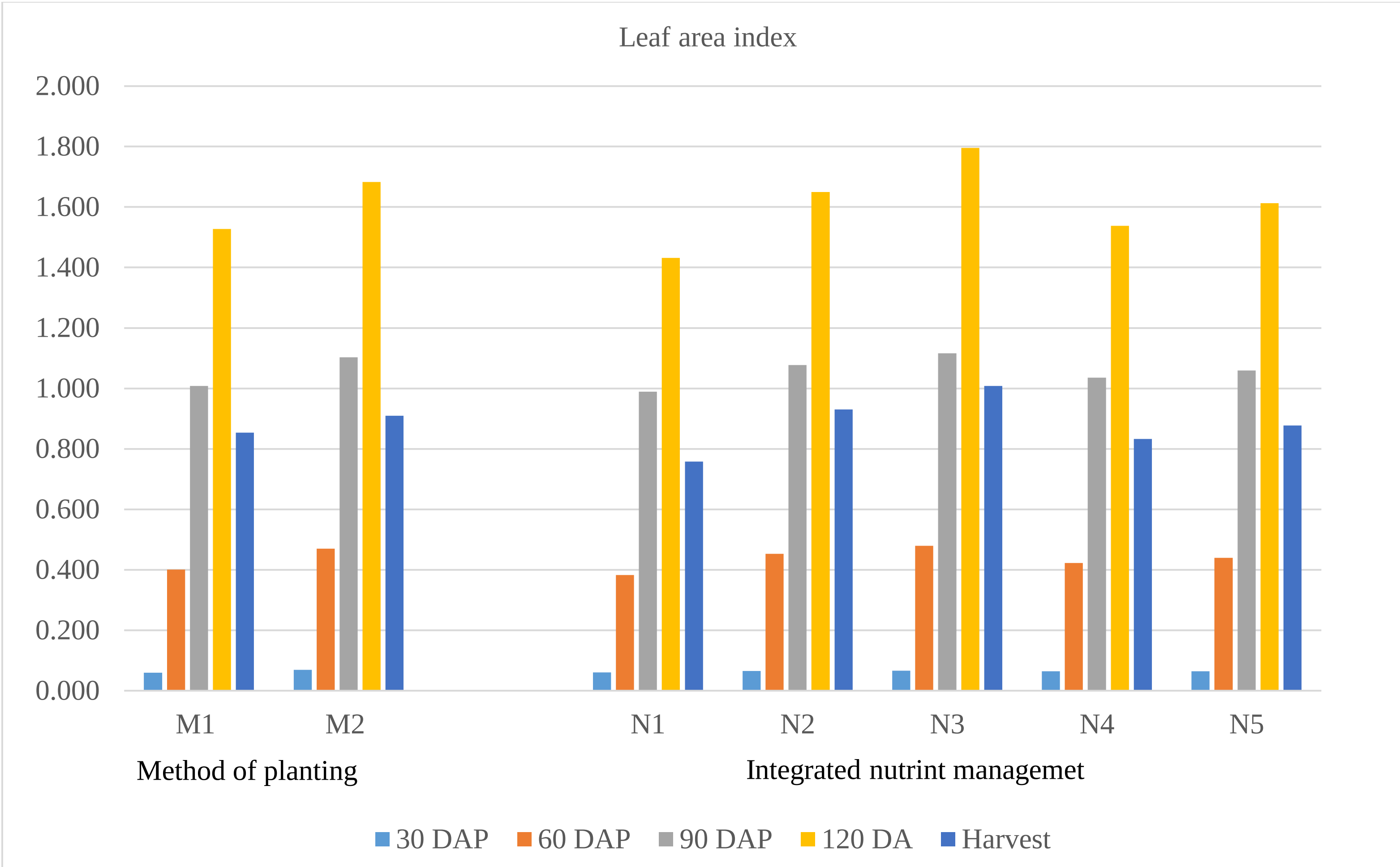



**Fig 4.2: Leaf area index of pigeonpea at different growth stages as influence by method of planting and integrated nutrient management**

### 4.1.7 Dry matter accumulation in leaves

The data regarding dry matter accumulation in leaves (g plant$^{-1}$) of pigeonpea at different growth stages (30, 60, 90, 120 DAP and at harvest) are presented in table 4.7. The results revealed that dry matter accumulation in leaves of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting system at all the stages of crop growth.

At 30 DAP, the transplanted ($M_2$) pigeonpea recorded dry matter accumulation in leaves (3.05 g plant$^{-1}$) which is significantly higher than the dry matter accumulation in leaves recorded (2.68 g plant$^{-1}$) under dibbling ($M_1$). Similar trend was followed at 60, 90 120 DAP and at harvest, this is due to more number of leaves.

Among the integrated nutrient management treatments at 30 DAP no significance difference of dry matter accumulation in leaves per plant was found between the INM treatments, whereas at 60 DAP, $N_3$-vermicompost recorded significantly higher dry matter accumulation in leaves (21.47 g plant$^{-1}$) compared to $N_4$ -neem cake (18.71 g plant$^{-1}$), $N_5$-green leaf manure (19.60 g plant$^{-1}$) and $N_1$-farmer's practice (17.16 g plant$^{-1}$) and was on par with $N_2$-FYM (20.19 g plant$^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. Similar trend was followed at 60, 90 120 DAP and at harvest. The dry matter accumulation at harvest stage recorded lower than 120 DAP, this is due to reduction of total number of leaves per plant at harvest stage which directly influences the dry matter of leaves.

The interaction effect among the method of planting and integrated nutrient management on leaf area per plant found non-significant during all stages of plant growth.

### 4.1.8 Dry matter accumulation in stem

The data concerned to dry matter accumulation in stem (g plant$^{-1}$) at different stages of crop growth (30, 60, 90, 120 DAP and at harvest) are presented in table 4.8. The results indicated that dry matter accumulation in stem of pigeonpea was

**Table 4.7: Effect of method of planting and integrated nutrient management on dry matter accumulation per plant at different stages of crop growth**

| Treatments | Dry matter accumulation in leaves (g $plant^{-1}$) | | | | |
|---|---|---|---|---|---|
| | **30 DAP** | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 2.68 | 17.90 | 45.12 | 68.35 | 38.00 |
| **M2 : Transplanted** | 3.05 | 20.96 | 49.21 | 74.90 | 40.58 |
| **Mean** | 2.87 | 19.43 | 47.16 | 71.63 | 39.29 |
| **S. Em.±** | 0.06 | 0.34 | 0.67 | 0.97 | 0.66 |
| **C.D.(P=0.05)** | 0.16 | 1.01 | 1.99 | 2.88 | 1.95 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 2.72 | 17.16 | 44.38 | 63.88 | 34.14 |
| **N2 : FYM** | 2.91 | 20.19 | 48.02 | 74.35 | 41.43 |
| **N3 : Vermicompost** | 2.97 | 21.47 | 49.84 | 79.43 | 44.85 |
| **N4 : Neem cake** | 2.85 | 18.71 | 46.34 | 68.59 | 37.22 |
| **N5 : Green leaf manure** | 2.88 | 19.60 | 47.24 | 71.88 | 38.82 |
| **Mean** | 2.87 | 19.43 | 47.16 | 71.63 | 39.29 |
| **S. Em.±** | 0.09 | 0.54 | 1.06 | 1.53 | 1.04 |
| **C.D.(P=0.05)** | NS | 1.60 | 3.14 | 4.55 | 3.08 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**Table 4.8: Effect of method of planting and integrated nutrient management on dry matter accumulation in stem per plant at different stages of crop growth**

| | Dry matter accumulation in stem (g $plant^{-1}$) | | | | |
|---|---|---|---|---|---|
| **Treatments** | **30 DAP** | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 3.47 | 17.28 | 39.77 | 211.27 | 403.69 |
| **M2 : Transplanted** | 3.78 | 20.41 | 44.23 | 229.72 | 431.23 |
| **Mean** | 3.62 | 18.85 | 42.00 | 220.49 | 417.46 |
| **S. Em.±** | 0.09 | 0.37 | 0.62 | 4.29 | 7.15 |
| **C.D.(P=0.05)** | 0.26 | 1.09 | 1.84 | 12.75 | 21.24 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 3.37 | 16.55 | 39.22 | 190.69 | 377.21 |
| **N2 : FYM** | 3.76 | 19.67 | 43.16 | 233.49 | 433.48 |
| **N3 : Vermicompost** | 3.91 | 21.04 | 44.83 | 251.24 | 456.68 |
| **N4 : Neem cake** | 3.49 | 17.97 | 40.89 | 207.24 | 402.94 |
| **N5 : Green leaf manure** | 3.60 | 19.00 | 41.90 | 219.81 | 417.00 |
| **Mean** | 3.62 | 18.85 | 42.00 | 220.49 | 417.46 |
| **S. Em.±** | 0.14 | 0.58 | 0.98 | 6.78 | 11.30 |
| **C.D.(P=0.05)** | NS | 1.72 | 2.91 | 20.16 | 33.59 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

significantly influenced due to integrated nutrient management practices and method of planting system at all the stages of crop growth.

At 30 DAP, the transplanted ($M_2$) pigeonpea recorded significantly higher dry matter accumulation in stem (3.78 g $plant^{-1}$) compared to dibbled ($M_1$) pigeonpea. Similar trend was found in all stages of the crop growth. The early establishment of the plant enabled well developed root system, this facilitated the photosynthetic ability of crop with leading to greater biomass production. More dry matter accumulation in stem and leaf parts, further supported by higher rot biomass, canopy spread and plant height.

Among the integrated nutrient management treatments at 30 DAP no significance difference of dry matter accumulation in stem per plant was found between the INM treatments, whereas at 60 DAP, $N_3$-vermicompost recorded significantly higher dry matter accumulation in stem (21.04 g $plant^{-1}$) compared to $N_4$-neem cake (17.97 g $plant^{-1}$), $N_5$-green leaf manure (19.00 g $plant^{-1}$) and $N_1$-farmer's practice (16.55 g $plant^{-1}$) and was on par with $N_2$-FYM (19.67 g $plant^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other. Similar trend was followed at 60, 90 120 DAP and at harvest with higher dry matter accumulation in $N_3$ (44.83, 251.24, 456.68 g $plant^{-1}$ respectively) at all the stages of crop. The increase in dry matter in $N_{3,}$ was due to the better growth parameters as discussed above in this chapter, which is contribute by all the growth attributing parameters.

The interaction effect among the method of planting and integrated nutrient management on dry matter accumulation in stem per plant found non-significant during all stages of plant growth.

### 4.1.9 Dry matter accumulation in reproductive parts

The data related to dry matter accumulated in reproductive parts (g $plant^{-1}$) of pigeonpea at different growth stages (120 DAP and at harvest) are presented in table 4.9. The results indicated that dry matter accumulation in reproductive parts of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting system at all the stages of crop growth.

**Table 4.9: Effect of method of planting and integrated nutrient management on dry matter accumulation in reproductive parts per plant at different stages of crop growth**

| Treatments | Dry matter accumulation in reproductive parts (g plant$^{-1}$) | |
|---|---|---|
| | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | |
| **M1 : Dibbled** | 12.22 | 317.27 |
| **M2 : Transplanted** | 13.56 | 356.49 |
| **Mean** | 12.89 | 336.88 |
| **S. Em.±** | 0.24 | 5.91 |
| **C.D.(P=0.05)** | 0.71 | 17.57 |
| **Nutrient ( N )** | | |
| **N1 : Control** | 11.42 | 299.10 |
| **N2 : FYM** | 13.28 | 345.62 |
| **N3 : Vermicompost** | 14.33 | 375.91 |
| **N4 : Neem cake** | 12.55 | 328.14 |
| **N5 : Green leaf manure** | 12.87 | 335.65 |
| **Mean** | 12.89 | 336.88 |
| **S. Em.±** | 0.38 | 9.35 |
| **C.D.(P=0.05)** | 1.13 | 27.79 |
| **Interaction (M X N)** | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg ha$^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t ha$^{-1}$, Vermicompost @ 5 t ha$^{-1}$, Neem cake @ 0.25 t ha$^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t ha$^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg ha$^{-1}$ and Borax @ 5 kg ha$^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg ha$^{-1}$).

At 120 DAP, the transplanted pigeonpea ($M_2$) recorded significantly higher dry matter accumulation in reproductive parts (13.56 g plant$^{-1}$) compared to that recorded by dibbled pigeonpea. Similar trend was followed at harvest stage with highest dry matter accumulation (356.49 g plant$^{-1}$) in transplanted method of sowing, since the its performance in all the growth parameters was better over the dibbled crop and which enabled it to produce the more number of yield attributing parameters.

Among the integrated nutrient management treatments, $N_3$-vermicompost recorded significantly higher dry matter accumulation in reproductive parts (14.33 g plant$^{-1}$) compared to $N_4$-neem cake (12.55 g plant$^{-1}$), $N_5$-green leaf manure (12.87 g plant$^{-1}$) and $N_1$-farmer's practice (11.42 g plant$^{-1}$) and was on par with $N_2$-FYM (5.73 g plant$^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. Similar trend was followed at harvest (375.91 g plant$^{-1}$). The combined effect of the organic manures along with inorganic fertilizers and micronutrients also supply of all the nutrients in balanced form which resulted the crop to produce the higher pods per plant.

The interaction effect among the method of planting and integrated nutrient management on dry matter accumulation in stem per plant found non-significant during all stages of plant growth.

### 4.1.10 Total dry matter production per plant

The data regarding dry matter production per plant (g plant$^{-1}$) of pigeonpea at different stages of crop growth (30, 60, 90, 120 DAP and at harvest) are presented in table 4.10**.** The results indicated that the dry matter production of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting system at all the stages of crop growth.

At 30 DAP, the transplanted pigeonpea ($M_2$) recorded dry matter production of 6.83 g plant$^{-1}$, which is significantly higher than the dry matter production recorded (6.15) under dibbled pigeonpea ($M_1$).

Among the integrated nutrient management treatments at 30 DAP no significance difference of dry matter production per plant was found between the INM

**Table 4.10: Effect of method of planting and integrated nutrient management on total dry matter production per plant at different stages of crop growth**

| | Total dry matter production (g $plant^{-1}$) | | | | |
|---|---|---|---|---|---|
| **Treatments** | **30 DAP** | **60 DAP** | **90 DAP** | **120 DAP** | **At harvest** |
| **Method of planting ( M )** | | | | | |
| **M1 : Dibbled** | 6.15 | 35.18 | 84.89 | 291.84 | 758.97 |
| **M2 : Transplanted** | 6.83 | 41.37 | 93.43 | 318.18 | 828.30 |
| **Mean** | 6.49 | 38.27 | 89.16 | 305.01 | 793.64 |
| **S. Em.±** | 0.14 | 0.70 | 1.27 | 5.33 | 12.97 |
| **C.D.(P=0.05)** | 0.40 | 2.08 | 3.79 | 15.84 | 38.55 |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 6.09 | 33.72 | 83.59 | 265.99 | 710.44 |
| **N2 : FYM** | 6.66 | 39.86 | 91.18 | 321.13 | 820.53 |
| **N3 : Vermicompost** | 6.88 | 42.52 | 94.67 | 345.00 | 877.44 |
| **N4 : Neem cake** | 6.33 | 36.68 | 87.23 | 288.39 | 768.30 |
| **N5 : Green leaf manure** | 6.49 | 38.59 | 89.14 | 304.56 | 791.47 |
| **Mean** | 6.49 | 38.27 | 89.16 | 305.01 | 793.64 |
| **S. Em.±** | 0.21 | 1.11 | 2.01 | 8.43 | 20.51 |
| **C.D.(P=0.05)** | NS | 3.29 | 5.99 | 25.05 | 60.95 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

treatments, whereas at 60 DAP, $N_3$-vermicompost recorded significantly higher dry matter production (42.52 g plant$^{-1}$) compared to $N_4$ -neem cake (36.68g plant$^{-1)}$, $N_5$-green leaf manure (38.59 g palnt$^{-1}$), $N_1$-farmer's practice (33.72 g plant$^{-1}$) and was on par with $N_2$-FYM (39.86 g plant$^{-1}$). Further, $N_{2,}$ $N_{4,}$ and $N_5$ were on par with each other. Similar trend was followed at 60, 90 120 DAP and at harvest. And highest dry matter per plant was recorded in $N_3$ (877.44 g plant$^{-1}$).

The interaction effect among the method of planting and integrated nutrient management on dry matter production per plant found non-significant during all stages of plant growth.

## 4.2 Yield attributes of pigeonpea

### 4.2.1 Number of pods per plant

The data concerned to number of pods per plant of pigeonpea are presented in table 4.11. The number of pods per plant of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting.

The transplanted pigeonpea ($M_2$) recorded significantly higher number of pods per plant (800.04) compared to dibbling ($M_1$). As the performance of transplanted pigeonpea in growth parameters was superior over the dibbled crop and resulted in more number of pods per plant.

Among the integrated nutrient treatments, $N_3$-vermicompost recorded significantly higher number of pods per plant (860.89) when compared to that observed under $N_2$-FYM (783.02), $N_4$ -Neem cake (739.44), $N_5$-Green leaf manure (760.60) and $N_1$-Farmer's practice (672.28). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. Sharma *et al*. (2009) reported similar higher number of pods plant$^{-1}$ with application of FYM @ 5 t ha$^{-1}$ + seed inoculation with *Rhizobium* + micronutrient ($ZnSO_4$ @ 15 kg ha$^{-1}$).

The interaction effect among the method of planting and integrated nutrient management on number of pods per plant found non-significant.

**Table 4.11: Effect of method of planting and integrated nutrient management on number of pods per plant, number of seeds per pod, seed weight per plant and hundred seed weight of pigeonpea**

| Treatments | Seed yield per plant (g $plant^{-1}$) | Number of pods per plant | Number of seeds per pod | Test weight (g) |
|---|---|---|---|---|
| **Method of Planting ( M )** | | | | |
| **M1 : Dibbled** | 183.99 | 726.45 | 2.55 | 11.39 |
| **M2 : Transplanted** | 213.18 | 800.04 | 2.56 | 11.67 |
| **Mean** | 198.59 | 763.25 | 2.56 | 11.53 |
| **S. Em.±** | 4.44 | 13.86 | 0.04 | 0.10 |
| **C.D.(P=0.05)** | 13.19 | 41.17 | NS | NS |
| | | | | |
| **N1 : Control** | 163.72 | 672.28 | 2.49 | 11.29 |
| **N2 : FYM** | 209.18 | 783.02 | 2.60 | 11.62 |
| **N3 : Vermicompost** | 232.47 | 860.89 | 2.61 | 11.82 |
| **N4 : Neem cake** | 188.28 | 739.44 | 2.53 | 11.44 |
| **N5 : Green leaf manure** | 199.28 | 760.60 | 2.55 | 11.49 |
| **Mean** | 198.59 | 763.25 | 2.56 | 11.53 |
| **S. Em.±** | 7.02 | 21.91 | 0.06 | 0.16 |
| **C.D.(P=0.05)** | 20.86 | 65.10 | NS | NS |
| **Interaction (M X N)** | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**4.2.2 Number of seeds per pod**

The number of seeds per pod of pigeonpea was not significantly influenced by different method of planting.

The INM treatments $N_3$-vermicompost recorded slightly higher number of seeds per pod (2.61) than all the other treatments. The number of seeds per pod of INM treatments ranged from 2.49 to 2.61 (Table 4.11).

The interaction effect among the method of planting and integrated nutrient management on number of seeds per pod found non-significant.

**4.2.3 Seed yield per plant**

The data pertaining to seed yield per plant of pigeonpea (g) are presented in Table 14. The seed yield per plant of pigeonpea was significantly influenced due to integrated nutrient management practices and method of planting.

The seed yield per plant (213.18 g) recorded by transplanted pigeonpea ($M_2$) was significantly higher than the seed yield per plant recorded under dibbled treatments. This is due to the transplanted pigeonpea had improved the rate of photosynthesis, dry matter accumulation and its translocation to pods as referred in terms of higher values of growth and yield components.

Among the INM treatments, $N_3$-Vermicompost recorded significantly higher seed yield per plant (232.47 g $plant^{-1}$) compared to $N_2$-FYM (209.18), $N_4$ -Neem cake (188.28 g), $N_5$-Green leaf manure (199.28 g) and $N_1$-Farmer's practice (163.72 g). Further, $N_4$ and $N_5$ were on par with each other. Gholve *et al.* (2005), and Hajari et al.**, (**2015) reported similar results.

The interaction effect among the method of planting and integrated nutrient management on seed weight per plant found non-significant.

**4.2.4 Hundred seed weight**

The hundred seed weight (g) of pigeonpea was not significantly influenced by different method of planting.

In case of integrated nutrient management treatments also found to be nonsignificant. However the $N_3$-vermicompost treatment recorded slightly higher weight (g) of hundred seed (11.82) than all the other treatments. The number of seeds per pod of INM treatments ranged from 11.82 to 11.29 (Table 4.11).

The interaction effect among the method of planting and integrated nutrient management on 100 seed weight found non-significant.

### 4.2.5 Grain yield

The data regarding grain yield (kg $ha^{-1}$) of pigeonpea are presented in table 4.12 and depicted in fig.4.3. The seed yield of pigeonpea was significantly influenced due to different method of planting and integrated nutrient management treatments.

The transplanted pigeonpea ($M_2$) recorded significantly higher seed yield (2386 kg $ha^{-1}$) compared to dibbled pigeonpea ($M_1$). Mallikarjun (2012), was also reported similar results with hybrid pigeonpea over dibbled. The results are in accordance with the earlier findings of Anon. (2009); Ahalawat *et al.* (1975); Patel *et al.* (1984); Goyal *et al.* (1989); Shaik Mohammad (1997) and Parameswari *et al*. (2003). The higher grain yield is due to high in yield attributing parameters, like number of pods per plant, pod yield per, which contribute to obtain the higher yield of the crop.

Among the integrated nutrient treatments, $N_3$-vermicompost recorded significantly higher seed yield (2448 kg $ha^{-1}$) when compared to that observed under $N_4$ -neem cake (2067 kg $ha^{-1}$), $N_5$-green leaf manure (2140 kg $ha^{-1}$), $N_2$-FYM (2193 kg $ha^{-1}$) and $N_1$-farmer's practice (1822 kg $ha^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. Gholve *et al.* (2005), and Hajari *et al.*, (2015) with application of vermicompost and Pandey et *al.*, (2015), Arjun Sharma *et al.*, (2012) and Patil *et al.*, (2007), with application of FYM also reported similar results. Anon. (2012) also found significant results with application of RDF + FYM 5 t $ha^{-1}$, gave higher seed yield over RDF. Pandey *et al.* (2013) also reported similar results with application of 2.5 t $ha^{-1}$ vermicompost. The higher yield in vermicompost is due to presence of large number of microbial biochemical products which are released slowly to the rhizosphere and enables the plant to improve its growth and development and results in higher yielding parameters

The interaction effect among the method of planting and integrated nutrient management on Seed yield (kg $ha^{-1}$) found non-significant.

### 4.2.6 Stalk yield

The data concerned to stalk yield (kg $ha^{-1}$) of pigeonpea are presented in table 4.12 and depicted in Fig. 4.3. The stalk yield of pigeonpea was significantly influenced due to different method of planting and integrated nutrient management treatments.

The transplanted pigeonpea ($M_2$) recorded significantly higher stalk yield (4987 kg $ha^{-1}$) compared to that recorded by dibbled ($M_1$) method of planting, it is due to better growth parameters at all stages of the crop and resulted in the higher accumulation of dry matter in the stalk of the plant.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher stalk yield (5168 kg $ha^{-1}$) compared to $N_2$-FYM (4703 kg $ha^{-1}$), $N_4$-neem cake (4500 kg $ha^{-1}$), $N_5$-green leaf manure (4592 kg $ha^{-1}$) and $N_1$-farmer's practice (4005 kg $ha^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. The stalk yield was higher with application of vermicompost was due to better growth parameters and higher accumulation of dry matter in stem parts that contributed for the higher stalk yield production.

The interaction effect among the method of planting and integrated nutrient management on Seed yield (kg $ha^{-1}$) found non-significant.

### 4.2.7 Husk yield

The data pertaining to husk yield (kg $ha^{-1}$) of pigeonpea are presented in table 4.12 and depicted in Fig. 4.3. The husk yield of pigeonpea was significantly influenced due to different method of planting and integrated nutrient management treatments.

**Table 4.12: Effect of method of planting and integrated nutrient management on grain yield, stalk yield, husk yield and harvest index of pigeonpea**

| Treatments | Grain yield (Kg ha$^{-1}$) | Stalk yield (Kg ha$^{-1}$) | Husk yield (Kg ha$^{-1}$) | Harvest index |
|---|---|---|---|---|
| **Method of Planting ( M )** | | | | |
| **M1 : Dibbled** | 1882 | 4200 | 1205 | 0.258 |
| **M2 : Transplanted** | 2386 | 4987 | 1413 | 0.271 |
| **Mean** | 2134 | 4594 | 1309 | 0.265 |
| **S. Em.±** | 49.07 | 73.60 | 24.50 | 0.002 |
| **C.D.(P=0.05)** | 145.80 | 218.69 | 72.79 | 0.006 |
| **Nutrient ( N )** | | | | |
| **N1 : Control** | 1822 | 4005 | 1129 | 0.261 |
| **N2 : FYM** | 2193 | 4703 | 1358 | 0.265 |
| **N3 : Vermicompost** | 2448 | 5168 | 1499 | 0.268 |
| **N4 : Neem cake** | 2067 | 4500 | 1255 | 0.263 |
| **N5 : Green leaf manure** | 2140 | 4592 | 1305 | 0.266 |
| **Mean** | 2134 | 4594 | 1309 | 0.265 |
| **S. Em.±** | 77.59 | 116.38 | 38.74 | 0.003 |
| **C.D.(P=0.05)** | 231 | 346 | 115 | NS |
| **Interaction (M X N)** | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg ha$^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t ha$^{-1}$, Vermicompost @ 5 t ha$^{-1}$, Neem cake @ 0.25 t ha$^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t ha$^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg ha$^{-1}$ and Borax @ 5 kg ha$^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg ha$^{-1}$).

The results indicated that the transplanted pigeonpea ($M_2$) recorded the husk yield (1413 kg ha$^{-1}$), which is significantly higher than the husk yield recorded under dibbling pigeonpea.

Among the intercropped treatments, $N_3$-vermicompost recorded significantly higher husk yield (1499 kg ha$^{-1}$) compared to $N_4$-neem cake (1255 kg ha$^{-1}$), $N_5$-green leaf manure (1305 kg ha$^{-1}$), and $N_1$-farmer's practice (1129 kg ha$^{-1}$) and was on par with $N_2$ ( FYM) (1358 kg ha$^{-1}$. Further, $N_2$, $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on Husk yield (kg ha$^{-1}$) found non-significant.

**4.2.8 Harvest index**

The data related to harvest index of pigeonpea are presented in table 4.12. The harvest index of pigeonpea was significantly influenced due to different method of planting and integrated nutrient management treatments.

The results revealed that the transplanted pigeonpea ($M_2$) recorded significantly higher harvest index (0.271) compared to dibbling ($M_1$) method of planting. This was due to high yield recorded in transplanted and where, dibbled crop resulted in low yields even with the appreciable biological yield *i.e.* low sink capacity.

Among the INM treatments, there is no significance difference due to effect of nutrient combinations on harvest index. The $N_3$-vermicompost and $N_2$-FYM recorded harvest index 0.268 and 0.265 respectively, followed by $N_5$ -green leaf manure (0.266), when compared to that observed under $N_4$-neem cake (0.263),and $N_1$-farmer' practice (0.261). This is because, the $N_3$ nutrient combination recorded higher yields than other treatments even with significant increase in biological yield, which gave higher harvest index with application of vermicompost. The application of FYM and green leaf manure also recorded similar harvest index values.

The interaction effect among the method of planting and integrated nutrient management on harvest index found non-significant.

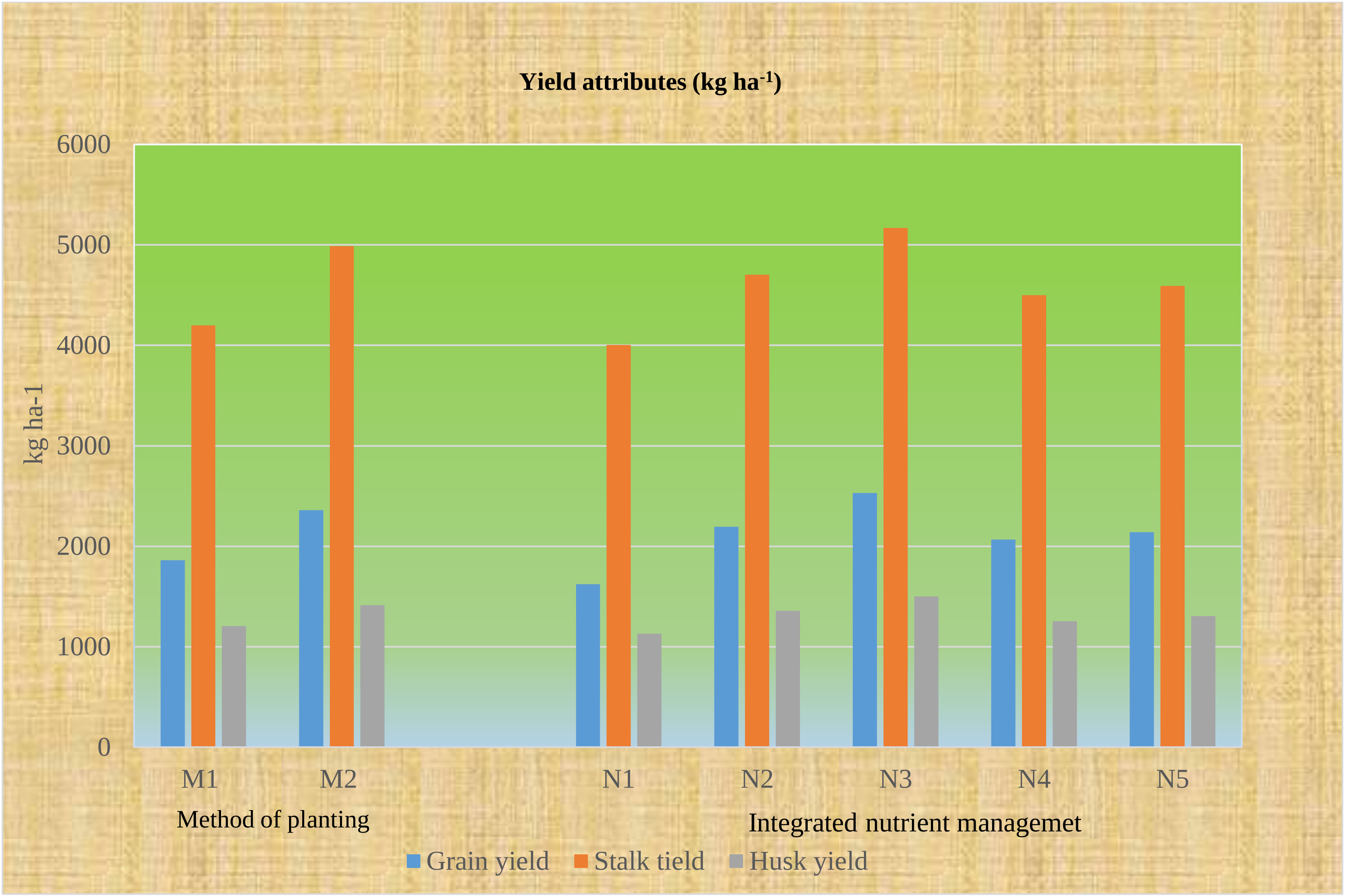



**Fig 4.3: Yield attributes of pigeonpea as influenced by method of planting and integrated nutrient management.**

## 4.3 Quality parameters of pigeonpea

### 4.3.1 Protein content in seeds

The data regarding protein content (%) of pigeonpea seeds are presented in table 4.13. The protein content of pigeonpea seeds was non-significantly influenced due to different method of planting and integrated nutrient management treatments.

The interaction effect among the method of planting and integrated nutrient management on protein content (%) found non-significant.

### 4.3.2 Protein yield

The data concerned to protein yield (kg $ha^{-1}$) of pigeonpea are presented in table 4.13. The results revealed that the protein yield of pigeonpea was significantly influenced due to different method of planting and integrated nutrient management treatments.

The transplanted pigeonpea (M1) recorded significantly higher protein yield (470.78 kg $ha^{-1}$) when compared to dibbled pigeonpea ($M_1$). The protein yield is dependent on grain yield of pigeonpea, where the significant higher yields were recorded in transplanted than compared to the dibbled crop.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher protein yield (508 kg $ha^{-1}$) when compared to that observed under $N_1$, $N_2$, $N_4$ and $N_5$. Further, $N_2$, $N_3$ and $N_4$ were on par with each other. As the protein yield is computed based on the economical yield, hence the aggregate positive yields and protein content resulted in significant protein yield.

The interaction effect among the method of planting and integrated nutrient management on protein yield (kg $ha^{-1}$) found non-significant.

## 4.4 Nutrient content in seed and stalk of pigeonpea

The nutrient content in seed and stalk at harvest as influenced by different method of planting and integrated nutrient management practices in pigeonpea is presented with tables.

**Table 4.13: Effect of method of planting and integrated nutrient management on protein content and protein yield of Pigeonpea**

| Treatments | Protein content (%) | Protein yield (kg $ha^{-1}$) |
|---|---|---|
| **Method of establishment ( M )** | | |
| **M1 : Dibbled** | 19.61 | 365.35 |
| **M2 : Transplanted** | 19.94 | 470.78 |
| **Mean** | 19.77 | 418.06 |
| **SEm±** | 0.24 | 8.07 |
| **C.D at 5%** | NS | 23.98 |
| **Nutrient ( N )** | | |
| **N1 : Control** | 19.54 | 316.58 |
| **N2 : FYM** | 20.04 | 439.33 |
| **N3 : vermicompost** | 20.11 | 508.76 |
| **N4 : Neem cake** | 19.57 | 404.96 |
| **N5 : Green leaf manure** | 19.62 | 420.69 |
| **Mean** | 19.77 | 418.06 |
| **SEm±** | 0.38 | 12.76 |
| **C.D at 5%** | NS | 37.92 |
| **Interaction (M X N)** | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

### 4.4.1 Primary nutrient content in stalk and seed

#### 4.4.1.1 Nitrogen content in seed

The results revealed that the nitrogen content in seed at harvest was found non-significant due to method of planting and nutrient management practices during experimentation (Table 4.14).

The interaction effect among the method of planting and integrated nutrient management on nitrogen content found non-significant.

#### 4.4.1.2 Nitrogen content in stalk

The results revealed that the nitrogen content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.14).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of nitrogen (0.93 %) in stalk as compared to dibbling (0.76 %), this may be due to better establishment at early stages which, enabled the good plant and root system that enabled the roots to fix and absorb more nitrogen from atmosphere.

Among the integrated nutrient management treatments no significant difference was found. Whereas treatment $N_3$-vermicompost showed higher content of nitrogen (0.96 %) as compared to rest of the treatments.

The interaction effect among the method of planting and integrated nutrient management on nitrogen content in stalk found non-significant.

#### 4.4.1.3 Phosphorous content in seed

The results revealed that the phosphorous content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.14).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of phosphorous (0.377 %) in seed as compared to dibbling (0.346 %). The property of the pigeonpea roots is to solubilize the soil bound P, and convert the P to available form, hence the transplanted pigeonpea was better in all the growth parameters as discussed above in this chapter, so the uptake and content was more in case of transplanted pigeonpea with respect to seed and stalk parts.

Among the integrated nutrient management treatments no significant difference was found between the treatments, whereas treatment $N_3$-vermicompost showed higher content of phosphorous (0.377 %) in seed as compared to rest of the treatments.

The interaction effect among the method of planting and integrated nutrient management on phosphorous content in seed found non-significant.

**4.4.1.4 Phosphorous content in stalk**

The results revealed that the phosphorous content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.14).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of phosphorous (0.66 %) in stalk as compared to dibbling (0.58 %). This is also was due the better root system that enabled the transplanted pigeonpea to actively absorb and accumulate in plant parts as discussed above in this chapter.

Among the integrated nutrient management treatments no significant difference was found for phosphorous content in stalk, whereas treatment $N_3$-vermicompost showed higher content of phosphorous (0.68 %) as compared to rest of the treatments.

The interaction effect among the method of planting and integrated nutrient management on phosphorous content in stalk found non-significant.

**4.4.1.5 Potassium content in seed**

The results revealed that the potassium content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.14).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of potassium (1.569 %) in stalk as compared to dibbling (1.502 %).

**Table 4.14: Effect of method of planting and integrated nutrient management on primary nutrient content in seed and stalk of pigeonpea (after harvest)**

| Treatments | Primary nutrient content (%) | | | | | |
|---|---|---|---|---|---|---|
| | N | | P | | K | |
| | Seed | Stalk | Seed | Stalk | Seed | Stalk |
| **M1 : Dibbled** | 3.14 | 0.76 | 0.346 | 0.058 | 1.502 | 0.737 |
| **M2 : Transplanted** | 3.19 | 0.93 | 0.377 | 0.066 | 1.569 | 0.763 |
| **Mean** | 3.16 | 0.84 | 0.362 | 0.062 | 1.536 | 0.750 |
| **SEm±** | 0.04 | 0.04 | 0.006 | 0.002 | 0.014 | 0.009 |
| **C.D at 5%** | NS | 0.13 | 0.019 | 0.006 | 0.041 | 0.026 |
| **Nutrient ( N )** | | | | | | |
| **N1 : Control** | 3.13 | 0.80 | 0.355 | 0.060 | 1.520 | 0.729 |
| **N2 : FYM** | 3.21 | 0.84 | 0.358 | 0.063 | 1.547 | 0.748 |
| **N3 : vermicompost** | 3.22 | 0.96 | 0.377 | 0.068 | 1.540 | 0.768 |
| **N4 : Neem cake** | 3.13 | 0.80 | 0.356 | 0.061 | 1.539 | 0.728 |
| **N5 : Green leaf manure** | 3.14 | 0.83 | 0.362 | 0.059 | 1.531 | 0.778 |
| **Mean** | 3.16 | 0.84 | 0.362 | 0.062 | 1.536 | 0.750 |
| **SEm±** | 0.06 | 0.07 | 0.010 | 0.003 | 0.022 | 0.014 |
| **C.D at 5%** | NS | NS | NS | NS | NS | NS |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

Among the integrated nutrient management treatments no significant difference was found between the treatments.

The interaction effect among the method of planting and integrated nutrient management on potassium content in seed found non-significant.

**4.4.1.6 Potassium content in stalk**

The results revealed that the potassium content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.14).

Among the method of planting the transplanted ($M_1$) found significantly higher content of potassium (0.763 %) in stalk as compared to dibbling (0.737 %). The higher potassium

Among the integrated nutrient management treatments no significant difference was found for potassium content in stalk. This may be due to early establishment and vigorous growth development that made the plant to absorb more nutrients as a result the higher content was observed in transplanted pigeonpea which even had a better root system that enabled it to positively link with nutrient absorption and content in plant parts.

The interaction effect among the method of planting and integrated nutrient management on phosphorous content in stalk found non-significant.

**4.4.2 Secondary nutrient content in stalk and seed**

**4.4.2.1 Calcium content in seed**

The results revealed that the calcium content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.15).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of calcium (1.358 %) in seed as compared to dibbling (1.210 %).

Among the integrated nutrient management treatments no significant difference was found between the treatments, whereas treatment $N_3$-vermicompost showed higher content of calcium (1.324 %) in seed as compared to rest of the treatments.

The interaction effect among the method of planting and integrated nutrient management on calcium content in seed found non-significant.

**4.4.2.2 Calcium content in stalk**

The results revealed that the calcium content in stalk at harvest was found non-significant as influenced by method of planting and the integrated nutrient management practices during experimentation (Table 4.15).

**4.4.2.3 Magnesium content in seed**

The results revealed that the magnesium content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.15).

Among the method of planting, the transplanted ($M_1$) crop found significantly higher content of magnesium (1.421 %) in seed as compared to dibbling (1.336 %).

Among the integrated nutrient management treatments no significant difference was found between the treatments.

The interaction effect among the method of planting and integrated nutrient management on magnesium content in seed found non-significant.

**4.4.2.4 Magnesium content in stalk**

The results revealed that the magnesium content in stalk at harvest was found to be non-significant as influenced by method of planting and the integrated nutrient management practices during experimentation (Table 4.15).

**Table 4.15: Effect of method of planting and integrated nutrient management on secondary nutrient content in seed and stalk of pigeonpea (after harvest)**

| | Secondary nutrient content (%) | | | | | |
|---|---|---|---|---|---|---|
| | Ca | | Mg | | S | |
| **Treatments** | **Seed** | **Stalk** | **Seed** | **Stalk** | **Seed** | **Stalk** |
| **Method of establishment ( M )** | | | | | | |
| **M1 : Dibbled** | 1.210 | 7.035 | 1.336 | 1.544 | 1.641 | 0.602 |
| **M2 : Transplanted** | 1.358 | 7.753 | 1.421 | 1.775 | 1.811 | 0.680 |
| **Mean** | 1.284 | 7.394 | 1.379 | 1.660 | 1.726 | 0.641 |
| **SEm±** | 0.035 | 0.264 | 0.020 | 0.079 | 0.023 | 0.023 |
| **C.D at 5%** | 0.105 | NS | 0.060 | NS | 0.067 | 0.068 |
| **Nutrient ( N )** | | | | | | |
| **N1 : Control** | 1.256 | 7.279 | 1.366 | 1.610 | 1.727 | 0.638 |
| **N2 : FYM** | 1.293 | 7.067 | 1.368 | 1.566 | 1.668 | 0.604 |
| **N3 : vermicompost** | 1.324 | 7.796 | 1.374 | 1.816 | 1.719 | 0.689 |
| **N4 : Neem cake** | 1.240 | 7.419 | 1.398 | 1.676 | 1.734 | 0.639 |
| **N5 : Green leaf manure** | 1.309 | 7.409 | 1.386 | 1.630 | 1.784 | 0.636 |
| **Mean** | 1.284 | 7.394 | 1.379 | 1.660 | 1.726 | 0.641 |
| **SEm±** | 0.056 | 0.418 | 0.032 | 0.124 | 0.036 | 0.036 |
| **C.D at 5%** | NS | NS | NS | NS | NS | NS |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**4.4.2.5 Sulphur content in seed**

The results revealed that the sulphur content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.15).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of sulphur (1.811 %) in stalk as compared to dibbling (1.641 %).

Among the integrated nutrient management treatments no significant difference was found between the treatments for sulphur content in seed.

The interaction effect among the method of planting and integrated nutrient management on sulphur content in seed found non-significant.

**4.4.2.6 Sulphur content in stalk**

The results revealed that the sulphur content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.15).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of sulphur (0.680 %) in stalk as compared to dibbling (0.602 %).

Among the integrated nutrient management treatments no significant difference was found for sulphur content in stalk.

The interaction effect among the method of planting and integrated nutrient management on phosphorous content in stalk found non-significant.

**4.4.3 Micronutrient content in stalk and seed**

**4.4.3.1 Iron content in seed**

The results revealed that the iron content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.16).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of calcium (36.06 mg $kg^{-1}$) in seed as compared to dibbling (30.90 mg $kg^{-1}$).

Among the integrated nutrient management treatments no significant difference was found between the treatments.

The interaction effect among the method of planting and integrated nutrient management on iron content in seed found non-significant.

**4.4.3.2 Iron content in stalk**

The results revealed that the iron content in stalk at harvest was found non-significant as influenced by method of planting and the integrated nutrient management practices during experimentation (Table 4.16).

**4.4.3.3 Copper content in seed**

The results revealed that the copper content in seed at harvest was found significant influenced due to method of planting and non-significant difference among the integrated nutrient management practices during experimentation (Table 4.16).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of copper (11.00 mg $kg^{-1}$) in stalk as compared to dibbling (10.31mg $kg_{-1}$).

Among the integrated nutrient management treatments no significant difference was found between the treatments for copper content in seed.

The interaction effect among the method of planting and integrated nutrient management on copper content in seed found non-significant.

**4.4.3.4 Copper content in stalk**

The results revealed that the copper content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.16).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of copper (5.90 mg $kg^{-1}$) in stalk as compared to dibbling (5.51 mg $kg^{-1}$).

Among the integrated nutrient management treatments no significant difference was found for copper content in stalk.

The interaction effect among the method of planting and integrated nutrient management on copper content in stalk found non-significant.

**4.4.3.5 Zinc content in seed**

The results revealed that the zinc content in seed at harvest was found non-significant as influenced by method of planting and the integrated nutrient management practices during experimentation (Table 4.16).

**4.4.3.6 Zinc content in stalk**

The results revealed that the zinc content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.16).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of zinc (23.78 mg $kg^{-1}$) in stalk as compared to dibbling (18.39 mg $kg^{-1}$).

Among the integrated nutrient management treatments no significant difference was found for zinc content in stalk.

The interaction effect among the method of planting and integrated nutrient management on zinc content in stalk found non-significant.

**4.4.3.7 Manganese content in seed**

The results revealed that the manganese content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.16).

Among the method of planting, the transplanted ($M_1$) found significantly higher content of manganese (31.30 mg $kg^{-1}$) in seed as compared to dibbling (27.28 mg $kg^{-1}$).

Among the integrated nutrient management treatments no significant difference was found for manganese content in seed.

The interaction effect of the method of planting and integrated nutrient management on manganese content in seed found non-significant.

**4.4.3.8 Manganese content in stalk**

The results revealed that the manganese content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.16).

In the method of planting the transplanted ($M_1$) found significantly higher content of manganese (12.14 mg $kg^{-1}$) in stalk as compared to dibbling (10.17 mg $kg^{-1}$).

Among the integrated nutrient management treatments no significant difference was found for manganese content in stalk.

The interaction effect among the method of planting and integrated nutrient management on manganese content in stalk found non-significant.

**4.4.3.9 Boron content in seed**

The results revealed that the boron content in seed at harvest was found non-significant as influenced by method of planting and the integrated nutrient management practices during experimentation (Table 4.16).

**4.4.3.10 Boron content in stalk**

The results revealed that the boron content in stalk at harvest was found significant as influenced by method of planting and non-significant difference among the nutrient management practices during experimentation (Table 4.16).

Among the method of planting the transplanted ($M_1$) found significantly higher content of boron (14.02 mg $kg^{-1}$) in stalk as compared to dibbling (12.55 mg $kg^{-1}$).

Among the integrated nutrient management treatments no significant difference was found for manganese content in stalk.

The interaction effect among the method of planting and integrated nutrient management on manganese content in stalk found non-significant.

**Table 4.16: Effect of method of planting and integrated nutrient management on micronutrient content in seed and stalk of pigeonpea (after harvest)**

| | Micronutrient content (mg $kg^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fe | | Cu | | Zn | | Mn | | B | |
| **Treatments** | **Seed** | **Stalk** | **Seed** | **Stalk** | **Seed** | **Stalk** | **Seed** | **Stalk** | **Seed** | **Stalk** |
| **Method of establishment ( M )** | | | | | | | | | | |
| **M1 : Dibbled** | 30.90 | 85.56 | 10.31 | 5.51 | 16.40 | 18.39 | 27.28 | 10.17 | 14.46 | 12.55 |
| **M2 : Transplanted** | 36.06 | 98.19 | 11.00 | 5.90 | 16.18 | 23.78 | 31.30 | 12.14 | 14.07 | 14.02 |
| **Mean** | 33.48 | 91.87 | 10.66 | 5.71 | 16.29 | 21.09 | 29.29 | 11.15 | 14.27 | 13.28 |
| **SEm±** | 1.32 | 6.01 | 0.15 | 0.12 | 0.51 | 1.75 | 0.62 | 0.50 | 0.16 | 0.49 |
| **C.D at 5%** | 3.92 | NS | 0.44 | 0.37 | NS | 5.19 | 1.83 | 1.48 | NS | 1.45 |
| **Nutrient ( N )** | | | | | | | | | | |
| **N1 : Control** | 34.61 | 85.62 | 10.89 | 5.60 | 16.47 | 20.84 | 29.83 | 10.32 | 13.98 | 13.01 |
| **N2 : FYM** | 33.67 | 83.39 | 10.55 | 5.65 | 16.83 | 19.17 | 28.87 | 10.59 | 14.44 | 12.63 |
| **N3 : vermicompost** | 34.29 | 101.86 | 10.65 | 5.77 | 16.61 | 24.31 | 29.40 | 13.46 | 14.17 | 14.52 |
| **N4 : Neem cake** | 31.61 | 92.46 | 10.71 | 5.79 | 15.41 | 21.90 | 29.14 | 10.65 | 14.42 | 13.09 |
| **N5 : Green leaf manure** | 33.22 | 96.05 | 10.48 | 5.72 | 16.12 | 19.22 | 29.20 | 10.74 | 14.32 | 13.17 |
| **Mean** | 33.48 | 91.87 | 10.66 | 5.71 | 16.29 | 21.09 | 29.29 | 11.15 | 14.27 | 13.28 |
| **SEm±** | 2.08 | 9.51 | 0.23 | 0.19 | 0.80 | 2.76 | 0.97 | 0.79 | 0.25 | 0.77 |
| **C.D at 5%** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer’s practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

## 4.5 Total nutrient uptake

The total uptake of nutrients at harvest as influenced by different method of planting and integrated nutrient management practices in pigeonpea is presented with tables and depicted in fig.4.3.

### 4.5.1 Total uptake of primary nutrients

#### 4.5.1.1 Total uptake of nitrogen

The results indicated that total uptake of nitrogen (kg $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.17.

Among the method of planting the transplanted ($M_1$) found significantly higher total uptake of nitrogen (135.38 kg $ha^{-1}$) as compared to dibbling (99.56 kg $ha^{-1}$). The uptake of was higher in transplanted is due to better absorption and fixing of atmospheric nitrogen with the aid of better root system of transplanted crop over the dibbling and also rapid growth and development of transplanted crop over the dibbling which resulted higher accumulation of dry matter in grain and stalk.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher nitrogen uptake (146.39 kg $ha^{-1}$) compared to $N_1$-control (91.82 kg $ha^{-1}$), $N_2$-FYM (121.63 kg $ha^{-1}$), $N_4$-neem cake (111.34 kg $ha^{-1}$) and $N_5$ green leaf manure (116.16 kg $ha^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. The effect of application organic manures will directly influence the activity of the microorganisms, which enables the N-fixing microorganisms (*Rhizobium*) to fix N by symbiotic association with legumes, so with application of organic source of manures like vermicompost and FYM resulted in higher amount of N-fixation and uptake than compared to other treatments.

The interaction effect among the method of planting and integrated nutrient management on nutrient uptake found non-significant.

**4.5.1.2 Total uptake of phosphorous**

The results indicated that total uptake of phosphorous (kg $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.17.

Among the method of planting the transplanted ($M_1$) found significantly higher total uptake of phosphorous (13.16 kg $ha^{-1}$) as compared to dibbling (9.60 kg $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher phosphorous uptake (14.10 kg $ha^{-1}$) compared to $N_{1-}$ control (8.84 kg $ha^{-1}$), $N_2$ - FYM (11.75 kg $ha^{-1}$), $N_4$ - neem cake (10.89 kg $ha^{-1}$) and $N_5$ green leaf manure (11.32 kg $ha^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on nutrient uptake found non-significant.

**4.5.1.3 Total uptake of potassium**

The results indicated that total uptake of potassium (kg $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.17.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of potassium (90.39 kg $ha^{-1}$) as compared to dibbling (86.04 kg $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher potassium uptake (90.39 kg $ha^{-1}$) compared to $N_{1-}$ control (62.18 kg $ha^{-1}$), $N_2$-FYM (79.37 kg $ha^{-1}$), $N_4$-neem cake (73.87 kg $ha^{-1}$) and $N_5$-green leaf manure (78.85 kg $ha^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total potassium uptake found non-significant.

**Table 4.17: Effect of method of planting and integrated nutrient management on uptake of primary nutrient by seed and stalk of pigeonpea (after harvest)**

| | Nutrient uptake (kg ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | | | P | | | K | | |
| **Treatments** | **Seed** | **Stalk** | **Total** | **Seed** | **Stalk** | **Total** | **Seed** | **Stalk** | **Total** |
| **Method of establishment ( M )** | | | | | | | | | |
| **M1 : Dibbled** | 58.46 | 41.11 | 99.56 | 6.45 | 3.15 | 9.60 | 27.97 | 39.86 | 67.82 |
| **M2 : Transplanted** | 75.33 | 60.05 | 135.38 | 8.92 | 4.24 | 13.16 | 37.03 | 49.01 | 86.04 |
| **Mean** | 66.89 | 50.58 | 117.47 | 7.68 | 3.69 | 11.38 | 32.50 | 44.43 | 76.93 |
| **SEm±** | 1.29 | 3.16 | 3.54 | 0.16 | 0.15 | 0.23 | 0.60 | 0.95 | 1.42 |
| **C.D at 5%** | 3.84 | 9.40 | 10.52 | 0.47 | 0.45 | 0.70 | 1.78 | 2.83 | 4.21 |
| **Nutrient ( N )** | | | | | | | | | |
| **N1 : Control** | 50.65 | 41.17 | 91.82 | 5.76 | 3.08 | 8.84 | 24.66 | 37.53 | 62.18 |
| **N2 : FYM** | 70.29 | 51.34 | 121.63 | 7.92 | 3.83 | 11.75 | 34.08 | 45.29 | 79.37 |
| **N3 : vermicompost** | 81.40 | 64.99 | 146.39 | 9.55 | 4.55 | 14.10 | 39.03 | 51.36 | 90.39 |
| **N4 : Neem cake** | 64.79 | 46.55 | 111.34 | 7.39 | 3.51 | 10.89 | 31.87 | 42.00 | 73.87 |
| **N5 : Green leaf manure** | 67.31 | 48.85 | 116.16 | 7.81 | 3.51 | 11.32 | 32.86 | 45.99 | 78.85 |
| **Mean** | 66.89 | 50.58 | 117.47 | 7.68 | 3.69 | 11.38 | 32.50 | 44.43 | 76.93 |
| **SEm±** | 2.04 | 5.00 | 5.60 | 0.25 | 0.24 | 0.37 | 0.95 | 1.51 | 2.24 |
| **C.D at 5%** | 6.07 | 14.87 | 16.64 | 0.74 | 0.72 | 1.10 | 2.81 | 4.48 | 6.65 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg ha$^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t ha$^{-1}$, Vermicompost @ 5 t ha$^{-1}$, Neem cake @ 0.25 t ha$^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t ha$^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg ha$^{-1}$ and Borax @ 5 kg ha$^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg ha$^{-1}$).

### 4.5.2 Total uptake of secondary nutrients

#### 4.5.2.1 Total uptake of calcium

The results indicated that total uptake of calcium (kg $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.18 and fig. 4.5.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of calcium (53.01 kg $ha^{-1}$) as compared to dibbling (40.36 kg $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher calcium uptake (55.94 kg $ha^{-1}$) compared to $N_1$- control (39.46 kg $ha^{-1}$), $N_2$-FYM (45.96 kg $ha^{-1}$), $N_4$-neem cake (45.32 kg $ha^{-1}$) and $N_5$-green leaf manure (46.75 kg $ha^{-1}$). Further, $N_1$, $N_2$, $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total calcium uptake found non-significant.

#### 4.5.2.2 Total uptake of magnesium

The results indicated that total uptake of magnesium (kg $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.18.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of magnesium (14.78 kg $ha^{-1}$) as compared to dibbling (10.85 kg $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher magnesium uptake (15.76 kg $ha^{-1}$) compared to $N_1$- control (10.50 kg $ha^{-1}$), $N_2$-FYM (12.60 kg $ha^{-1}$), $N_4$-neem cake (12.58 kg $ha^{-1}$) and $N_5$-green leaf manure (12.64 kg $ha^{-1}$). Further, $N_1$, $N_2$, $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total magnesium uptake found non-significant.

**Table 4.18: Effect of method of planting and integrated nutrient management on uptake of secondary nutrient by seed and stalk of pigeonpea (after harvest)**

| | Nutrient uptake (kg $ha^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ca | | | Mg | | | S | | |
| **Treatments** | **Seed** | **Stalk** | **Total** | **Seed** | **Stalk** | **Total** | **Seed** | **Stalk** | **Total** |
| **Method of establishment ( M )** | | | | | | | | | |
| **M1 : Dibbled** | 2.26 | 38.10 | 40.36 | 2.48 | 8.37 | 10.85 | 3.06 | 3.26 | 6.32 |
| **M2 : Transplanted** | 3.21 | 49.80 | 53.01 | 3.35 | 11.43 | 14.78 | 4.27 | 4.36 | 8.63 |
| **Mean** | 2.73 | 43.95 | 46.69 | 2.92 | 9.90 | 12.81 | 3.66 | 3.81 | 7.48 |
| **SEm±** | 0.09 | 1.86 | 1.88 | 0.06 | 0.56 | 0.58 | 0.09 | 0.17 | 0.21 |
| **C.D at 5%** | 0.27 | 5.54 | 5.59 | 0.19 | 1.68 | 1.72 | 0.28 | 0.49 | 0.62 |
| **Nutrient ( N )** | | | | | | | | | |
| **N1 : Control** | 2.05 | 37.42 | 39.46 | 2.22 | 8.28 | 10.50 | 2.82 | 3.28 | 6.10 |
| **N2 : FYM** | 2.87 | 43.09 | 45.96 | 3.02 | 9.58 | 12.60 | 3.68 | 3.69 | 7.37 |
| **N3 : vermicompost** | 3.35 | 52.59 | 55.94 | 3.47 | 12.29 | 15.76 | 4.39 | 4.64 | 9.03 |
| **N4 : Neem cake** | 2.58 | 42.74 | 45.32 | 2.91 | 9.67 | 12.58 | 3.57 | 3.68 | 7.26 |
| **N5 : Green leaf manure** | 2.82 | 43.93 | 46.75 | 2.98 | 9.66 | 12.64 | 3.86 | 3.77 | 7.64 |
| **Mean** | 2.73 | 43.95 | 46.69 | 2.92 | 9.90 | 12.81 | 3.66 | 3.81 | 7.48 |
| **SEm±** | 0.14 | 2.95 | 2.98 | 0.10 | 0.89 | 0.92 | 0.15 | 0.26 | 0.33 |
| **C.D at 5%** | 0.43 | 8.75 | 8.84 | 0.30 | 2.65 | 2.72 | 0.44 | 0.78 | 0.98 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

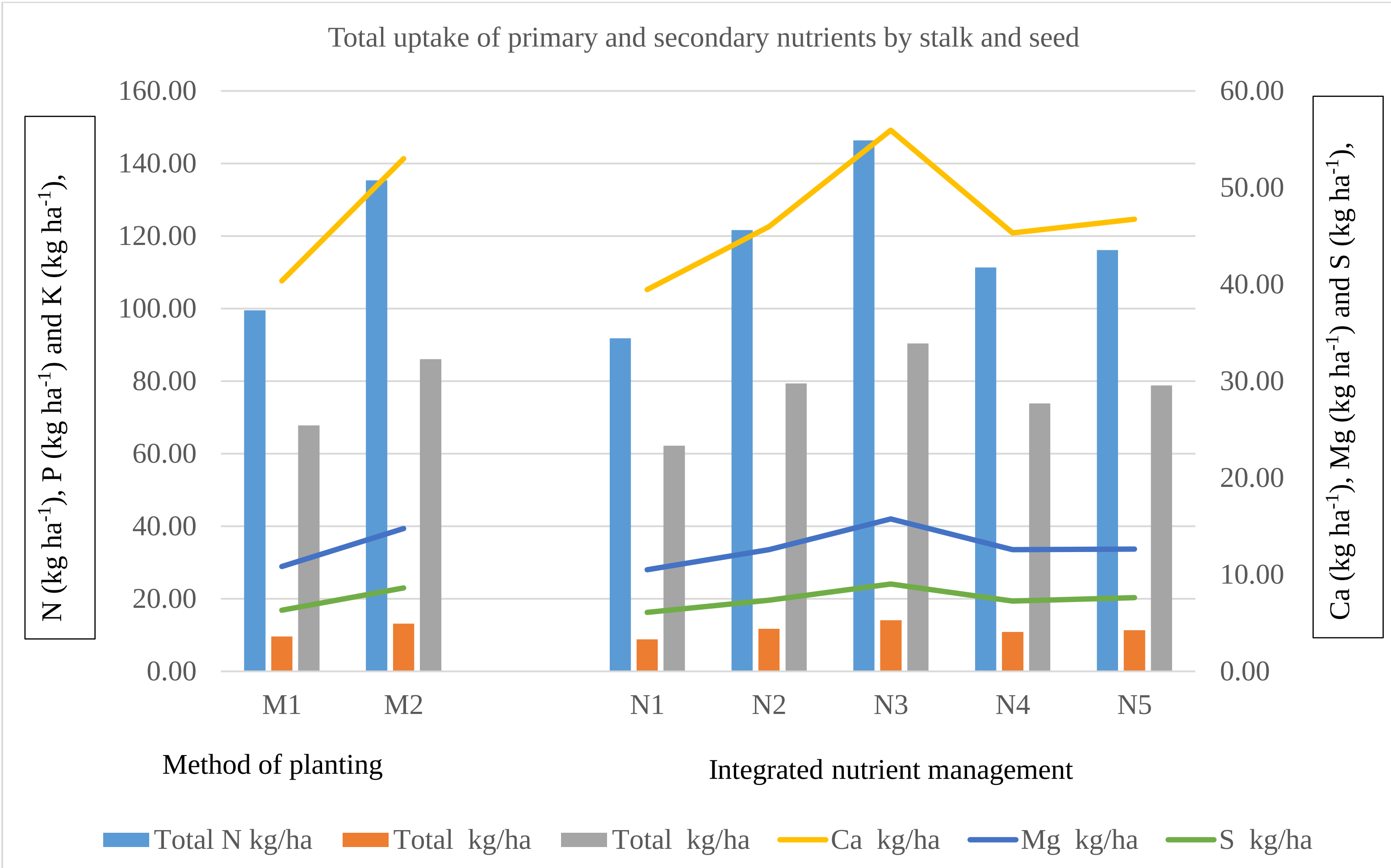



**Fig 4.4: Total uptake of primary and secondary nutrients by stalk and seed (kg ha$^{-1}$) as influenced by method of planting and integrated nutrient management**

#### 4.5.2.3 Total uptake of sulphur

The results indicated that total uptake of sulphur (kg $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.18.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of sulphur (8.63 kg $ha^{-1}$) as compared to dibbling (6.32 kg $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher magnesium uptake (9.03 kg $ha^{-1}$) compared to $N_1$-control (6.10 kg $ha^{-1}$), $N_2$ - FYM (7.37 kg $ha^{-1}$), $N_4$ - neem cake (7.26 kg $ha^{-1}$) and $N_5$ green leaf manure (7.64 kg $ha^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total magnesium uptake found non-significant.

### 4.5.3 Total uptake of micronutrients

#### 4.5.3.1 Total uptake of iron

The results indicated that total uptake of iron (g $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.19.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of iron (718.10 g $ha^{-1}$) as compared to dibbling (521.87 g $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher iron uptake (778.45 g $ha^{-1}$) compared to $N_{1-}$ control (497.60 g $ha^{-1}$), $N_2$-FYM (580.05 g $ha^{-1}$), $N_4$ - neem cake (597.93 g $ha^{-1}$) and $N_5$-green leaf manure (645.89 g $ha^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total iron uptake found non-significant.

**4.5.3.2 Total uptake of copper**

The results indicated that total uptake of copper (g $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.19.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of copper (63.63 g $ha^{-1}$) as compared to dibbling (49.02 g $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher copper uptake (65.53 g $ha^{-1}$) compared to $N_1$-control (46.0 g $ha^{-1}$), $N_2$-FYM (57.53 g $ha^{-1}$), $N_4$-neem cake (55.52 g $ha^{-1}$) and $N_5$-green leaf manure (56.43 g $ha^{-1}$). Further, $N_{2,}$ $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total copper uptake found non-significant.

**4.5.3.3 Total uptake of manganese**

The results indicated that total uptake of manganese (g $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.19.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of manganese (191.09 g $ha^{-1}$) as compared to dibbling (130.15 g $ha^{-1}$).

Among the INM treatments, no significant difference between the treatments was observed for total uptake of manganese.

The interaction effect among the method of planting and integrated nutrient management on total copper uptake found non-significant.

**Table 4.19: Effect of method of planting and integrated nutrient management on uptake of micronutrient by seed and stalk (after harvest)**

| Treatments | Nutrient uptake (g ha$^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fe | | | Cu | | | Mn | | |
| | Seed | Stalk | Total | Seed | Stalk | Total | Seed | Stalk | Total |
| **Method of establishment ( M )** | | | | | | | | | |
| **M1 : Dibbled** | 57.16 | 464.71 | 521.87 | 19.20 | 29.82 | 49.02 | 30.55 | 99.60 | 130.15 |
| **M2 : Transplanted** | 85.18 | 632.92 | 718.10 | 25.87 | 37.76 | 63.63 | 38.06 | 153.04 | 191.09 |
| **Mean** | 71.17 | 548.82 | 619.98 | 22.53 | 33.79 | 56.32 | 34.30 | 126.32 | 160.62 |
| **SEm±** | 2.70 | 42.37 | 41.79 | 0.48 | 0.94 | 1.14 | 1.11 | 11.91 | 12.03 |
| **C.D at 5%** | 8.02 | 125.89 | 124.15 | 1.43 | 2.78 | 3.39 | 3.28 | 35.39 | 35.74 |
| **Nutrient ( N )** | | | | | | | | | |
| **N1 : Control** | 56.36 | 441.24 | 497.60 | 17.72 | 28.88 | 46.60 | 26.53 | 107.21 | 133.74 |
| **N2 : FYM** | 73.76 | 506.29 | 580.05 | 23.29 | 34.24 | 57.53 | 36.88 | 118.01 | 154.89 |
| **N3 : vermicompost** | 87.55 | 690.90 | 778.45 | 26.85 | 38.68 | 65.53 | 41.62 | 165.14 | 206.76 |
| **N4 : Neem cake** | 66.00 | 531.93 | 597.93 | 22.29 | 33.23 | 55.52 | 31.84 | 126.47 | 158.31 |
| **N5 : Green leaf manure** | 72.17 | 573.72 | 645.89 | 22.51 | 33.92 | 56.43 | 34.66 | 114.75 | 149.41 |
| **Mean** | 71.17 | 548.82 | 619.98 | 22.53 | 33.79 | 56.32 | 34.30 | 126.32 | 160.62 |
| **SEm±** | 4.27 | 66.99 | 66.07 | 0.76 | 1.48 | 1.81 | 1.75 | 18.83 | 19.02 |
| **C.D at 5%** | 12.68 | NS | NS | 2.27 | 4.39 | 5.37 | 5.19 | NS | NS |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg ha$^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t ha$^{-1}$, Vermicompost @ 5 t ha$^{-1}$, Neem cake @ 0.25 t ha$^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t ha$^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg ha$^{-1}$ and Borax @ 5 kg ha$^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg ha$^{-1}$).

**4.5.3.4 Total uptake of zinc**

The results indicated that total uptake of zinc (g $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.20.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of zinc (152.28 g $ha^{-1}$) as compared to dibbling (106.02 g $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher zinc uptake (166.81 g $ha^{-1}$) compared to $N_1$-control (101.94 g $ha^{-1}$), $N_2$-FYM (128.51 g $ha^{-1}$), $N_4$-neem cake (121.82 g $ha^{-1}$) and $N_5$-green leaf manure (126.66 g $ha^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total copper uptake found non-significant.

**4.5.3.5 Total uptake of boron**

The results indicated that total uptake of boron (g $ha^{-1}$) at harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.20.

Among the method of planting, the transplanted ($M_1$) found significantly higher total uptake of zinc (123.24 g $ha^{-1}$) as compared to dibbling (94.92 g $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher boron uptake (133.49 g $ha^{-1}$) compared to $N_{1-}$ control (89.40 g $ha^{-1}$), $N_2$-FYM (108.49 g $ha^{-1}$), $N_4$-neem cake (105.20 g $ha^{-1}$) and $N_5$-green leaf manure (108.85 g $ha^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other.

The interaction effect among the method of planting and integrated nutrient management on total copper uptake found non-significant.

**Table 4.20: Effect of method of planting and integrated nutrient management on uptake of micronutrient by seed and stalk (after harvest)**

| Treatments | Nutrient uptake (g $ha^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Zn | | | B | | |
| | Seed | Stalk | Total | Seed | Stalk | Total |
| **Method of establishment ( M )** | | | | | | |
| **M1 : Dibbled** | 50.88 | 55.14 | 106.02 | 26.97 | 67.96 | 94.92 |
| **M2 : Transplanted** | 73.53 | 78.74 | 152.28 | 33.17 | 90.07 | 123.24 |
| **Mean** | 62.21 | 66.94 | 129.15 | 30.07 | 79.01 | 109.08 |
| **SEm±** | 1.61 | 3.63 | 3.92 | 0.64 | 3.44 | 3.56 |
| **C.D at 5%** | 4.77 | 10.79 | 11.65 | 1.90 | 10.23 | 10.56 |
| **Nutrient ( N )** | | | | | | |
| **N1 : Control** | 48.83 | 53.12 | 101.94 | 22.64 | 66.76 | 89.40 |
| **N2 : FYM** | 64.00 | 64.51 | 128.51 | 31.67 | 76.81 | 108.49 |
| **N3 : vermicompost** | 74.76 | 92.05 | 166.81 | 35.65 | 97.84 | 133.49 |
| **N4 : Neem cake** | 60.59 | 61.22 | 121.82 | 29.69 | 75.51 | 105.20 |
| **N5 : Green leaf manure** | 62.85 | 63.81 | 126.66 | 30.70 | 78.14 | 108.85 |
| **Mean** | 62.21 | 66.94 | 129.15 | 30.07 | 79.01 | 109.08 |
| **SEm±** | 2.54 | 5.74 | 6.20 | 1.01 | 5.45 | 5.62 |
| **C.D at 5%** | 7.54 | 17.06 | 18.43 | 3.00 | 16.18 | 16.70 |
| **Interaction (M X N)** | NS | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

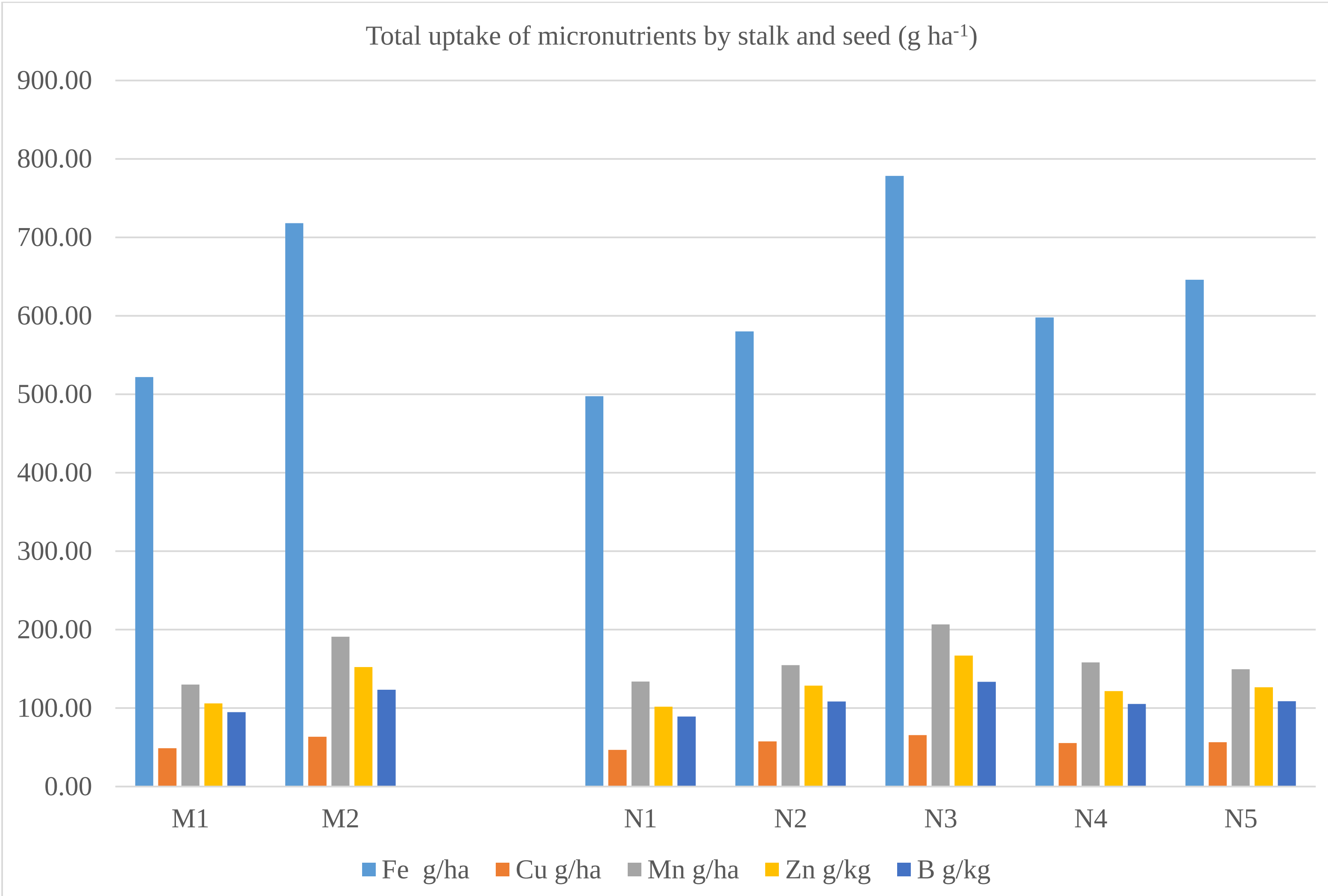



**Fig. 4.5: Total uptake of micronutrients by stalk and seed (g ha$^{-1}$) as influenced by method of planting and integrated nutrient management**

## 4.6 Physico-chemical properties of soil

### 4.6.1 pH

The results indicated that soil pH was not significantly influenced by different method of planting and integrated nutrient management treatments as presented in table 4.21 and represented in fig. 4.6.

The interaction effect among the method of planting and integrated nutrient management on soil pH found non-significant.

### 4.6.2 Electrical conductivity

There was no significance difference in electrical conductivity (EC) of soil as influenced by method of planting and integrated nutrient management as presented in table 4.21 and represented in fig. 4.6.

### 4.6.3 Organic carbon

The results indicated that organic carbon content in soil after harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.21.

Among the method of planting, the organic carbon content in soil found to be non -significant.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher content of soil organic carbon (5.56 g $kg^{-1}$ of soil) compared to $N_1$-control (4.18 g $kg^{-1}$), $N_2$-FYM (4.90 g $kg^{-1}$), $N_4$-neem cake (4.59 g $kg^{-1}$) and $N_5$-green leaf manure (4.68 g $kg^{-1}$). Further, $N_2$, $N_4$ and $N_5$ were on par with each other. Similar results were given by Sharma *et al.* (2003) *i.e.* addition of FYM or vermicompost enhanced the organic carbon content of soil.

The interaction effect among the method of planting and integrated nutrient management on soil organic carbon content found non-significant.

**Table 4.21: Effect of method of planting and integrated nutrient management on physico-chemical properties of soil (after harvest)**

| Treatments | pH | EC ($dS\ m^{-1}$) | Organic carbon ($g\ kg^{-1}$ of soil) |
|---|---|---|---|
| **Method of establishment ( M )** | | | |
| **M1 : Dibbled** | 7.66 | 0.335 | 4.79 |
| **M2 : Transplanted** | 7.69 | 0.361 | 4.78 |
| **Mean** | 7.67 | 0.348 | 4.78 |
| **S. Em.±** | 0.06 | 0.010 | 0.13 |
| **C.D.(P=0.05)** | NS | NS | NS |
| **Nutrient ( N )** | | | |
| **N1 : Control** | 7.73 | 0.348 | 4.18 |
| **N2 : FYM** | 7.70 | 0.347 | 4.90 |
| **N3 : vermicompost** | 7.59 | 0.352 | 5.56 |
| **N4 : Neem cake** | 7.72 | 0.345 | 4.59 |
| **N5 : Green leaf manure** | 7.63 | 0.348 | 4.68 |
| **Mean** | 7.67 | 0.348 | 4.78 |
| **S. Em.±z** | 0.09 | 0.015 | 0.20 |
| **C.D.(P=0.05)** | NS | NS | 0.61 |
| **Interaction (M X N)** | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

**4.6.4 Gravimetric moisture content at field capacity**

The results indicated that gravimetric moisture content (ϴw) in soil at field capacity after harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.22.

Among the method of planting, the gravimetric moisture content (ϴw) in soil at field capacity found to be non -significant.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher content of soil moisture (40.40 %) compared to $N_1$-control (34.53 %), $N_4$-neem cake (36.04 %) and on par with $N_2$-FYM (37.75 %) and $N_5$-green leaf manure (37.45 %).

The interaction effect among the method of planting and integrated nutrient management on gravimetric moisture content of soil found non-significant.

**4.6.5 Volumetric moisture content at field capacity**

The results indicated that volumetric moisture content (ϴv) in soil at field capacity after harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.22.

Among the method of planting, the gravimetric moisture content (ϴv) in soil at field capacity found to be non-significant.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher content of soil moisture (53.31 %) compared to $N_{1-}$ control (47.27 %), $N_4$-neem cake (48.91 %) and on par with $N_2$-FYM (50.72 %), $N_5$-green leaf manure (50.44 %).

The interaction effect among the method of planting and integrated nutrient management on volumetric moisture content of soil found non-significant.

**4.6.6 Bulk density**

The results indicated that bulk density of soil after harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.22.

Among the method of planting, the bulk density of soil found to be non - significant.

Among the INM treatments, $N_3$-vermicompost recorded significantly lower bulk density (1.32 kg $m^{-3}$) compared to $N_1$-control (1.37 kg $m^{-3}$), $N_4$-neem cake (1.36 kg $m^{-3}$) and on par with $N_2$-FYM (1.34 kg $m^{-3}$) and $N_5$-green leaf manure (1.35 kg $m^{-3}$) The results are in conformity with the findings of Sharma *et al.* (2003) addition of FYM or vermicompost 10 t $ha^{-1,}$ BD of soil and significance reduced due to application of greenleaf manure , Bajpai *et al.* (2006), Singh *et al*. (2000).

The interaction effect among the method of planting and integrated nutrient management on bulk density of soil found non-significant.

### 4.6.7 Porosity

The results indicated that porosity of soil after harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.22.

Among the method of planting, the porosity of soil found to be non -significant.

Among the INM treatments, $N_3$-vermicompost recorded significantly higher soil porosity (47.61 %) compared to $N_1$-control (45.61 %), $N_4$-neem cake (46.15 %) and on par with $N_2$-FYM (46.66 %) and $N_5$ green leaf manure (46.49 %). Sharma *et al.* (2003) addition of FYM or vermicompost- 10 t $ha^{-1}$ enhanced the porosity of soil.

The interaction effect among the method of planting and integrated nutrient management on porosity of soil found non-significant.

### 4.6.8 Available nitrogen

The results indicated that available nitrogen in soil after harvest was significantly influenced by different method of planting and integrated nutrient management as presented in table 4.23 and represented in fig.4.6.

Among the method of planting, the available nitrogen in soil found to be non - significant.

**Table 4.22: Effect of method of planting and integrated nutrient management on moisture content and physical properties of soil (after harvest)**

| Treatments | Gravimetric moisture content at FC (ϴw) (%) | Volumetric moisture content at FC (ϴv) (%) | Bulk density ($Mg\ m^{-3}$) | Porosity (%) |
|---|---|---|---|---|
| **Method of establishment ( M )** | | | | |
| **M1 : Dibbled** | 36.93 | 49.90 | 1.35 | 46.33 |
| **M2 : Transplanted** | 37.54 | 50.36 | 1.34 | 46.67 |
| **Mean** | 37.24 | 50.13 | 1.35 | 46.50 |
| **SEm±** | 0.69 | 0.70 | 0.01 | 0.26 |
| **C.D at 5%** | NS | NS | NS | NS |
| **Nutrient ( N )** | | | | |
| **N1 : Control** | 34.53 | 47.27 | 1.37 | 45.61 |
| **N2 : FYM** | 37.75 | 50.72 | 1.34 | 46.66 |
| **N3 : vermicompost** | 40.40 | 53.31 | 1.32 | 47.61 |
| **N4 : Neem cake** | 36.04 | 48.91 | 1.36 | 46.15 |
| **N5 : Green leaf manure** | 37.45 | 50.44 | 1.35 | 46.49 |
| **Mean** | 37.24 | 50.13 | 1.35 | 46.50 |
| **SEm±** | 1.10 | 1.11 | 0.01 | 0.41 |
| **C.D at 5%** | 3.26 | 3.30 | 0.03 | 1.22 |
| **Interaction (M X N)** | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

Among the INM treatments, $N_3$-vermicompost recorded significantly higher soil available nitrogen (251 kg $ha^{-1}$) compared to $N_1$- control (215 kg $ha^{-1}$), $N_4$ -neem cake (226 kg $ha^{-1}$) and on par with $N_2$-FYM (234 kg $ha^{-1}$) and $N_5$-green leaf manure (230 kg $ha^{-1}$). The application of FYM increases the residual available N and P (Dudhat *et al.*, 1997). Fertility and N content will be increased due to application of FYM (Babalad, 2000). This is due to more addition of organic carbon to soil, which increases the activity of microorganisms and intern the biological fixation of atmospheric N by rhizobium, increases the nitrogen to the plant and also fix in the soil.

The interaction effect among the method of planting and integrated nutrient management on available nitrogen in soil found non-significant.

### 4.6.9 Available phosphorous

The results indicated that available phosphorous in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.23).

### 4.6.10 Available potassium

The results indicated that available potassium in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (table 4.23).

### 4.6.11 Exchangeable calcium

The results indicated that exchangeable calcium in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.24).

### 4.6.12 Exchangeable magnesium

The results indicated that exchangeable magnesium in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.24).

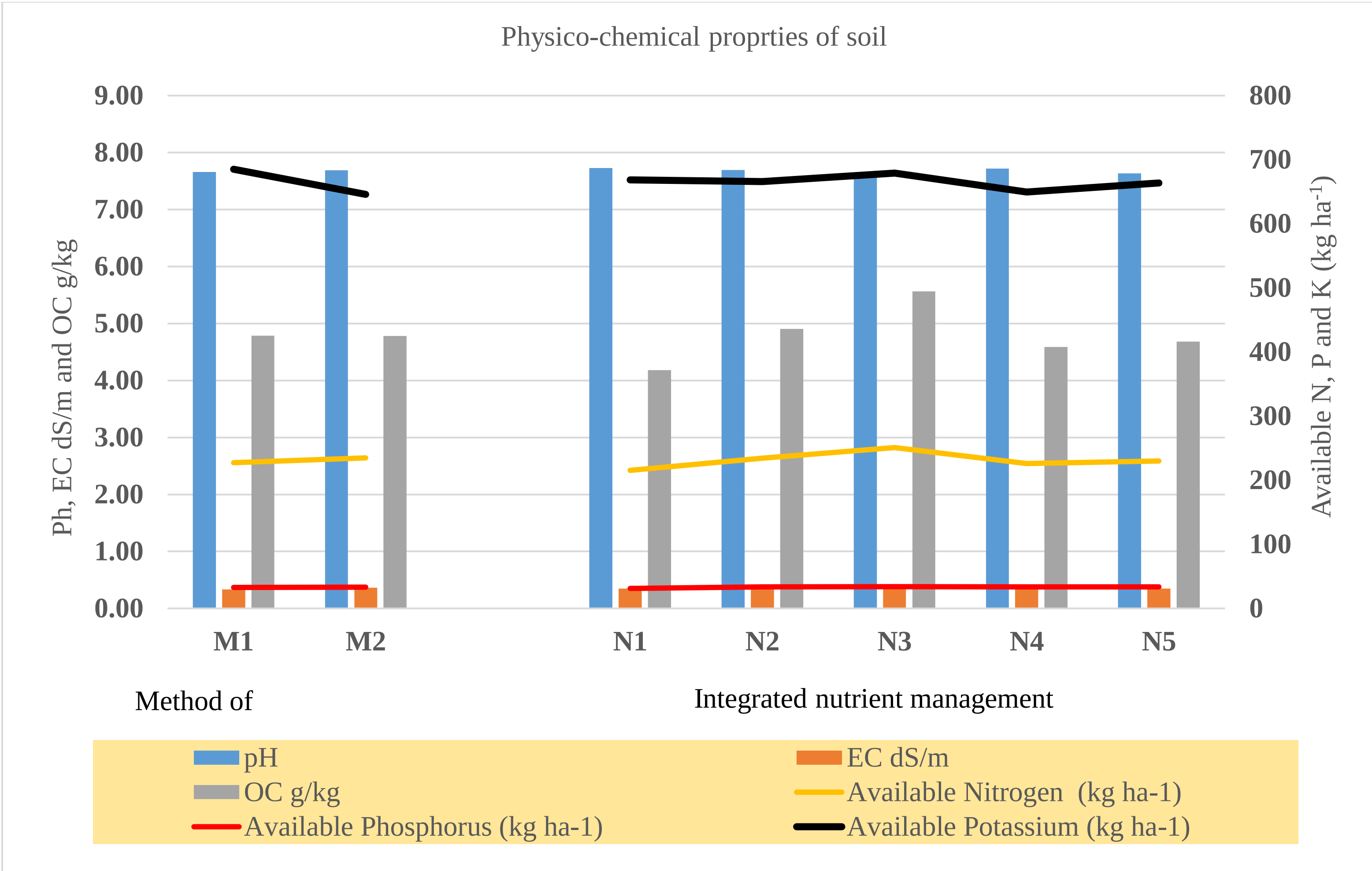



**Fig 4.6: Physico-chemical properties (pH, EC, OC, (Available N, P and K) as influenced by method of planting and integrated nutrient management**

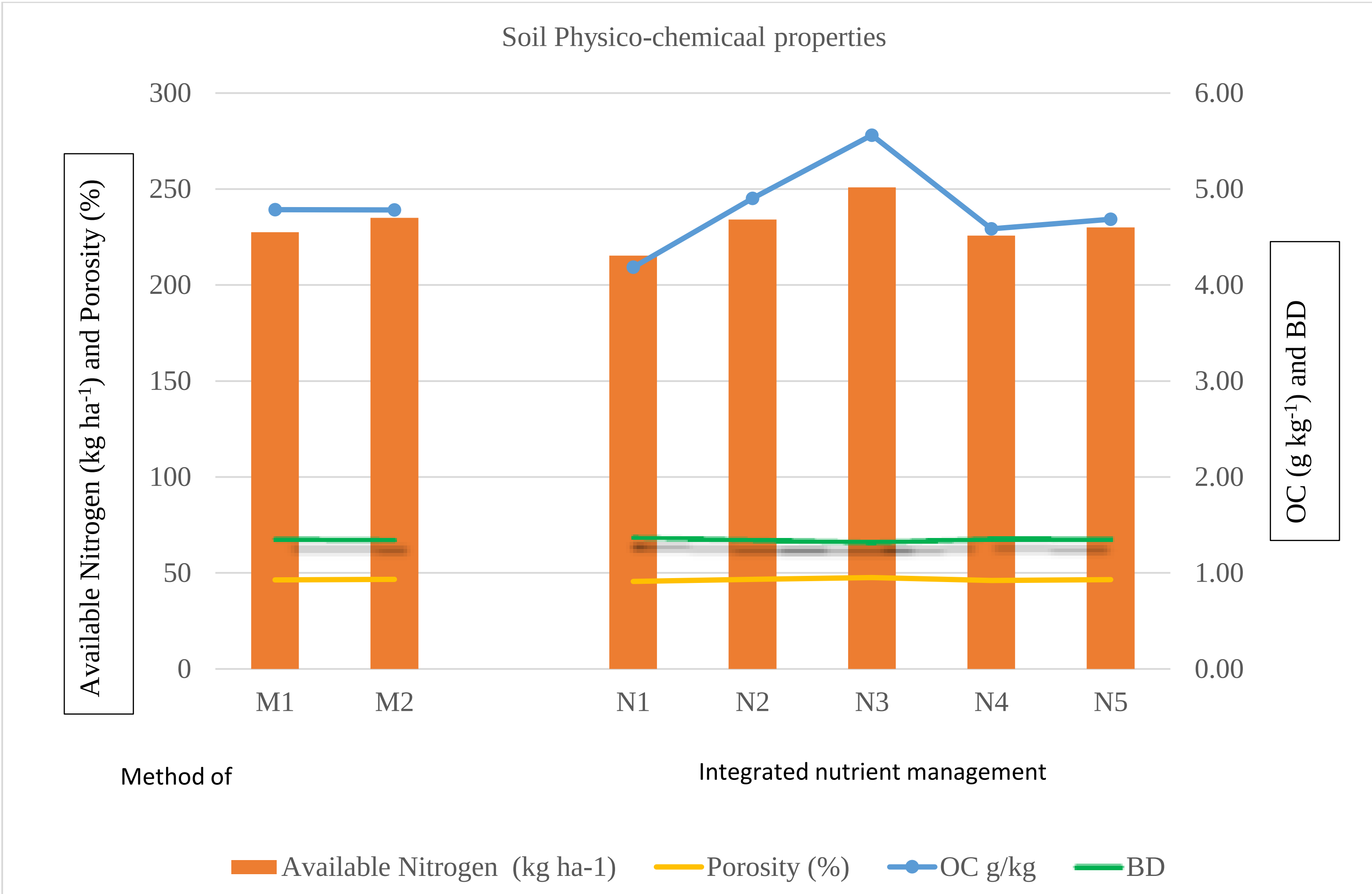



**Fig. 4.7: Effect of soil physico-chemical properties (Available N kg ha$^{-1}$, Porosity %, Organic C %. Bulk density Mg m$^{-3}$) due to method of planting and integrated nutrient management.**

**Table 4.23: Effect of method of planting and integrated nutrient management on available major nutrients in soil (after harvest)**

| Treatments | Available Nitrogen (kg ha$^{-1}$) | Available Phosphorus (kg ha$^{-1}$) | Available Potassium (kg ha$^{-1}$) |
|---|---|---|---|
| **Method of establishment ( M )** | | | |
| **M1 : Dibbled** | 227 | 32.80 | 685 |
| **M2 : Transplanted** | 235 | 33.34 | 646 |
| **Mean** | 231 | 33.07 | 666 |
| **S. Em.±** | 4.64 | 0.50 | 13.63 |
| **C.D.(P=0.05)** | NS | NS | NS |
| **Nutrient ( N )** | | | |
| **N1 : Control** | 215 | 31.14 | 669 |
| **N2 : FYM** | 234 | 33.44 | 666 |
| **N3 : Vermicompost** | 251 | 33.92 | 679 |
| **N4 : Neem cake** | 226 | 33.41 | 650 |
| **N5 : Green leaf manure** | 230 | 33.45 | 664 |
| **Mean** | 231 | 33.07 | 666 |
| **S. Em.±** | 7.34 | 0.79 | 21.55 |
| **C.D.(P=0.05)** | 22 | NS | NS |
| **Interaction (M X N)** | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg ha$^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t ha$^{-1}$, Vermicompost @ 5 t ha$^{-1}$, Neem cake @ 0.25 t ha$^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t ha$^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg ha$^{-1}$ and Borax @ 5 kg ha$^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg ha$^{-1}$).

**Table 4.24: Effect of method of planting and integrated nutrient management on secondary nutrient in soil (after harvest)**

| Treatments | Exchangeable Calcium (kg $ha^{-1}$) | Exchangeable Magnesium (kg $ha^{-1}$) | Available Sulphur (kg $ha^{-1}$) |
|---|---|---|---|
| **Method of establishment ( M )** | | | |
| **M1 : Dibbled** | 15259 | 3144 | 19.02 |
| **M2 : Transplanted** | 15283 | 3048 | 20.89 |
| **Mean** | 15271 | 3096 | 19.95 |
| **S. Em.±** | 93 | 36 | 0.63 |
| **C.D.(P=0.05)** | NS | NS | NS |
| **Nutrient ( N )** | | | |
| **N1 : Control** | 15456 | 3078 | 18.26 |
| **N2 : FYM** | 15420 | 3098 | 20.27 |
| **N3 : Vermicompost** | 15241 | 3098 | 21.05 |
| **N4 : Neem cake** | 15115 | 3111 | 20.20 |
| **N5 : Green leaf manure** | 15122 | 3095 | 20.00 |
| **Mean** | 15271 | 3096 | 19.95 |
| **S. Em.±** | 146.57 | 57.66 | 1.00 |
| **C.D.(P=0.05)** | NS | NS | NS |
| **Interaction (M X N)** | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

### 4.6.13 Available sulphur

The results indicated that available sulphur in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.24).

### 4.6.14 Available zinc

The results indicate that available zinc in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.25).

### 4.6.15 Available iron

The results indicated that available iron in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.25).

### 4.6.16 Available boron

The results indicated that available boron in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (table 4.25).

### 4.6.17 Available copper

The results indicated that available copper in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.25).

### 4.6.18 Available manganese

The results indicated that available manganese in soil after harvest was found non-significant as influenced by different method of planting and integrated nutrient management (Table 4.25).

**Table 4.25: Effect of method of planting and integrated nutrient management on available micronutrient in soil (after harvest)**

| Treatments | Available micronutrients (mg $kg^{-1}$) | | | | |
|---|---|---|---|---|---|
| | **Zn** | **Fe** | **B** | **Cu** | **Mn** |
| **Method of establishment ( M )** | | | | | |
| **M1 : Dibbled** | 1.44 | 13.37 | 1.74 | 1.64 | 5.22 |
| **M2 : Transplanted** | 1.70 | 14.71 | 1.90 | 1.79 | 5.42 |
| **Mean** | 1.57 | 14.04 | 1.82 | 1.72 | 5.32 |
| **SEm±** | 0.12 | 0.83 | 0.06 | 0.06 | 0.18 |
| **C.D at 5%** | NS | NS | NS | NS | NS |
| **Nutrient ( N )** | | | | | |
| **N1 : Control** | 1.39 | 13.44 | 1.70 | 1.65 | 4.96 |
| **N2 : FYM** | 1.60 | 13.49 | 1.81 | 1.69 | 5.28 |
| **N3 : Vermicompost** | 1.56 | 15.32 | 1.89 | 1.77 | 5.46 |
| **N4 : Neem cake** | 1.44 | 13.23 | 1.83 | 1.72 | 5.67 |
| **N5 : Green leaf manure** | 1.86 | 14.72 | 1.87 | 1.75 | 5.23 |
| **Mean** | 1.57 | 14.04 | 1.82 | 1.72 | 5.32 |
| **SEm±** | 0.18 | 1.32 | 0.09 | 0.09 | 0.29 |
| **C.D at 5%** | NS | NS | NS | NS | NS |
| **Interaction (M X N)** | NS | NS | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

## 4.7 Economics

The data on cost of cultivation (₹ $ha^{-1}$), gross returns (₹ $ha^{-1}$), net returns (₹ $ha^{-1}$) and benefit cost ratio (B:C) as influenced by nutrient management (Table 4.26).

### 4.7.1 Cost of cultivation

The cost of cultivation recorded under different treatments is presented in table 4.26 and depicted in Fig. 4.8.

The results revealed that the cost of cultivation was lower in dibbled (₹ 31478 $ha^{-1}$) compared to Transplanted (₹ 34378 $ha^{-1}$).

Among the integrated nutrient management treatments, $N_3$-vermicomost recorded higher cost of cultivation (₹ 36863 $ha^{-1}$) compared to all the other treatments *viz*., $N_2$ (₹ 33363 $ha^{-1}$), $N_4$ (₹ 32863 $ha^{-1}$), $N_5$ (₹ 33363 $ha^{-1}$) and the treatment $N_1$ (₹ 28188 $ha^{-1}$) which is least cost among the other nutrient treatment combinations.

### 4.7.2 Gross returns

The gross returns recorded under different treatments are presented in table 4.26 and depicted in Fig. 10.

Among the method of planting $M_2$-transplanted pigeonpea recorded higher gross returns (₹ 149215 $ha^{-1}$) compared to all the other integrated nutrient treatments (₹ 96926 to 129724 $ha^{-1}$). While, the control treatment (farmer’s practice) recorded gross returns of (₹ 96926 $ha^{-1}$).

### 4.7.3 Net returns

The data on net returns (₹ $ha^{-1}$) as influenced by different method of planting and integrated nutrient management nutrients are presented in table 4.26 and depicted in Fig. 10.

The dibbed crop ($M_1$) recorded significantly lower net returns (₹ 79036 $ha^{-1}$) when compared to transplanted ($M_2$) (₹ 104993 $ha^{-1}$) in case of method of planting.

Among the integrated nutrient management treatments, the $N_3$-vermicompost treatment recorded significantly higher net returns (₹ 112352 $ha^{-1}$) as compared to remaining treatments and the $N_2$- FYM treatment also recorded (₹ 96361 $ha^{-1}$) significantly higher net returns as compared to $N_1$- control (farmer's practice) (₹ 68798 $ha^{-1}$) and was on par with $N_4$ (₹ 89456 $ha^{-1}$) and $N_5$. (93168 $ha^{-1}$). The results are conformity with the findings of Patil *et al*. (2007) with application of 5t $ha^{-1}$ vermicompost.

**4.7.4 Benefit cost ratio**

The benefit cost ratio as influenced by different sources of nutrients is presented in table 4.26.

Among the method of planting, $M_2$-transplanted pigeonpea crop have recorded significantly highest B:C ratio (4.04) as compared to dibbled pigeonpea.

The benefit cost ratio was significantly influenced by different integrated nutrient combination treatments. Among all the treatments, $N_3$-vermicompost recorded significantly higher benefit cost ratio (4.04) compared to $N_1$-control (farmer's practice) which is least B:C ratio among the nutrient combination treatments and on par with $N_2$ (3.88), $N_5$ (3.78) and $N_4$ (3.71). Gholve *et al*. (2005) also reported higher B:C with vermicompost application 3 t $ha^{-1}$ + *Rhizobium.*

**Table 4.26: Economics of pigeonpea as influenced by method of planting and integrated nutrient management**

| Treatments | Cost of cultivation (₹ $ha^{-1}$) | Gross returns (₹ $ha^{-1}$) | Net returns (₹ $ha^{-1}$) | B:C Ratio |
|---|---|---|---|---|
| **Method of establishment ( M )** | | | | |
| **M1 : Dibbled** | 31478 | 110514 | 79036 | 3.50 |
| **M2 : Transplanted** | 34378 | 139371 | 104993 | 4.04 |
| **Mean** | --- | 124943 | 92015 | 3.77 |
| **SEm±** | --- | 2513 | 2513 | 0.08 |
| **C.D at 5%** | --- | 7467 | 7467 | 0.23 |
| **Nutrient ( N )** | | | | |
| **N1 : Control** | 28188 | 96926 | 68738 | 3.43 |
| **N2 : FYM** | 33363 | 129724 | 96361 | 3.88 |
| **N3 : Vermicompost** | 36863 | 149215 | 112352 | 4.04 |
| **N4 : Neem cake** | 32863 | 122319 | 89456 | 3.71 |
| **N5 : Green leaf manure** | 33363 | 126531 | 93168 | 3.78 |
| **Mean** | --- | 124943 | 92015 | 3.77 |
| **SEm±** | --- | 3974 | 3974 | 0.12 |
| **C.D at 5%** | --- | 11807 | 11807 | 0.36 |
| **Interaction (M X N)** | --- | NS | NS | NS |

NS: Non significant, DAP: Days after planting, RDF: 20:50 kg $ha^{-1}$ of N and $P_2O_5$. Control: RDF only (farmer's practice), FYM @ 5 t $ha^{-1}$, Vermicompost @ 5 t $ha^{-1}$, Neem cake @ 0.25 t $ha^{-1}$, Green leaf manure (*Gliricidia*) @ 5 t $ha^{-1}$. All the treatments except control was applied with micronutrients ($ZnSO_4$ @ 25 kg $ha^{-1}$ and Borax @ 5 kg $ha^{-1}$), biofertilizer: (*Rhizobium* as seed treatment) and gypsum @100 kg $ha^{-1}$).

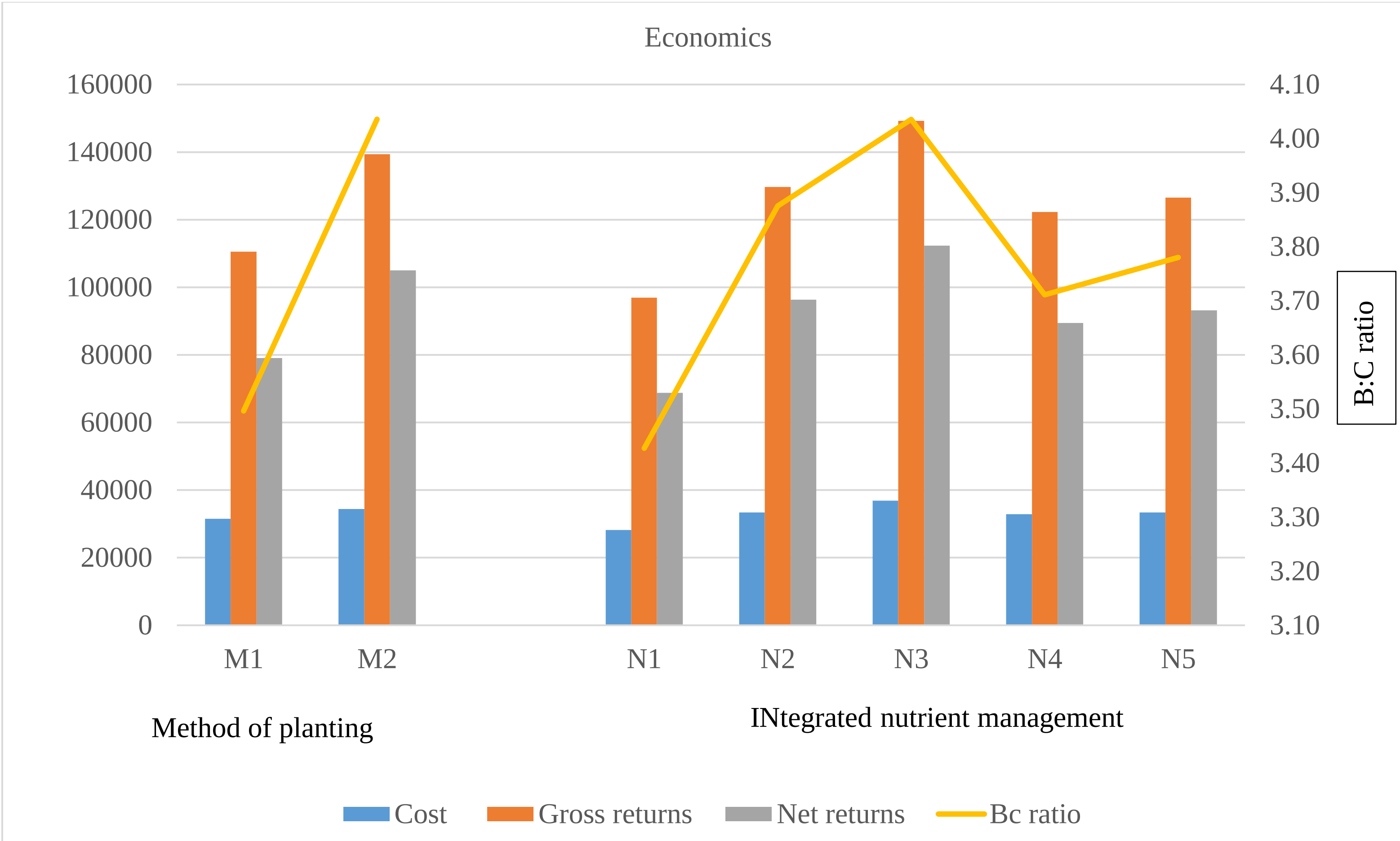



Fig 4.8: **Economics of pigeonpea as influenced by method of planting and integrated nutrient management**

**Plate IV: A view of transplanting pigeonpea technique (*Kharif* 2016-17)**

# CHAPTER-IV

# SUMMARY AND CONCLUSIONS

A field experiment on "Evaluation of soil physico-chemical properties, growth and yield of pigeonpea as influenced by method of planting and integrated nutrient management in *Vertisols* of Karnataka" experiment was conducted at farmer's field of Raichur, Karnataka under the project 'Bhoo-Samruddhi', ICRISAT, Hyderabad, Telangana, during the *Kharif*, 2016 in factorial randomized block design with two factors, factor-1 at two levels on method of planting i.e. $M_1$-Dibbling and $M_2$-Transplanted. Factor-2 at five levels on different integrated nutrient management practices with inorganic fertilizers (RDF, micronutrients and gypsum) and organic manures i.e. $N_1$-control (farmer's practice), $N_2$-FYM, $N_3$-vermicompost, $N_4$-neem cake, $N_5$-green leaf manure (*Gliricidia*). The growth and yield attributes, quality parameters, nutrient content and uptake and soil physico-chemical properties recorded during the study period have presented and discussed. The summary and conclusion of results obtained in present study are given in this chapter.

## SUMMARY

The growth attributing character viz., plant height, number of leaves, number of primary and secondary branches per plant, leaf area, leaf area index and dry matter accumulation in plant, were recorded during 30, 60, 90, 120, and at harvest. Among these plant height at all stages were significantly affected due to method of planting. Maximum plant height of 213 cm was recorded in $M_{2,}$ maximum number of primary and secondary branches per plant at harvest was recorded in $M_2$ method of planting (14.35 and 37.29 respectively). Dry matter accumulation per plant due to different method of plating was highest in $M_2$ (828.30 g plant$^{-1}$). The leaf area and leaf area index at 120 DAP was highest in the $M_2$ (151.49 dm$^2$ and 1.683 respectively) treatment. Similarly $M_2$ planting method recorded significantly more number of pods per plant and seed yield per plant as compared to $M_1$.

Integrated nutrient management treatments had significant effect on growth (plant height, number of leaves, number of primary and secondary branches per plant, leaf area, leaf area index and dry matter accumulation in plant) and yield components (number of pods per plant and seed yield per plant). In all cases INM treatment $N_3$ recorded significantly higher values of these parameters than other treatments except at 30 DAP. The control (farmer's practice) treatment have recorded lowest values than other treatments in all stages of crop growth. There is no significance among the interaction effect of the planting method and integrated nutrient management in all stages of the crop growth and yield attributes.

The seed yield and stalk yields and harvest index were affected significantly due to different planting methods. Planting method $M_1$ recorded the seed yield of 2386 kg $ha^{-1}$, Stalk yield 4987 kg $ha^{-1}$ and harvest index 0.271, which was significantly higher than $M_1$ method of planting.

Similarly, yield of both the components as well as harvest index were affected significantly due to different integrated nutrient management practices and $N_3$ recorded significantly higher yields of both the components as well as harvest index (2448 kg $ha^{-1}$, 5168 kg $ha^{-1}$ and 0.268 respectively). The interaction of different method of planting and integrated nutrient management practices found non-significant with respect to these yield components and harvest index.

Protein content was not affected significantly due to different planting methods, while, protein yield was significantly affected due to different method of planting and $M_2$ recorded higher protein yield (470.78 $kgha^{-1}$). Protein content was slightly higher (20.11%) in $N_3$ than other treatments and protein yield was significantly affected due to different integrated nutrient management practices. Among the INM, the protein yield (508.76 kg $ha^{-1}$) was recorded in $N_3$-(vermicompost). The interaction of MxN had no significant effect on protein content and protein yield.

Among the primary, secondary and micronutrients, there is a significant effect due to method of planting. The N in stalk, content of P, K, and S in seed and stalk were found higher in $M_2$ method of planting. In case of micronutrients Fe and Cu in seed, B and Zn in stalk and Mn in both was affected due to different method of planting and highest in $M_2$. However, the primary, secondary and micronutrient content in seed and stalk due to different integrated nutrient management found to be non-significant. The effect of MxN was not significant on content of primary, secondary and micronutrient in seed and stalk.

The uptake of primary, secondary and micronutrients by seed, stalk and their total were significantly affected due to different method of planting and planting method $M_2$ recorded significantly higher uptake of these nutrients by components of pigeonpea as compared to planting method $M_1$. As for as different integrated nutrient management is concerned, they had significant effect on uptake of primary, secondary and micronutrients by seed, stalk and their total. In majority of nutrients, source $N_3$ recorded significantly higher uptake of these nutrients by seed, stalk and their total uptake. The interaction of method of planting and integrated nutrient management had no significant on uptake of these nutrients by seed, stalk and their total uptake.

None of the soil physical properties (bulk density, moisture content at field capacity i.e. Θw and Θv, and porosity), chemical (pH, EC, and OC) and fertility (available N, P and K and exchangeable Ca and Mg, available $CaCl_2$ extractable S and DTPA extractable Fe, Mn, Zn, and Cu, and available B by azo methane-H method) properties of soil were significantly affected due to method of planting. However, among these properties, bulk density, moisture content at field capacity i.e. Θw and Θv, and porosity, organic C and available N were affected significantly due to integrated nutrient management and comparatively higher content of these nutrients in soil were recorded in $N_3$. The interaction effect of MxN was non-significant on physico-chemical and fertility of soil.

Higher net profit and B:C ratio values under treatments of $M_2$ and $N_3$ were ₹ 104993 $ha^{-1}$ and 4.04 and ₹ 112352 $ha^{-1}$ and 4.04, respectively which were higher than the remaining treatments. However, the interactions found non-significance due to method of planting and integrated nutrient management.

## CONCLUSIONS

From the results of the present study, following conclusions emerged.

1. The transplanted pigeonpea has a significantly higher seed yield as compared to dibbling method of planting. Hence the negative effect of delayed planting on reduction of economical yield can be overcome by adopting the transplanting technology in the delayed sowing conditions due to delayed rains and unfavorable conditions at the time of early sowing.

2. Among the integrated nutrient management, the pigeonpea with $N_3$-vermicompost @ 5 t $ha^{-1}$ gave significantly higher grain yield, followed by $N_2$-FYM @ 5 t $ha^{-1}$ and $N_5$-greenleaf manure @ 5 t $ha^{-1}$, and these treatments found ideal and remunerative under integration with inorganic fertilizers for sustainable increase in productivity.

3. Significant improvement in the soil physico-chemical properties due to integrated nutrient management with vermicompost followed by FYM and green leaf manure was noticed, also these treatments also recorded the higher grain yield of pigeonpea with higher nutrient uptake and maintained the soil health.

4. The significantly higher net returns and benefit cost ratio were obtained in the both the planting methods ($M_2$) and integrated nutrient management practices with use of organic source ($N_3$), than compared to farmers practice, which recorded lowest yield and returns than other integrated nutrient management practices.

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**Appendix A: Calendar of cultural operations**

| Sl. No. | Field operation | Frequency | Date of operation |
|---|---|---|---|
| **A.** | **Pre-sowing** | | |
| 1. | Nursery (for transplanting crop) | 1 | 19/06/2016 |
| 2. | Tractor ploughing | 1 | 26/06/2016 |
| 3. | Harrowing with tractor | 1 | 27/06/2016 |
| 4. | Field layout | 1 | 03/07/2016 |
| 5. | Incorporation of organic manures | 1 | 04/07/2016 |
| 6. | Fertilizer application | 1 | 13/07/2016 and 14/07/2016 |
| 7. | Dibbling and Transplanting | 1 | 14/07/2016 |
| **B.** | **Post sowing operations** | | |
| 1. | Gap filling | 1 | 25/07/2016 |
| 2. | Hand weeding | 2 | 08/08/2016 and 04/09/2016 |
| 3. | Pesticide spraying | 5 | 08/08/2016, 03/09/2016, 28/10/2016, 27/11/2016 and 20/12/2016 |
| 4. | Nipping | 1 | 12/09/2016 |
| 5. | Irrigation | 1 | 11/11/2016 |
| 6. | Harvesting | 1 | 28/01/2017 |

# Appendix B: Price of inputs and outputs (₹ $ha^{-1}$)

| Sl. No. | Particulars | Price (₹) |
|---|---|---|
| **(A) Total fixed cost of dibbled crop** | | |
| 1. | Land preparation (ploughing and harrowing) | 3800 |
| 2. | Pigeonpea seeds | 800 |
| 3. | Sowing of seeds | 1200 |
| 4. | Irrigation | 800 |
| 5. | Hand weeding | 4500 |
| 6. | Gap filling and thinning | 600 |
| 7. | Manure application | 900 |
| 8. | Pesticides | 4650 |
| 9. | Pesticides application | 1950 |
| 10. | Nipping | 750 |
| 11. | Harvesting and threshing | 4500 |
| | **Total** | **24450** |
| **(B) Total fixed cost of transplanted crop** | | |
| 1. | Land preparation (ploughing and harrowing) | 3800 |
| 2. | Nursery cost (seed, labour, plastic trays and nursery manure) | 3400 |
| 3. | Transplanting | 1500 |
| 4. | Irrigation | 800 |
| 5. | Hand weeding | 4500 |
| 6. | Gap filling and thinning | 600 |
| 7. | Manure application | 900 |
| 8. | Pesticides | 4650 |
| 9. | Pesticides application | 1950 |
| 10. | Nipping | 750 |
| 11. | Harvesting and threshing | 4500 |
| | **Total** | **27350** |

| (C) Price of inputs | | |
|---|---|---|
| 1. | Tractor ploughing | 3000 ha$^{-1}$ |
| 2. | Tractor harrowing and planking | 800 ha$^{-1}$ |
| 3. | Labour charges | 150 day$^{-1}$ |
| 4. | Pigeonpea hybrid (ICPH 2740) seed | 200 kg$^{-1}$ |
| 5. | Irrigation | 80 hr$^{-1}$ |
| 6. | FYM | 500 t$^{-1}$ |
| 7. | Vermicompost | 1200 t$^{-1}$ |
| 8. | Neem cake | 8000 .t$^{-1}$ |
| 9. | *Gliricidia* | 500 t$^{-1}$ |
| 10. | Urea | 5.3 kg$^{-1}$ |
| 11. | Di-ammonium phosphate | 21 kg$^{-1}$ |
| 12. | Gypsum | 2 kg$^{-1}$ |
| 13. | Borax | 68 kg$^{-1}$ |
| 14. | Zinc sulphate | 42 kg$^{-1}$ |
| 13. | Biofertilizer 250g | 25 pac$^{-1}$ |
| **(D) Selling price of produce** | | |
| 1 | Grain | 55 kg$^{-1}$ |
| 2 | Stalk | 1.50 kg$^{-1}$ |

## Appendix C: Total cost of cultivation per treatment

| Sl. no. | Treatments | | Treatment details | Price (₹) |
|---|---|---|---|---|
| 1. | **T1** | **M$_1$**: Dibbled | **N$_1$**: Control (Farmer's practice) | 26738 |
| 2. | **T2** | | **N$_2$**: FYM (5 t ha$^{-1}$) | 31913 |
| 3. | **T3** | | **N$_3$**: Vermicompost (5 ha$^{-1}$) | 35413 |
| 4. | **T4** | | **N$_4$**: Neem cake (0.25 t ha$^{-1}$) | 31413 |
| 5. | **T5** | | **N$_5$**: Green leaf manure (Gliricidia 5 t ha$^{-1}$) | 31913 |
| 6. | **T6** | **M$_2$**: Transplanted | **N$_1$**: Control (Farmer's practice) | 29638 |
| 7. | **T7** | | **N$_2$**: FYM (5 t ha$^{-1}$) | 34813 |
| 8. | **T8** | | **N$_3$**: Vermicompost (5 ha$^{-1}$) | 38313 |
| 9. | **T9** | | **N$_4$**: Neem cake (0.25 t ha$^{-1}$) | 34313 |
| 10. | **T10** | | **N$_5$**: Green leaf manure (Gliricidia 5 t ha$^{-1}$) | 34813 |

# VITA

| | | |
|---|---|---|
| Name | : | Somashekar T N |
| Date of birth | : | 10 December, 1993 |
| Present Address | : | Room No. : 114, Sundram PG boy's hostel, College of Agriculture, IGKV, Raipur (C.G.) |
| Phone | : | 9964485776 |
| Email | : | somashekar8880@gmail.com |
| Permanent Address | : | J Thimmasandra (V & P), Srinivaspur (Tq.) Kolar (Dist.), Karnataka, Pin Code - 563135 |

Academic Qualifications:

| **Degree** | **Year** | **University/Institute** |
|---|---|---|
| Board of Secondary Education | 2009 | Karnataka Secondary Education Board |
| Pre-University Board | 2011 | Department of Pre-University Education, Karnataka |
| B.Sc. (Agriculture) | 2015 | University of Agricultural Sciences, Bengaluru, Karnataka |
| M.Sc. (Ag) Soil Science and Agricultural Chemistry | 2017 | Indira Gandhi Krishi Vishwavidyalay, Raipur (C.G.) |

Professional Experience (If any): Rural Agricultural Work Experience Programme

Membership of Professional Societies (If any):

Awards / Recognitions (If any):

Publications (If any):

Signature