FOLIAR NUTRITION OF COWPEA [*Vigna unguiculata* (L.)] UNDER DIFFERENT MANAGEMENT SYSTEMS

SUGINA P.

(2018-11-077)

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

PADANNAKKAD, KASARAGOD - 671 314

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by

SUGINA P.

(2018-11-077)

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2020

DECLARATION

I, hereby declare that this thesis entitled "**FOLIAR NUTRITION OF COWPEA (*Vigna unguiculata* L.) UNDER DIFFERENT MANAGEMENT SYSTEMS**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Padannakkad
17.09.2020

Sugina P
2018-11-077

CERTIFICATE

Certified that this thesis entitled "**FOLIAR NUTRITION OF COWPEA [*Vigna unguiculata* (L.)**] **UNDER DIFFERENT MANAGEMENT SYSTEMS**" is a record of research work done independently by Ms. Sugina P (2018-11-077) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Padannakkad
17.09.2020

Dr. Bridgit T. K.
Professor and Head
Dept. of Agronomy
College of Agriculture,
Padannakkad

CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Sugina P., a candidate for the degree of **Master of Science in Agriculture** with major in Agronomy**,** agree that the thesis entitled **"FOLIAR NUTRITION OF COWPEA (*Vigna unguiculata* L.) UNDER DIFFERENT MANAGEMENT SYSTEMS"** may be submitted by Ms. Sugina P., in partial fulfilment of the requirement for the degree.

Dr. Bridgit, T. K.
(Chairman, Advisory Committee)
Professor and Head
Dept. of Agronomy
College of Agriculture, Padannakkad

Dr. Mini P. K.
(Member, Advisory Committee)
Professor and Head
Dept. of Agricultural engineering
College of Agriculture, Padannakkad

Shri. Ratheesh P. K.
(Member, Advisory Committee)
Assistant Professor
Dept. of Agronomy
RARS. Pilicode

Dr. Binitha N. K.
(Member, Advisory Committee)
Assistant Professor
Dept of Soil Science and
Agri. Chemistry
College of Agriculture, Padannakkad

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Dedicated to

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LIST OF ABBREVIATIONS AND SYMBOLS

@	-	At the rate of
Anova	-	Analysis of variance
AICRP	-	All India coordinated research project
B	-	Boron
BCR	-	Benefit cost ratio
ºC	-	Degree Celsius
Ca	-	Calcium
CD	-	Critical difference
Cm	-	Centimeter
cm^2	-	Centimeter square
Cu	-	Copper
$CuSO_4$	-	Copper sulphate
DAS	-	Days after sowing
DTPA	-	Diethylene triamine penta acetate
°E	-	East
EC	-	Electrical conductivity
Fe	-	Iron
$FeSO_4$	-	Iron sulphate
FYM	-	Farm yard manure
G	-	Gram
g cm^{-3}	-	Gram per centimeter cube
g ha^{-1}	-	Gram per hectare
g L^{-1}	-	Gram per litre
H_3BO_3	-	Boric acid
ha^{-1}	-	Per hectare
K	-	Potassium
K_2O	-	Potassium oxide
KAU	-	Kerala Agricultural University

Kg	-	Kilogram
kg $plant^{-1}$	-	Kilogram per plant
kg ha^{-1}	-	Kilogram per hectare
L.	-	Linneaus
L ha^{-1}	-	Litre per hectare
Ltd	-	Limited
M	-	Meter
Mm	-	Milli metre
Mg	-	Magnesium
mg kg^{-1}	-	Milligram per kilogram
mg L^{-1}	-	Milligram per litre
ml $acre^{-1}$	-	Milli liter per acre
Mn	-	Manganese
$MnSO_4$	-	Manganese sulphate
Mo	-	Molybdenum
MOP	-	Muriate of Potash
N	-	Nitrogen
°N	-	North
$(NH_4)_6Mo_7O_{24}.4H_2O$	-	Ammonium molybdate
NS	-	Not significant
OC	-	Organic carbon
P	-	Phosphorus
P_2O_5	-	Phosphorous pentoxide
Ph	-	Soil reaction
POP	-	Package of practices
ppm	-	Parts per million
PPNMU	-	Plant propagation and nursery management unit
ppt	-	Parts per trillion
q ha^{-1}	-	Quintal per hectare

RARS	-	Regional Agricultural Research Station
S	-	Sulphur
SEm (±)	-	Standard error mean
t ha^{-1}	-	Tonne per hectare
var.	-	Variety
Zn	-	Zinc
$ZnSO_4$	-	Zinc sulphate

INTRODUCTION

1. INTRODUCTION

Cowpea is one of the ancient crops known to man. The most popular pulse crop, cowpea [*Vigna unguiculata* (L.) Walp] commonly known in India as *lobia* and in Kerala as *Vellappayar*, belongs to family Leguminosae. Similar to all pulse crops it has the capacity to fix atmospheric nitrogen with the help of *Rhizobium leguminosarum.* It is an annual herb with a strong principal root and many spreading lateral roots in surface soil. Cowpea seed contains carbohydrates (63.6%); proteins (24.8%) especially lysine and tryptophan; fat (1.9%), fiber (6.3%), thiamine (0.00074%), riboflavin (0.0042%) and niacin (0.00281%) (Bressani, 1985). Cowpea, being a multipurpose crop, can be used in many ways such as grain pulse, green vegetable, mulching, livestock feed etc.

Cowpea can adapt to various situations and cultivation methods such as sole cropping, inter-cropping, mixed cropping and in agro – forestry systems. Among the Asian countries, India is the major producer and in India cowpea is mostly cultivated in arid and semi-arid tracts of Karnataka, Tamil Nadu, Maharashtra, Gujarat and Kerala (Tiwari and Shivhare, 2016).

Organic farming has recently emerged as an important practice especially in northern parts of Kerala, in view of the growing demand of safe and healthy food, long term sustainability and pollution associated with indiscriminate use of agrochemicals. While considering the environmental security as a major objective there are many disputes regarding the production potential of crops.

In conventional cultivation practices, excess use of chemicals would leads to environmental pollution whereas in organic cultivation practices, reduction in yield potential is often identified. Hence combined and balanced application of nutrients through organic and inorganic sources is needed and that will help to impart pest and disease resistance and reduces the use of chemical pesticides and ultimately leads to higher productivity.

Humic acid is commonly used for the production of crops and vegetables in greenhouse horticulture. Use of humic acid and fulvic acid enhanced growth, yield and seed weight in cowpea (Kahraman, 2017). It improve soil fertility due to enhanced availability of nutrients, which in turn stimulates the growth, development, yield and quality of plants. Also, the application of different levels of humic acid has resulted in a significant change in agronomic, morphological, physiological, and quality related characteristics of cowpea. (Azarpour *et al*., 2011; Wright and Lenssen, 2013; Motaghi and Nejad, 2014).

Liquid organic formulations *viz., panchgavyam* and *jeevamrutham* are meant to improve the soil properties without degrading the environment by utilizing the locally available material (Amareswari and Sujathamma, 2014). *Jeevamrutham* is an organic solution, prepared from farm wastes such as cattle dung and urine along with the use of other ingredients like jaggery, pulse powder, fertile soil and water; and thus enriched with soil microorganisms (Kabse *et al.,* 2009).

The production and productivity of cowpea is comparatively low due to poor management and pest and disease incidence. In major parts of Kerala, micronutrient deficiencies are severe, which also contribute to low yield in cowpea**.** Micronutrients namely, zinc (Zn), copper (Cu), iron (Fe), manganese (Mn), boron (B), molybdenum (Mo), chlorine (Cl), nickel (Ni), and cobalt (Co) play a major role in the growth and development of plants (Mengel and Kirkby 2001). As per the GPS-aided analysis of more than 2 lakh soil samples, Zn (36.5%) is identified as the major deficient element followed by Fe (12.8%), Cu (4.2%), Mn (7.1%), B (23.4%) and scattered deficiency of Mo has been observed in acid soils (Shukla *et al*., 2018). Deficiency is mostly due to enhanced crop uptake, which is triggered by intensified agricultural practices. Inorganic micronutrient formulations are available to supplement the micronutrients and to alleviate deficiencies in crops. Application of nutrients as foliar spray increases the absorption of nutrients which in turn reflect on growth, yield, and quality of the produce. Research conducted by Anitha *et al*. (2005) under AICRP on arid legumes during kharif seasons found that foliar application of micronutrients like iron and zinc has significant influence on the yield of cowpea.

Kerala Agricultural University has developed a “micro nutrient solution” and a micro nutrient mixture ‘KAU nutrient multi mix –*sampoorna*’ to solve the problem of micro nutrient deficiency in crops.

Hence a field experiment was conducted to assess the direct and indirect effect of liquid organic formulations and micronutrient combinations along with normal recommendations of organic and integrated nutrient management on growth, yield and pest and disease incidence in cowpea with the following objective.

- To evaluate the effect of foliar nutrition under organic and integrated nutrient management practices in cowpea

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study entitled “Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems.” was carried out to understand the effect of organic and inorganic foliar nutrition under different management systems. In this chapter, efforts have been made to review the outline of research carried out by the earlier workers and their findings on the given research theme which would be helpful and are directly linked with the objectives of the study.

The literature on foliar nutrition of organic and micronutrient formulations, their effect on growth and yield of cowpea and also on the chemical properties of plant and soil are reviewed here.

2.1 ORGANIC AND INTEGRATED MANAGEMENT SYSTEMS

2.1.1. Organic nutrient management system

"Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved” (IFOAM, 2005).

The production of organic cowpea helps to increase the scope of export, international market now prefers more organic products to achieve health security. In northern districts of Kerala, which is said to be badly-affected by the use of indiscriminate agro chemicals, organic farming has much more importance. Kasargod has been declared as organic farming district by the Government of Kerala (Business line, 2011). At the same time there are lot of disputes on the production capacity of organic compared to modern cultivation practices.

Excess use of pesticides and inorganic fertilizers has resulted in economic and environmental imbalances. Therefore, organic fertilizers are excellent candidates to reduce the use of agrochemicals and fertilizers in the soil (Singh and Prasad 2011; Daur 2013)

2.1.1.1. Effect of organic manure on growth characters

In cowpea, dry matter production was significantly increased by the application of cow dung and garbage and enhanced the nitrogen fixation in the roots but the size of the nodules were small compared to without organic amendments application (Olayinka *et al*., 1998)

In brinjal application of organic manures such as farmyard manure, neem leaf, vermicompost, neem cake, *Azospirillum* and *Phosphobacterium* enhanced the leaf area index and dry matter production compared to inorganic fertilizer (Rao and Shankar, 2001)

Balachandar *et al* (2003) conducted an experiment on black gram and found that organic amendments improved the nodulation in black gram. Rajkhowa *et al* (2003) also reported similar result.

Plant height and leaf area index of the sorghum plants were enhanced by the application of farmyard manure, *Azospirillum* and PSB alone or in combination (Patidar and Mali, 2004)

Combined application of poultry manure and cattle manure at the rate of 10 kg each enhanced the leaf area of cowpea (Adeoye *et al.*, 2011)

2.1.1.2. Effect of organic manures on yield characters and yield

Application of farmyard manure @ 5 t ha^{-1} enhanced the number of pods per plant (29.80), 1000 grain weight (29.17 g), number of grains per pod (7) , grain yield (301.30 kg ha^{-1}) and stover yield (14.93 q ha^{-1}) in black gram (Singh *et al.*, 2008).

In cowpea, an experiment was conducted by Adeoye *et al*. (2011) to know the growth and yield response of cowpea to poultry and cattle manure and found that application of poultry manure significantly increased the yield followed by mixed application of poultry and cattle manure.

Babaji *et al*. (2011) conducted an experiment in cowpea and found that increased application of farmyard manure increased the pod yield.

Number of pods per plant was significantly increased by the application of cow dung at the rate of 15 and 30 t ha^{-1}in groundnut and the effect was more with 30 t ha^{-1}. In the case of pod yield, cow dung @ 30 t ha^{-1} significantly enhanced the pod yield compared to without application (Musa and Singh, 2015).

2.1.1.3 Effect of organic manure on nutrient content of plant

A work was conducted by Minhas and Sood (1994) to know the effect of inorganics and organics on soil, yield and nutrient uptake by three crops in rotation on an acid alfisol and found that farmyard manure enhanced the uptake of P by potato and maize.

Application of farmyard manure and mineral nutrients showed a positive influence on the uptake of major and micro nutrients by cowpea (Sharma *et al*., 2002)

Application of farmyard manure (5 t ha^{-1}) along with recommended dose of N, P and K enhanced the percentage of N, P, and K in french basil (Anwar *et al.,* 2005).

2.1.1.4. Effect of organic manure on nutrient status of soil

Exchangeable Ca and Mg showed a positive relationship with manure application in cotton based experiment (Olsen *et al.,* 1970)

Application of farmyard manure increased the organic C and total N contents while nitrogenous fertilizer application decreased the content of organic C and total N in soil (Srivastava, 1985)

In rice- cowpea cropping systems of semi-arid tropics, application of farm yard manure produced higher soil organic carbon (0.49%) and total nitrogen content (454 mg kg^{-1}) in soil (Banger *et al*., 2009).

Organic farming enhanced organic C content (0.63%) in soil compared to chemical and integrated farming. In organic farming situation, soil N, P_2O_5, K_2O and S were found to be more after the *kharif* crop and DTPA extractable micronutrients such as Zn, Fe, Mn and Cu after the harvest of *kharif* and *rabi* crops compared to chemical farming (Vidyavathi *et al*., 2012).

Application of farm yard manure at the rate of 10 t ha^{-1} in cowpea increased the organic carbon content of the soil (Kanwar and Sharma, 2014)

2.1.2. Integrated nutrient management system

In most of the tropical countries essential nutrient deficiencies are common and that acts as one of the reasons for low yield of cowpea (Abayomi *et al.*, 2008).

Application of inorganic fertilizer meets the immediate nutrient requirement of plant and increase the yield of crops. Intensive crop production removes excess amount of nutrients from the soil and to sustain the production and soil fertility, nutrients should be added to the soil through inorganic form (Oldham, 2008)

Organic manure application improves the soil quality by promoting the production of enzymes such as dehydrogenase, alkaline phosphatases, β-glucosidase and urease (Liu *et al*., 2010)

2.1.2.1. Effect of integrated nutrient management on plant growth

Potash fertilizers enhanced the plant height and number of leaves per plant in onion (Vachhani and Patel, 1993).

In cowpea, application of N (120 kg ha^{-1}) increased the plant height, number of leaves per plant and number of branches per plant (Paliwal *et al.*, 1999)

Application of phosphorus fertilizer at the rate of 60 kg ha^{-1} increased the vegetative growth in french bean (Singh and Verma, 2002)

Ali *et al*. (2006) conducted an experiment to know the effect of different levels of potash on growth and yield of mung bean varieties and found that potash fertilizers significantly influenced the plant height.

Application of nitrogenous fertilizer 100-110 kg ha^{-1} enhanced the plant height in french bean (Shanke *et al*., 2003)

Plant height, leaf area per plant and number of branches per plant was found to be higher in mineral fertilizer application compared with other organic fertilizers like poultry manure, cattle manure, farm yard manure, pigeon manure and rabbit manure (Ahmed and Elzaawely, 2010).

A work was conducted by Daramy *et al*. (2017) in Ghana found that application of inorganic nitrogen and phosphorous fertilizer did not significantly influenced the growth parameters of cowpea.

2.1.2.2. Effect of integrated nutrient management on yield and yield attributes of plant

Parmar *et al*. (1999) conducted an experiment in french bean and found that number of pods per plant, number of seeds per pod and seed yield was increased by the application of different levels of nitrogen and phosphorus fertilizers

Application of farmyard manure at the rate of 20 t ha^{-1} along with 50% N, P and K content increased the fruit yield in cowpea (Sannigrahi *et al.*, 2001).

Dikhit and Khatik (2002) conducted an experiment at Jabalpur and found that application of 50% recommended dose of fertilizer along with 10 t ha^{-1} farmyard manure significantly increased the grain yield and stover yield in soya bean.

Singh and Verma (2002) conducted an experiment with different levels of fertilizers and found that phosphorous fertilizer enhanced the yield of French bean.

In mungbean, potasic fertilizer enhanced the pods per plant, seeds per pod and seed yield (Ali *et al*., 2006).

Nitrogen fertilizer significantly increased the plant height, number of pods per plant, and pod length in french bean (Shanke *et al.,* 2003)In soyabean, application of recommended dose of fertilizer along with farmyard manure enhanced the seed yield and yield attributes (Maheshbabu *et al*., 2008).

Daramy *et al*. (2017) conducted an experiment and found that application of phosphorous fertilizers enhanced the yield in cowpea.

A work was conducted by Joshi *et al*. in 2016 to study the effects of organic manures on growth and yield of summer cowpea and it was found that application of recommended dose of fertilizer (20: 40: 0 NPK kg ha^{-1}) significantly increased the green pod over different organic sources.

2.1.2.3. Effect of integrated nutrient management on nutrient contents in plant

Application of 30 kg N, 60 kg P and 30 kg K along with farm yard manure in fodder cowpea enhanced the nitrogen and potassium uptake by the plant (Pandya and Bhatt, 2007)

In chickpea, application of 40 kg P_2O_5 ha^{-1} and 20 Kg N ha^{-1} significantly increased the N and P uptake (Gupta *et al*., 2009)

Pandya and Bhatt in 2009 reported that the application of 150% N, P and K +FYM in cowpea increased the potassium and nitrogen content in plant.

A study was conducted by Verma *et al* (2015) to evaluate the effect of nitrogen and phosphorus levels on nutrient uptake by cowpea [*Vigna unguiculata* (L.) Walp] and residual N, P and K content in soil and found that application of N at the rate of 40 kg ha^{-1} and P at the rate of 80 kg ha^{-1} enhanced the N, P and K uptake.

Application of 30 kg N ha^{-1} enhanced the N, P and K contents in cowpea residue while the lowest contents were observed with control (without application) (Daramy *et al.*, 2016)

2.1.2.4. Effect of integrated nutrient management on nutrient status of soil

In a rice-wheat-cowpea cropping system at Pantnagar, it was found that 100% NPK+FYM increased the DTPA extractable Fe, Mn and Cu after 20 years of experimentation (Ram, 2000)

Experiment conducted by Santhosh (2008) revealed that application of 100% recommended dose of fertilizer enhanced the organic carbon, available N, P, K, Ca, Mg, S, Zn, Cu, Fe and Mn content in soil.

Integrated application of organic and inorganic nutrients as 50% NPK + 50% FYM in rice- cowpea cropping system showed a higher soil organic carbon percentage and total nitrogen content in soil (Banger *et al.*, 2009).

Pandya and Bhatt (2009) conducted an experiment to evaluate the effects of fertilizer levels and FYM on yield, nutrient content, soil nutrient status and quality of fodder cowpea and found that 100% NPK + FYM increased the organic carbon and available potassium content of the soil.

Zhao *et al. (*2009) reported that application of farmyard manure combined with chemical fertilizer increased the organic carbon, available N and P content of soil.

2.2. INFLUENCE OF ORGANIC AND INORGANIC FOLIAR NUTRITION ON GROWTH, YIELD AND YIELD ATTRIBUTES, NUTRIENT CONTENT IN PLANT AND NUTRIENT STATUS OF SOIL

2.2.1. Micro nutrient formulations

In plant system micro nutrients are essential for the metabolism of the plant by acting as a constituent of enzymes thus involved in growth and yield of crops (Kazi *et al*., 2012) and reduction in yield was found with deficiencies of these micronutrients (Udode- Haes *et al*., 2012). Wide spread micro nutrient deficiencies are now observed due to the injudicious macro nutrient fertilizer application.

2.2.1.1 Effect of micro nutrients on plant growth

In mung bean, application of Zn at the rate of 300 ppm as foliar spray significantly increased the leaf area per plant (1315.1 cm^2) compared to control (1098.0 cm^2) (Ahmed *et al.*, 2011).

Application of Molybdenum as foliar spray on cowpea significantly increased the number of branches per plant compared to control. This effect was highest in foliar spray of 16 mg kg^{-1} concentration. Molybdenum also had a positive effect on the number of nodules per plant. Application of molybdenum (16 mg kg^{-1} concentration) as foliar spray produced highest number of nodules per plant, fresh weight and dry weight of nodules per plant. Further increase in the concentration reduced the positive effects (Gad and El-Moez, 2013).

Foliar application of micro nutrient mixture of Fe, Zn, Mn, Mo and B at different concentrations (Fe, Zn, Mn, Mo and B at 200, 200, 200, 20 and 20 ppm respectively) on cowpea significantly increased plant height and number of branches per plant. This mixture also enhanced the main root length and number of root nodules per plant compared to control. Spraying of micro nutrient mixture of Fe, Zn, Mn, Mo and B at the rate of 250, 250, 250, 25 and 25 ppm, respectively produced highest leaf area compared to other treatments in cowpea (Eisa and Ali, 2014).

In rice, application of $ZnSO_4$ at the rate of 2.5 ppm along with recommended dose of fertilizer enhanced the dry matter production (18.31 g/ pot) (Rajashekhar *et al.*, 2017).

A work conducted by Jhon (2019) in cowpea revealed that application of micro nutrient mixture solution of Fe, Zn, Cu, B, Mn and Mo at the rate of 2% increased the plant height and dry matter and the effect was significant during flower bud initiation and harvest, when applied at 15 DAS and 30 DAS but it could not produce significant effect on the number of nodules per plant.

2.2.1.2. Effect of micro nutrients on yield and yield attributes of plant

Application of 0.5% zinc sulfate during flowering enhanced the number of seeds per pod in mung bean (Basole *et al.*, 2003).

An experiment was conducted by Anitha *et al.* (2005) under AICRP arid legume during kharif seasons at RARS Pattambi and it was found that combined application of 0.5% $FeSO_4$ and 0.5% $ZnSO_4$ increased the seed yield by 43.09% compared to control in cowpea.

Foliar spray of Zn alone or in combination with Mn along with 1% urea increased the number of pods per plant and seed yield in mung bean (Ezzat *et al.*, 2012).

A work was conducted by Gad and Kandil in 2013 to evaluate the effect of molybdenum and different nitrogen levels on cowpea (*Vigna unguiculata*) and found that application of 100% nitrogen along with 16 ppm molybdenum as foliar spray increased the 100 seed weight.

Foliar application of Fe, Mn and Zn at the rate of 4 ppt produced significantly higher grain yield in *Brassica napus* (Bahrani and Pourreza, 2014).

After conducting an experiment Eisa and Ali (2014) concluded that application of micro nutrient mixture of Fe, Zn, Mn, Mo and B @ 150, 150, 150, 15 and 15 ppm, respectively, significantly increased the number of pods per plant. Further increase in concentration decreased the number of pods per plant in *Vicia faba.*

Foliar application of B at 4 weeks after planting @ 1.5 g L^{-1} enhanced pod weight per plant and improved the pod yield (3.38 t ha^{-1}) compared to control (1.61 t ha^{-1}) (Chatterjee and Bandyopadhyay, 2017).

Application of Fe, Zn and B significantly enhanced the pod weight per plant and the effect was more significant in plots treated with micro nutrient mixture @ 2% in cowpea (EL-Afifi *et al.,* 2016).

A field experiment was conducted to study the effect of B and Zn fertilization on rainfed cowpea and the results revealed that application of B @ 2.0 kg ha^{-1} produced significantly higher pod length compared to other treatment. B and Zn @ 1.5 kg ha^{-1} and 5 kg ha^{-1} respectively along with recommended dose of fertilizers increased biological yield (3.45 t ha^{-1}) and seed yield compared to control (2.47 t ha^{-1}) (Debnath *et al.*, 2018).

2.2.1.3. Effect of micro nutrients on nutrient contents in plant

In common bean (*Phaseolus vulgaris* L.), nitrogen content was increased by the application of Mo @ 40 g ha^{-1} as foliar spray at 25 days after plant emergence by enhancing the nitrogenase and nitrate reductase activity (Vieria *et al*., 1998).

In cowpea, application of Fe at the rate of 2 ppm increased the protein percentage (28.9%) while lowest protein percentage was obtained with B (1 ppm) and Zn (1 ppm) foliar spray (Salih, 2013). He also found that application of Fe, B and Zn increased the total nutrient content in cowpea.

In cowpea, boron (1.5 kg ha^{-1}) and zinc (5.00 kg ha^{-1}) along with recommended dose of fertilizer enhanced B and Zn uptake compared to control. Application of B at the rate of 2.00 kg ha^{-1} along with recommended dose of fertilizer increased higher P and K uptake whereas application of Zn at the rate of 7.5 kg ha^{-1} along with recommended dose of fertilizer enhanced N uptake (Debanath *et al.,* 2018).

2.2.1.4. Effect of micro nutrients on nutrient status of soil

In black gram nutrient mixture of Zn, B, Mo and S at the rate of 5.0 kg ha^{-1}, 1.5 kg ha^{-1}, 0.5 kg ha^{-1} and 40 kg ha^{-1} respectively enhanced the available nutrient status of soil (Poongothai and Chitdeshwari, 2003)

Salih (2013) reported that N content of soil increased with the application of micronutrients as foliar spray or soil application.

In mungbean, application of micro nutrients as a mixture of micro nutrient salts of $Fe_2SO_4.7H_2O$, $MnSO_4.5\ H_2O$, $ZnSO_4.7H_2O$, $CuSO_4.7H_2O$ and Borax along with recommended dose of fertilizer significantly increased the DTPA extractable Fe content in soil (9.50 mg kg^{-1}), DTPA- Zn content (1.10 mg kg^{-1}) and hot water extractable boron content (0.77 mg kg^{-1}) at harvest (Divyashree, 2018).

2.2.2. Organic formulations

2.2.2.1. Jeevamrutham

Microorganisms improve the soil fertility and soil health and that is effectively utilized in *jeevamrutham,* which is rich in microorganisms (Kabse *et al.,* 2009).

2.2.2.1.1. Effect of jeevamrutham on plant growth

Chandrakala in 2008 found that the combination of *beejamruth*, *jeevamrutha* and *panchagavyam* increased the plant growth in chilli.

Jeevamrutham application significantly influenced the drymatter production (96.4 g) in oriental pickling melon (*Cucumis melo var. conomon* L.) (Vemaraju, 2014).

Plant height, number of branches per plant and leaf area were enhanced by the combined application of *jeevamrutha (*1000 L ha^{-1}) and panchagavya (3%) in french bean (Basavaraj *et al.,* 2016).

In cowpea, growth parameters such as plant height, number of branches per plant and leaf area were significantly enhanced by the application of *jeevamrutham* (1000 L ha^{-1}) (Sutar, 2019).

2.2.2.1.2. Effect of jeevmrutham on yield and yield attributes of plant

In tomato, combined application of *beejamruth*, *jeevamrutham* and *panchagavyam* on 75 and 160 DAS increased the yield (Gore, 2010).

In chilli, application of *jeevamrutham* enhanced the fruit yield compared to treatment without *jeevamrutham* and the increase was about 7.98- 26.20 per cent (Boraiah, 2013).

Vemaraju (2014) conducted an experiment and revealed that application of *jeevamrutham* increased the number of fruits per plant (3.83), fruit weight (2.5kg) and yield in oriental pickling melon (30.33 t ha^{-1}).

Sutar (2019) found that *jeevamrutham* at the rate of 1000 L ha^{-1} had a positive influence on cowpea yield.

In sweet corn, cob weight per plant, green cob and fodder yield was increased by the application of *jeevamrutham* at the rate of 600 L ha^{-1} (Safiullah *et al.*, 2018)

2.2.2.1.3. Effect of jeevamrutham on nutrient contents in plant

Palekar (2006) found that application of *jeevamrutham* increased the availability and uptake of nutrients.

Combined application of *beejamruth, jeevamrutham* and *panchagavyam* increased the N, P and K content in plants (Gore, 2010)

Significantly higher content of nitrogen, phosphorus and potassium was observed with the application of *jeevamrutham* at the rate of 1000 L ha^{-1} (Sutar *et al*., 2017).

2.2.2.1.4. Effect of jeevamrutham on nutrient status of soil

Application of *jeevamrutham* increased the phosphorous content in soil when compared with recommended dose of fertilizer application (Ninan *et al*., 2013).

In oriental pickling melon (*Cucumis melo var. conomon* L.), application of *jeevamrutham* significantly increased the available N content (489 kg ha^{-1}) Vemaraju, 2014).

Combined application of *bijamruth, jeevamrutham*, vermicompost and *panchagavya* enhanced the available nitrogen content in soil (Rao *et al*., 2015).

Application of 5% *jeevamruth* along with recommended dose of fertilizer in okra enhanced the available potassium content in soil after the harvest of the crop (Borkar, 2019).

2.2.2.2. Humic acid

Humic acids are heterogeneous compounds consisting of both hydrophilic and hydrophobic functional groups. The hydrophilic groups of humic acid attract water molecule and increases the water retention capacity of soils (Stevenson, 1994).

Application of humic acid has direct and indirect effects on plant growth. Humic acid indirectly enhances the nutrient enrichment of the soil, microbial population, cation exchange capacity and also improves the soil structure. Direct effects are mainly achieved through various biochemical actions exerted at the cell wall, membrane or cytoplasm and mainly of hormonal nature (Varanini and Pinton, 2001; Chen *et al.,* 2004).

Humic acid increases the fertility status of the soil by enhancing nutrient availability of the soil and increase the growth, yield and quality of produce. It also improves the physiological and morphological characteristics of plant (Azarpour *et al*., 2011; Wright and Lenssen, 2013; Motaghi and Nejad, 2014).

2.2.2.2.1. Effect of humic acid on plant growth

Malik and Azam (1985) studied the effect of humic acid on wheat (*Triticum aestivum*) seedling growth at Faisalabad, Pakistan and found that shoot length was significantly increased by the application of humic acid at the rate of 54 mg L^{-1}.

After conducting an experiment on tomato and cucumber Atiyeh *et al.* (2002) concluded that humic acid application significantly increased the growth of tomato and cucumber when all plant nutrients were supplied adequately.

Application of humic acid at the rate of 1000 mg kg^{-1} produced significantly highest shoot and root fresh weight and dry weight (Tu¨rkmen *et al.,* 2004).

In snap bean, application of humic acid significantly enhanced the vegetative characters except number of branches per plant (El-Bassiony *et al.,* 2010).

In cowpea foliar application of 100 ppm humic acid produced highest leaf area index and lowest leaf area index was found in control. It also enhanced the total dry weight of plant compared to control (Motaghi and Nejad, 2014).

Rezazadeh *et al*. (2014) studied the effect of different levels of humic acid on components of biological nitrogen fixation in cowpea cultivars and found that application of humic acid (150 ppm) increased number of nodules per plant significantly compared to control.

A work conducted by Sani (2014) to study the foliar application of humic acid on plant height in canola and observed that humic acid application increased the plant height and highest was found at 2% concentration. The lowest plant height was recorded in control.

2.2.2.2.2. Effect of humic acid on yield and yield attributes of plant

Application of humic acid at the rate of 2 g L^{-1} increased the pod weight per plant in snap bean compared to other treatments (El-Bassiony *et al*., 2010).

A work was conducted by Azarpour *et al.* (2011) conducted an experiment and found that seed yield of cowpea significantly enhanced by the application of 50 mg L^{-1} humic acid as foliar spray.

Humic acid as soil application and foliar spray enhanced the grains per plant in soyabean (Waqas *et al.*, 2014).

Application of humic acid increased the number of pods per plant compared to control and the highest was observed in plots treated with 150 kg ha^{-1}. Number of pods per plant increased from 8.67 to 18.33 while an increment on seeds per pod was from 8.33 to 10.00. It also enhanced the 1000 seed weight to 199.29 g compared to plot without humic acid application (156.56 g) (Kahraman, 2017).

2.2.2.2.3. Effect of humic acid on nutrient contents in plant

An experiment was conducted by Sharif *et al.*, (2002) on wheat crop and found that plant accumulation of Fe and Cu was significantly influenced by the application of humic acid.

Application of humic acid at the rate of 20 kg ha^{-1} alone or in combination with foliar spray enhanced the nutrient uptake in rice (Bama and Selvakumari (2005).

Application of humic acid at the rate of 20 kg ha^{-1}increased the uptake of N, P, K, Fe and Zn in tomato (Tenshia and Singaram, 2008).

Application of humic acid as foliar spray at the rate of 0.1% and 0.2% increased the N, P and K content in faba bean seeds (El-Ghamry *et al.*, 2009).

In corn plants, application of humic acid as foliar nutrition and soil application significantly increased the N, P and K uptake by plants (Khaled and fawy, 2011).

El-Hak *et al.* (2012) conducted an experiment in Peas (*Pisum sativum* L.) and found that application of humic acid at the rate of 2 g L^{-1} enhanced the percentage of N, P and K of dry seed.

2.2.2.2.4. Effect of humic acid on nutrient status of soil

Chen *et al.* (1999) reported that application of humic acid enhanced the availability of micro nutrients such as Fe, Cu, Zn and Mn.

An experiment was conducted by Sharif *et al.*, (2002) on wheat crop and was found that application of humic acid increased the soil concentration of Zn, Mn and Cu.

Combined application of fertilizers and humic acid in onion increased the available N, P and K content in soil (Sangeetha *et al.*, 2006).

2.2.2.3. *Fulvic acid*

Foliar application of fulvic acid increased the bio availability of nutrient and its uptake, stimulated the plant metabolism and regulated the transaminase and invertase activity (Pascual *et al*. 1999).

The presence of more number of carboxyl groups imparted high acidity as well as cation exchange capacity for fulvic acid (Bocanegra *et al.* 2006) and it has the strong retention capacity in the soil solution (Zimmerli *et al.,* 2008).

2.2.2.3.1. Effect of fulvic acid on plant growth

Fulvic acid and humic acid mixed with sand in pot experiment decreased the number of nodules per plant but the weight per 10 nodules increased with the increasing concentration of fulvic and humic acid (Tan and Tantiwiramanond, 1983).

Application of fulvic acid as foliar spray along with 100% nitrogen through poultry manure in soyabean significantly increased the plant height at 30 DAS (32.6 cm) and 60 DAS (84.5 cm) (Kadam *et al.,* 2010).

Application of fulvic acid at the rate of 0.8 g L^{-1} in tomato increased the fresh and dry weight of root and shoot while the least was observed in 1.6 g L^{-1} (Suh *et al*., 2014).

Abdel-Baky *et al*. (2019) conducted an experiment in some faba bean cultivars and the results revealed that application of fulvic acid at the rate of 9 g L^{-1} increased plant height significantly at 75, 90 and 105 DAS. The leaf area index was significantly increased by fulvic acid application (3.15 and 3.36 at 90 DAS and after 105 DAS respectively) compared to control (2.01 and 2.92 at 90 DAS and after 105 DAS respectively). It also enhanced the number of branches per plant from 3.64 to 5.61 and 4.50 to 5.82 at 75 DAS and at 90 DAS.

2.2.2.3.2. Effect of fulvic acid on yield and yield attributes of plant

Khalil *et al.* (2011) conducted an experiment and revealed that application of fulvic acid influenced the yield in cucumber.

Fulvic acid application increased the number of fruits per plant. Fulvic acid at the rate of 0.8 g L^{-1} produced highest weight of fruits per plant compared to control whereas higher concentration of 1.1 g $L^{-1}$and 1.6 g L^{-1} reduced the effect in tomato (Suh *et al.*, 2014).

In cowpea. fulvic acid application @ 150 kg ha^{-1} produced higher seed yield (2009.42 kg ha^{-1}) while lowest yield was observed in control (Kahraman, 2017).

Test weight was significantly increased by the application of fulvic acid. Fulvic acid application @ 3.0 g L^{-1} produced higher test weight of 108.82 g in *Vicia faba* compared to control which recorded the lowest yield (86.83 g). It also increased the pod yield. (Al-jana *et al.*, 2018).

Fulvic acid application as foliar spray at the rate 9 g L^{-1} significantly increased the yield and yield attributes in faba bean compared to untreated plants. It also enhanced the pod weight per plant (68.27 g) significantly compared to control (50.90 g) (Abdel-Baky *et al.*, 2019).

2.2.2.3.3. Effect of fulvic acid on nutrient content in plant

Application of fulvic acid and humic acid enhaced the nutrient uptake in finger millet, maize and cowpea (Santhy *et al*., 2001).

Application of 100% N in the form of vermicompost along with fulvic acid sprays increased the N, P and K uptake (92.25 kg ha^{-1}, 49.61 kg ha^{-1} and 153.62 kg ha^{-1}) in soybean (Kadam *et al.*, 2010).

Application of fulvic acid influenced P, Ca, and S contents in tomato leaves. Fulvic acid application at the rate of 1.1 g L^{-1} enhanced the P content in leaves. In leaves, fulvic acid application @ 0.8 and 1.1 g L^{-1} increased the Ca and S content and had a positive effect on Mg, Fe, and Zn content though the effect was not significant (Suh *et al.*, 2014).

2.2.2.3.4. Effect of fulvic acid on nutrient status of soil

A study conducted by Pawar (2004) found that application of different composts along with fulvic acid in tomato significantly increased organic carbon (0.57 %), available N (202 kg ha^{-1}), P (22 kg ha^{-1}) and S (22 kg ha^{-1}) in soil.

Kadam (2006) studied the effect of organic nitrogen sources and fulvic acid application on yield and quality of soybean in inceptisol and revealed that available N, P, K, Fe, Zn and Cu was maximum in soil applied with poultry manure (1.7 t ha^{-1}) along with two fulvic acid sprays.

2.3. FOLIAR FERTILIZATION OF NUTRIENTS AND GROWTH OF CROPS

Nutrients are mostly absorbed through roots and translocated through stem. Evidences are available that the nutrients can be absorbed through leaves also. Cuticle covering on the leaf surface make the leaf structure different from the roots. The cuticle is permeable to organic, inorganic anions and undissociated molecule but the penetration is dependent on the kind of charge, adsorbability, and ion radius of the molecule (Franke, 1967).

In most of the case foliar applied nutrients passes through the leaf in the order cuticular wax, the cuticle, the cell wall, and the membrane (Middleton and Sanderson, 1965; Franke, 1967) whereas inorganic ions may pass through the space between the layers (Dybing and Currier, 1961). Researches have shown that nutrients can be absorbed through stomata (Eichert *et al*., 1998; Eichert and Burkhardt, 2001) and is the easiest transmission method (Burkhardt *et al.* 1999).

Immobilization of the micro nutrient is the major limitation which requires repeated spraying after each new flush of growth appears, to get the positive effects (Papadakis *et al.*, 2007). A work conducted by Gettier *et al*. (1985) in soyabean found that two foliar sprays are required within the growing season for Mn fertilization. For immobilized nutrients foliar fertilization is effective and economic.

Foliar application should be done, when the plant is not in water stress or water logged condition and should be applied in cool environmental condition and turgid plant condition (Denelan, 1988; Girma *et al*. 2007). In windy days 3- 4 hours are required for the absorption of the nutrient. Application of foliar nutrition at proper time is more important and use of sticky material enhances the efficiency. The most critical period for foliar fertilization is the nutrient stress condition, which occurs in the plant under active vegetative growth (Cantisano, 2000).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An investigation entitled "Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems" was carried out at College of Agriculture, Padannakkad and Regional Agricultural Research Station (RARS) farm, Pilicode during 2019-20 to study the effect of foliar nutrition under organic and integrated nutrient management practices in cowpea [*Vigna unguiculata* (L.)].

Relevant details about materials used, methods adopted and practices employed at the time of research are presented in this chapter.

3.1. MATERIALS

3.1.1. Location

The location of the experimental site was the D block of Regional Agricultural Research Station (RARS), Pilicode. Geographically, the site is situated at 12º 12' N latitude and 75º 10' E longitude and at an altitude of 15 m above mean sea level. The region has a warm tropical humid climate.

3.1.2. Soil type

The type of soil present in the experimental site is red loam. The land nearer to the experiment site was used for cassava cultivation, but the land used specifically for this experiment was uncultivated area. Initially, the field was completely infested with weeds. The physico-chemical properties of the soil is given in Table 1.

3.1.3. Climate

The weather parameters were recorded for the standard weeks during the crop period and are furnished in Appendix I and Fig. 1. The abstract of weather data is given in Table 2.

Table 1. Physico- chemical properties of soil

Particulars	**Content**	**Method used**
Physical properties		
Bulk density (g cm^{-3})	1.33	Undisturbed core sample (Black *et al.*, 1965)
Particle density (g cm^{-3})	2.45	Pycnometer (Black *et al.*, 1965)
Chemical properties		
pH	4.37	1:2.5 soil water suspension- pH meter (Jackson, 1958)
EC	0.124	Conductivity meter
Organic carbon (%)	0.89	Walkley and Black (1934)
Organic matter (%)	1.53	
Available N (kg ha^{-1})	250.00	Subbiah and Asija (1956)
Available P(kg ha^{-1})	42.30	Jackson (1958)
Available K(kg ha^{-1})	280.01	Pratt (1965)
Available Ca (mg kg^{-1})	170.00	Jackson (1958)
Available Mg (mg kg^{-1})	78.00	Jackson (1958)
Available S (mg kg^{-1})	5.62	Black *et al.* (1965
Available Zn (mg kg^{-1})	1.69	Emmel *et al.* (1977)
Available Fe (mg kg^{-1})	10.40	Sims and Johnson (1991)
Available Cu (mg kg^{-1})	0.65	Emmel *et al.* (1977)
Available Mn (mg kg^{-1})	22.0	Sims and Johnson (1991)

Table 2. The abstract of weather data during the experimental period (October 2019-December 2019)

Weather element	Range	Mean
Maximum temperature (^oC)	27.47 - 32.69	31.01
Minimum temperature (^oC)	22.10 - 23.79	23.16
Total rainfall (mm)	-	523
Total rainy days	-	13
Relative humidity (%)	74 - 92	79.97
Total evaporation (mm)	-	247.94

3.1.4. Season

The field experiment was conducted during rabi season from October to December, 2019.

3.1.5. Crop and variety

Cowpea var. PGCP 6 was used for the field experiment. It is an early maturing high yielding, bush type variety with short and semi erect nature developed from IT98K -889-1 following pure line selection. The plant has light green foliage and purple coloured flower. The crop attains 50% flowering at 40-45 days after planting and within 65-70 days, maturity. Pod is dark green in colour with a length of 16-18 cm and contains 14-16 brown coloured seeds per pod. The seeds are smooth, kidney to oval shaped with medium size. Crop has high level of resistance to yellow vein mosaic and bacterial blight and also higher level of tolerance to pests such as aphid, thrips, and bruchid. Yield potentiality of crop is 1800-2000 Kg ha^{-1} under good management practices and favourable condition.

3.1.6. Foliar application

Inorganic and organic foliar nutritions *viz.* '*sampoorna*- KAU multi mix', micro nutrient solution, *jeevamrutham*, humic acid and fulvic acid were included in the study.

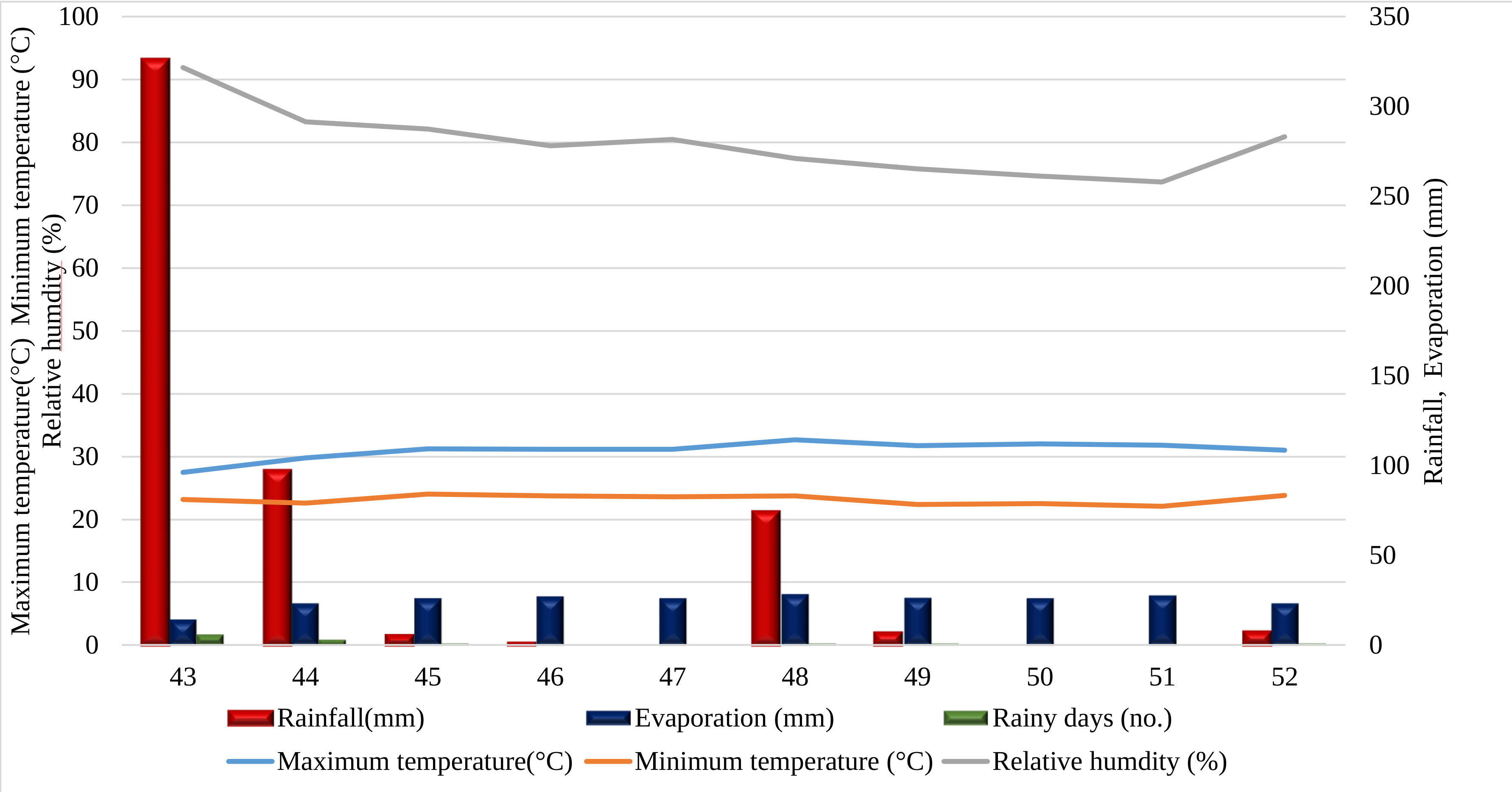

Fig. 1 weather parameters prevailed during the cropping season in standard weeks

3.1.6.1. 'Sampoorna – KAU multi mix'

In order to mitigate the micronutrient deficiencies multi nutrient mixture '*sampoorna* – KAU multi mix' was developed by Regional Agricultural Research Station (RARS), Pattambi under Kerala Agricultural University for rice, banana and vegetables. Among them, *sampoorna* mixture prescribed for vegetables was used in this experiment. '*sampoorna* – KAU multi mix' contains zinc (3.5-5%), copper (0.3-0.5%), boron (2.5-3.5%), molybdenum (0.01-0.02%), iron (<0.2%) and manganese (<0.2%).

3.1.6.2. Micro nutrient solution

The micro nutrient solution formulated at College of Agriculture, Padannakkad under Kerala Agricultural University is a combination of two solutions, solution A and solution B and for different crops. This was standardized for cowpea by Jhon (2019) and was used in the experiment. One litre of solution A contains $ZnSO_4.7H_2O$ (50 g), $CuSO_4.5H_2O$ (20 g), $FeSO_4.7H_2O$ (10 g), H_3BO_3 (10 g), $MnSO_4.H_2O$ (0.5 g) and $(NH_4)_6Mo_7O_{24}.4H_2O$ (0.5 g) and solution B contains an organic chelate.

3.1.6.3. Organic formulations

Jeevamrutham was prepared by mixing 500 g cow dung, 500 ml cow urine, 100 g green gram which was soaked overnight and ground, 25 g undisturbed soil 100 ml coconut water and 10 L water. After thorough mixing, mixture was kept for 3 days. Stirring was done twice a day in clock wise direction (Rameeza, 2016). *Jeevamrutham* contains N (0.077 - 0.1 %), P (0.016 - 0.017 %), K (0.012- 0.019 %), Fe (29.7 – 282 ppm), Zn (1.27- 4.29 ppm), Cu (0.38 – 1.58 ppm) Mn (1.8 -10.7 ppm) (Sreenivasa *et al*., 2011) *Jeevamrutham* (100%) as foliar nutrition was purchased from Kerala Agricultural University Sales& Information Centre (A unit under PPNMU Vellanikkara) and was used for the study.

Fulvic acid, extracted from the soil was collected from Dscign Biosys Pvt. Ltd., Bangalore and was used for the study. Powder formulation of fulvic acid contains carbon (5.9%), hydrogen (3.35%), oxygen (44.75%), nitrogen (0.75%) and sulphur (0.25%).

Humic acid was procured from Tropical Agro, Chennai. The product was extracted from humic substances.

Table 3. Chemical composition/ Characteristics of organic formulations

Organic formulations	Chemical composition/ Characteristics
Jeevamrutham	N (0.077 - 0.1%) P (0.016 - 0.017 %) K (0.012- 0.019 %) Fe (29.7 – 282 ppm) Zn (1.27- 4.29 ppm) Cu (0.38 – 1.58 ppm) Mn (1.8 -10.7 ppm)
Humic acid	Extracted from humic substance
Fulvic acid	C (5.9%) H (3.35%) O (44.75%), (0.75%) S (0.25%).

3.1.7. Manures and Fertilizers

Well decomposed FYM containing 0.5 per cent of N, 0.2 per cent of P_2O_5 and 0.5 per cent of K_2O was used for this experiment. The fertilizers used for the experiment were urea containing 46 % N, rajphos containing 20% P_2O_5 and MOP containing 60 % K_2O.

3.2. DESIGN AND LAYOUT

The details of the experiment and treatments are given below.

Design	:	Factorial RBD (2 x 6)
Replication	:	3
Crop	:	Cowpea
Variety	:	PGCP 6
Plot size	:	3 m x 3 m
Spacing	:	30 cm x 25 cm
Location	:	RARS Pilicode
Season	:	Rabi 2019

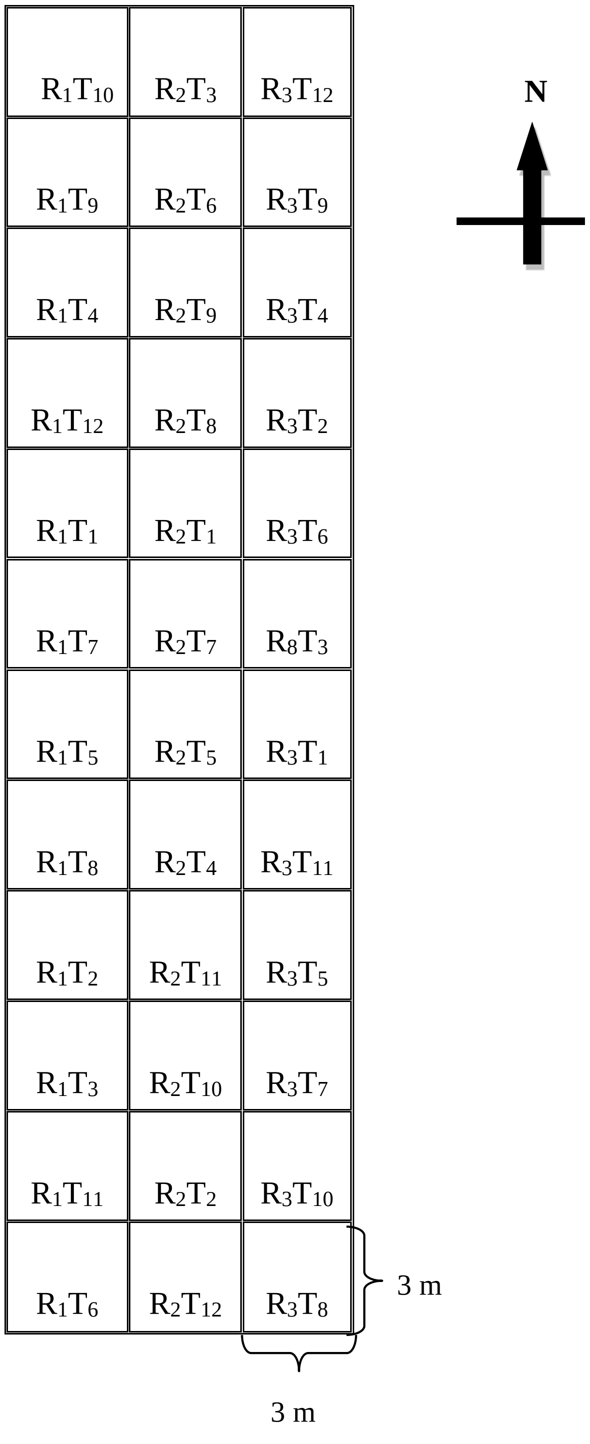

Fig. 2. Layout of the experimental plot

3.2.1 Treatments

3.2.1.1. Management systems – 2 nos.

S_1 – KAU Adhoc organic POP Recommendations (2017)

S_2 – KAU POP Recommendations (2016)

3.2.1.2. Foliar application – 6 nos.

F_0 – Without foliar application (control)

F_1 – *Sampoorna*

F_2 – Micronutrient solution

F_3 – *Jeevamrutham*

F_4 – Humic acid

F_5 – Fulvic acid

3.2.1.3. Treatment details

T_1 – KAU Adhoc organic POP Recommendations (S_1F_0)

T_2 – KAU Adhoc organic POP Recommendations+ *Sampoorna* (S_1F_1)

T_3 – KAU Adhoc organic POP Recommendations+ Micronutrient solution (S_1F_2)

T_4 – KAU Adhoc organic POP Recommendations+ *Jeevamrutham* (S_1F_3)

T_5 – KAU Adhoc organic POP Recommendations+ Humic acid (S_1F_4)

T_6 – KAU Adhoc organic POP Recommendations+ Fulvic acid (S_1F_5)

T_7 – KAU POP Recommendations (S_2F_0)

T_8 – KAU POP Recommendations + *Sampoorna* (S_2F_1)

T_9 – KAU POP Recommendations + Micronutrient solution (S_2F_2)

T_{10} – KAU POP Recommendations + *Jeevamrutham* (S_2F_3)

T_{11} – KAU POP Recommendations + Humic acid (S_2F_4)

T_{12} – KAU POP Recommendations + Fulvic acid (S_2F_5)

3.3. FIELD EXPERIMENT

3.3.1. Land preparation

The land was ploughed uniformly, levelled and the stubbles were removed and experimental plots were laid out as per the technical programme. Each plot was prepared with a height of 30 cm, length 300 cm and breadth 300 cm. A spacing of 50 cm was given between the plots. Based on the KAU package of practices recommendations lime was applied at the rate of 250 kg ha^{-1}. Soil samples were collected from the experimental plots for basic analysis. Individual plots were levelled uniformly before sowing

3.3.2. Seeds and sowing

The seeds of cowpea var. PGCP 6 procured from the Regional Agricultural Research Station, Pattambi were sown at the rate of 60 kg ha^{-1} with a spacing of 30 cm between the rows and 25 cm between the plants.

3.3.3. Application of manures and fertilizers

Farmyard manure was applied uniformly to all the plots @ 20 t ha^{-1} as basal dose and well mixed with top soil. In addition, in plots T_1, T_2, T_3, T_4, T_5 and T_6, farmyard manure (2 t ha^{-1}) and rock phosphate at the rate of 100 kg ha^{-1} was applied as nutrient supplements based on KAU adhoc organic POP Recommendation (2017). Fertilizers like urea, rajphos and MOP were applied in plots T_7, T_8, T_9, T_{10}, T_{11} and T_{12} based on KAU package of practice recommendation (2016) at the rate of 20:30:10 kg N: P_2O_5: K_2O ha^{-1}. Nitrogen was applied in two equal doses, first as basal dose and second dose at 15 DAS. Phosphorus and potassium were applied full as basal in all the plots.

3.3.4. Treatment application

Multi nutrient mixture '*sampoorna*- KAU multi mix' at the rate of 5 g L^{-1} and micronutrient solution (2 %) were applied as foliar spray at 15, 30, and 45 DAS. Fulvic acid at the rate of 2 g L^{-1}, humic acid at the rate of 250 ml ha^{-1} and *jeevamrutham* (100 %) (500 L ha^{-1}) as foliar spray were applied at weekly interval up to 45 DAS

3.3.5. Irrigation and after cultivation

Irrigation and hand weeding was done at regular intervals throughout the growth period. Initial weeding was done at 7 DAS, and continued at fortnightly intervals. Due to the rain fall obtained, immediately after sowing, irrigation was not given. In order to avoid waterlogging, drainage channels were provided. After that irrigation through hose was given at weekly intervals.

3. 3. 6. Plant protection

Nimbicidine was sprayed in the plots T_1, T_2, T_3, T_4, T_5 and T_6 at the rate of 5 ml L^{-1} while thiamethoxam was applied in plots T_7, T_8, T_9, T_{10}, T_{11} and T_{12} at the rate of 0.2 g L^{-1} to control aphids. Carbendazim (12%) + mancozeb (63%) was drenched at the rate of 2 g L^{-1} against sclerotium stem rot in plots T_7, T_8, T_9, T_{10}, T_{11} and T_{12}. In plots T_1, T_2, T_3, T_4, T_5 and T_6 *Trichoderma viride* was applied at the rate of 2 g L^{-1} to control sclerotium stem rot after the appearance of symptoms.

3.3.7. Harvesting

Fully matured pods were harvested for grain purpose. First harvesting was done at 60 DAS. Three harvests were obtained from the field. After harvesting, the pods were dried, threshed and cleaned to obtain the seeds.

3.4. OBSERVATIONS

3.4.1. Biometric observations

Biometric observations were taken during flowering and harvesting stage. The major biometric observations included are plant height (cm), number of branches per plant, number of nodules per plant, leaf area (cm^2) and total dry matter production (kg ha^{-1}).

3.4.1.1. Plant height

The height of the plant was taken from the node of the cotyledon to the tip of the main shoot of the plant. Plant height of five tagged plants were measured and average was calculated at flowering and at harvesting stage and expressed as plant height in cm.

3.4.1.2. Number of branches per plant

Number of branches per plant was taken at flowering and at harvesting stage. Average of five tagged plant were calculated and recorded as number of branches per plant.

3.4.1.3. Number of nodules per plant

Number of nodules per plant was recorded at 30 DAS. From each plot, five plants were randomly selected leaving the border plants. After uprooting the plants, the roots were immediately washed and removed of soil particles. Average value of the five plants was recorded as observation.

3.4.1.4. Leaf area

Area: weight method was used to calculate the leaf area. Five leaves from each plot were collected and plotted on a graph paper and the area was calculated. Dry weight of this five leaves were recorded after drying it in the oven. Similarly dry weight of all leaves were calculated and from that, leaf area was estimated.

3.4.1.5. Total dry matter

Five plants, marked for taking observations from each plot were uprooted for estimating total dry matter production. Fresh weight was recorded immediately after uprooting the plant. Uprooted plants were allowed for shade drying followed by oven drying at a temperature of 60°C. The dry weight was recorded and was used for calculating total dry matter produced and expressed in kg ha^{-1}basis.

Plate. 1. Field preparation

Plate. 2. Field layout and lime application

Plate. 3. Sowing

Plate. 4. Two leaf stage

Plate. 5. Flowering stage

Plate. 6. Harvesting stage

Plate. 7. Crop at 15 DAS

Plate. 8. Crop at 30 DAS

Plate. 9. Foliar spray on cowpea

Plate. 10. Harvesting

Plate. 11. General view of the experimental plot

3.4.2 Yield and yield attributes

Yield and yield attributes such as number of pods per plant, number of seeds per pod, pod weight per plant (g), test weight (100 seed weight), pod yield (kg ha^{-1}) and seed yield (kg ha^{-1}) were recorded at harvesting stage.

3.4.2.1. Number of pods per plant

Number of pods per plant was taken from five index plants and the average was recorded as the observation.

3.4.2.2. Number of seeds per pod

To find the number of seeds per pod, ten pods from five index plants were selected. From each pod, number of seeds were counted and the average was taken as the number of seeds per pod.

3.4.2.3. Pod weight per plant

Five index plants were selected from each plot. Pods from the index plants were collected separately and weighed. Average value of the index plants was taken as the pod weight per plant.

3.4.2.4. Test weight (100 seed weight)

From the seeds were threshed and cleaned and ten lots each containing 100 seeds from each plot were weighed and the average was recorded as test weight.

3.4.2.5. Pod yield

Total pod yield from each plot was calculated by adding the weight of the pods obtained from the three harvests and expressed in kg ha^{-1}.

3.4.2.6. Seed yield

Pods obtained from the plots were threshed and cleaned. Seeds obtained from each harvests were added and expressed in kg ha^{-1}.

3.4.3. Plant analysis

3.4.3.1. Nutrient content of plant

Five plants were selected randomly and uprooted from each plot. The uprooted plants were allowed for shade drying followed by oven drying at a temperature of 60℃. Dried sample grinded and made into a fine powder. Using the standard procedure as given in the Table 4 samples were analyzed for N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn at flowering and at harvesting stage.

3.4.3.2. Nutrient content of grain

Sampling was done from each plot. After threshing and sieving grains were dried in the oven at a temperature of 60 ℃ till a constant weight and powdered to analyze the nutrients such as N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn using standard procedures given in Table 4.

3.4.3.3. Nutrient uptake

3.4.3.3.1. Nutrient uptake of plant

Nutrient uptake by the plant was calculated by multiplying the nutrient content of the plant and dry matter production for nutrients such as N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn and was expressed in kg ha^{-1}.

3.4.3.3.2. Nutrient uptake of grain

The uptake of nutrients such as N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn by grain was calculated by multiplying the nutrient content of the grain and grain dry matter production

3.4.4. Soil analysis

Soil analysis was carried out before and after the field experiment as per the standard procedures given in Table 5.

3.4.4.1. Soil analysis before the experiment

A composite soil sample was collected from the field before the experiment. To obtain a sample, small portions of the soils were collected from ten well distributed spots using sampling tools. After mixing the samples, quartering was done to minimize the bias of the sample to a particular site and to reduce the soil sample size. Soil was air dried and were allowed to pass through 2 mm sieve and analysis of organic carbon, available N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn were done.

3.4.4.2 Soil analysis after the experiment

After the experiment soil samples were collected from each plot. To get a composite sample from a single plot, soil samples from five locations were collected and mixed. Air dried samples were allowed to pass through 2mm sieve and stored. Analysis for organic carbon, available N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn was carried out using standard procedure given in Table 5.

3. 4. 5. Diseases and pest incidence

During the entire crop duration, there were some incidence of pest and diseases, even though not severe. Aphid was the pest during the initial stages of growth and was effectively controlled using *Nimbicidine* at the rate of 5 ml L^{-1} in organic plots and *thiamethoxam* in inorganic plots at the rate of 0.2 g L^{-1}. Leaf roller and pod borer were the lepidopteran pest, which were controlled by hand picking. *Sclerotium* stem rot was observed in cowpea plants at harvesting stage, which was effectively controlled by drenching with Carbendazim (12%) + mancozeb (63%) in inorganic plots at the rate of 2 g $L^{-1}$and *Trichoderma viride* at the rate of 2 g L^{-1} in organic plots.

3.4.6. Economic analysis

3.4.6.1. Gross return

Gross return was calculated by using the market price of cowpea seed grain. Marketable yield was used to calculate the gross return instead of total yield

3.4.6.2. Net return

The cost of cultivation is computed using price of each input such as seed, fertilizer etc. at the time of experiment. The cost of cultivation is calculated for one ha. Net return is calculated by subtracting the cost of cultivation from gross return.

3.4.6.3. BCR

Benefit cost ratio is the indicator used in benefit cost analysis and is the ratio of gross return and cost of cultivation

$$BCR = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

3.4.7. Statistical analysis

The data obtained from the field experiment was statistically analyzed for drawing conclusions (Panse and Sukhatme in 1985)

Table 4. Analytical method followed for plant analysis

Sl. no.	Parameter	Methods	Reference
1.	Total N	Modified kjeldhal digestion method	Jackson (1958)
2.	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3.	Total K	Flame photometry	Jackson (1958)
4.	Total Ca	Atomic absorption spectroscopy	Issac and Kerber (1971)
5.	Total Mg	Atomic absorption spectroscopy	Issac and Kerber (1971)
6.	Total S	Turbidimetric method	Bhargava and Raghupathi (1995)
7.	Total Zn	Atomic absorption spectroscopy	Emmel *et al*. (1977)
8.	Total Fe	Atomic absorption spectroscopy	Piper (1966)
9.	Total Cu	Atomic absorption spectroscopy	Emmel *et al*. (1977)
10.	Total Mn	Atomic absorption spectroscopy	Piper (1966)

Table 5. Analytical method followed for soil analysis

Sl. no.	Parameters	Method	Reference
1	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
2	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
3	Available P	Bray extraction and photoelectric colorimetry	Jackson (1958)
4	Available K	Flame photometry	Pratt (1965)
5	Available Ca	Atomic absorption spectroscopy	Jackson (1958)
6	Available Mg	Atomic absorption spectroscopy	Jackson (1958)
7	Available S	Turbidimetric extraction	Black *et al.* (1965)
8	Available Fe	Atomic absorption spectroscopy	Sims and Johnson (1991)
9	Available Mn	Atomic absorption spectroscopy	Sims and Johnson (1991)
10	Available Zn	Atomic absorption spectroscopy	Emmel *et al.* (1977)
11	Available Cu	Atomic absorption spectroscopy	Emmel *et al.* (1977)

RESULTS

4. RESULTS

The field experiment entitled "Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems" was conducted at College of Agriculture Padannakkad and Regional Agricultural Research Station, Pilicode. The results obtained through the experiment was statistically analyzed and presented below.

4.1. BIOMETRIC OBSERVATIONS

Biometric observations such as plant height (cm), number of branches /plant, number of nodules/plant, leaf area (cm^2) and total dry matter (kg ha^{-1}) were taken during flowering and at harvesting stage and given in Table 6 and Table 7.

4.1.1. Plant height

The plant height was taken during flowering and at harvesting stage. The effect of management systems, foliar nutrition and their interaction effects are presented in Table 6. Effect of management systems on plant height was not significant both at flowering and at harvesting stages.

Foliar application of nutrients on plant height was not significant at flowering stage but was significant at harvesting stage. At harvesting stage, the treatment F_5 where fulvic acid was applied as foliar spray recorded maximum plant height (71.63 cm), followed by F_1 where *sampoorna* was applied as foliar nutrition (67.18 cm) and these treatments were on par and significantly superior to all other treatments.

Interaction effects of foliar nutrition and management systems were significant on plant height at flowering and at harvesting stage. At flowering stage S_2F_2, S_2F_1, S_1F_1, S_1F_3, S_2F_0, S_2F_5, S_2F_4 and S_1F_5 were on par and significantly superior to other treatment combinations. At harvesting stage, application of organic POP along with fulvic acid (S_1F_5) significantly enhanced the plant height which was on par with S_2F_1 (KAU POP with *sampoorna)* and significantly superior to other treatment combinations.

4.1.2. Number of branches per plant

Number of branches per plant was observed during flowering and at harvesting stage and are presented in Table 6. At flowering and at harvesting stage nutrient management systems did not show any significant effect on number of branches per plant.

Foliar application of nutrients significantly affected the branches per plant at both stages. Application of humic acid (F_4) recorded maximum number of branches per plant followed by F_2 at flowering stage which were on par and significantly superior to other treatments. At harvesting stage also F_4 recorded maximum number of branches per plant (8.88) and was on par with F_1 where *sampoorna* was applied as foliar spray (8.00) and both were significantly superior to other treatments.

Number of branches per plant was not affected by interaction effects of management system and foliar nutrition. However the treatment combination S_2F_4 produced higher number at both stages (at flowering 8.50 and at harvesting 8.92) compared to other treatment combinations.

4.1.3. Number of nodules per plant

Treatment effect on nodules per plant with respect to management systems, foliar nutrition and interaction are recorded in Table 6.

Nutrient management systems did not produce any significant effect on number of nodules per plant. However higher effect was obtained in KAU POP recommendation system.

The effect of foliar application of nutrients on nodules per plant was significant and the treatment F_3 (*jeevamrutham* application) significantly increased the number of nodules per plant (16.08) followed by F_5 (12.29).

Interaction effects also showed significant differences in the number of nodules per plant. The treatment combination S_2F_3 produced maximum number of nodules per plant (18.50) and was significantly superior to all other treatment combinations. .

Table 6. Effect of management system, foliar nutrition and their interaction effects on plant height, number of branches per plant and nodules per plant at flowering and harvesting stage

Treatment	Plant height (cm)		Branches per plant (no.)		Nodules per plant (no.)
Management systems (S)	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage	
S_1	53.56	63.16	6.69	7.47	11.30
S_2	55.18	65.42	7.12	7.76	11.40
SEm (±)	0.565	1.387	0.273	0.241	0.562
CD (0.05)	NS	NS	NS	NS	NS
Foliar application (F)					
F_0	53.41	61.37	6.08	7.20	8.25
F_1	56.16	67.18	6.45	8.00	9.70
F_2	54.12	62.00	7.25	7.12	11.04
F_3	53.20	59.66	6.75	7.16	16.08
F_4	54.12	63.91	8.29	8.88	10.75
F_5	55.21	71.63	6.62	7.33	12.29
SEm (±)	0.978	2.403	0.474	0.418	0.793
CD (0.05)	NS	7.092	1.398	1.233	2.872
Interaction effects (SxF)					
S_1F_0	52.83	60.33	6.16	7.08	10.00
S_1F_1	54.58	57.66	6.75	8.10	11.66
S_1F_2	50.91	59.25	7.33	6.83	11.33
S_1F_3	54.16	61.41	6.08	6.75	13.66
S_1F_4	52.50	63.33	8.08	8.8	9.33
S_1F_5	56.41	77.00	5.75	7.25	11.83
S_2F_0	54.00	62.41	6.00	7.33	6.50
S_2F_1	57.75	76.68	6.16	7.91	7.75
S_2F_2	57.33	64.75	7.16	7.41	10.75
S_2F_3	52.25	57.91	7.41	7.58	18.50
S_2F_4	57.50	64.50	8.50	8.91	12.16
S_2F_5	54.000	66.25	7.50	7.41	12.75
SEm (±)	1.383	3.398	0.670	0.591	1.37
CD (0.05)	4.082	10.030	NS	NS	4.062

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations

F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution

F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.1.4. Leaf area of the plant

Management systems showed significant difference on leaf area at flowering stage and at harvesting stage (Table 7). The treatment S_2, where KAU POP recommendations were followed, produced significantly higher leaf area per plant (1829 cm^2) both at flowering and at harvesting stage compared to S_1 (1489 cm^2) where KAU adhoc organic POP recommendations were applied.

Foliar application of nutrients failed to produce a significant effect on leaf area at flowering and at harvesting stage. However, application of micronutrient solution (F_2) produced higher leaf area at flowering stage (1879 cm^2) and at harvesting stage application of fulvic acid (F_5) recorded higher leaf area (1570 cm^2).

Interaction effects were non-significant both at flowering stage and at harvesting stage. At flowering stage S_2F_5 produced higher leaf area (2129 cm^2) followed by S_2F_2. At harvesting stage S_2F_2 produced maximum leaf area (1830 cm^2)

4.1.5. Total dry matter production

Influence of management systems, foliar nutrition and their interaction effects on total dry matter production are given in Table 7. Total dry matter production was recorded during flowering stage and at harvesting stage. At flowering stage and at harvesting stage integrated management system (S_2) where KAU POP recommendation was followed, recorded significantly higher dry matter production than organic management system (S_1).

With regard to foliar nutrition, significant difference was observed at flowering stage and at harvesting stage.

Foliar application of fulvic acid (F_5) recorded highest dry matter content (1600 kg ha^{-1}) which was on par with F_4, F_2 and F_3 and significantly superior to other treatments at flowering stage. F_5 produced higher effect (2527 kg ha^{-1}) at harvesting stage also and was on par with F_3.

Table 7. Effect of management system, foliar nutrition and their interaction effects on leaf area and total dry matter production at flowering and harvesting stage

Treatment	Leaf area (cm^2)		Total dry matter (kg ha^{-1})	
Management systems (S)	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage
S_1	1489	1267	1205	1790
S_2	1829	1660	1511	2439
SEm (±)	90	63	62	78
CD (0.05)	267	186	184	230
Foliar application (F)				
F_0	1537	1356	1128	1900
F_1	1717	1255	1170	1994
F_2	1879	1509	1364	1983
F_3	1669	1549	1362	2205
F_4	1507	1540	1526	2078
F_5	1645	1570	1600	2527
SEm (±)	156	109	108	135
CD (0.05)	NS	NS	319	398
Interaction effects (SxF)				
S_1F_0	1283	999	989	1200
S_1F_1	1306	1098	1133	1500
S_1F_2	1680	1187	1195	1600
S_1F_3	1765	1536	1190	1767
S_1F_4	1280	1378	1422	1911
S_1F_5	1619	1401	1302	1667
S_2F_0	1790	1614	1207	2300
S_2F_1	2029	1512	1268	2389
S_2F_2	2078	1830	1433	2200
S_2F_3	1573	1562	1533	2500
S_2F_4	1672	1701	1630	2489
S_2F_5	2129	1739	1897	2755
SEm (±)	222	154	153	191
CD (0.05)	NS	NS	555	694

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

Total dry matter production was significantly influenced by interaction effects at flowering and at harvesting stage. The treatment combination S_2F_5 produced higher dry matter both at flowering and at harvesting stage (at flowering 1897 kg ha^{-1} and at harvesting 2755 kg ha^{-1}) and was on par with S_2F_2, S_2F_3 and S_2F_4 at flowering stage while at harvesting stage S_2F_5 was on par with all the combinations of foliar nutrition with S_2, where KAU POP recommendations used.

4.2. YIELD AND YIELD ATTRIBUTES

Yield and yield attributes including number of pods /plant**,** number of seeds /pod, pod weight /plant (g), test weight (100 seed weight) (g), pod yield (kg ha^{-1}) and seed yield (kg ha^{-1}) were recoded and presented in Table 8 and Table 9.

4.2.1. Number of pods per plant

The influence of nutrient management systems, foliar fertilization and their interaction effects on number of pods per plant are presented in Table 8. The number of pods per plant was not significantly influenced by interaction effects. Management system, S_2 produced higher number of pods per plant (12.38) and significantly differ from S_1.

Significant effect on number of pods per plant was observed with foliar nutrition. The treatment with fulvic acid foliar application (F_5) recorded the highest number (12.99) followed by F_1 (12.56) and F_3 (11.08) which were on par and significantly superior to other treatments.

4.2.2. Number of seeds per pod

The results revealed that number of seeds per pod (Table 8) was not significantly influenced either by management systems or foliar nutrition and their interaction. However, S_2 where KAU POP recommendation was followed recorded higher number of seeds (16.14) than S_1. In foliar application, F_4 produced highest number of seeds per pod followed by F_1 and F_5. Among the treatment combinations S_2F_4 produced maximum number of seeds per pod followed by S_2F_1.

Table 8. Effect of management system, foliar nutrition and their interaction effects on pods per plant, seeds per pod and pod weight per plant

Treatment	Yield attributes		
Management systems (S)	Pods per plant (no.)	Seeds per pod (no.)	Pod weight per plant (g)
S_1	10.29	15.16	18.55
S_2	12.38	16.14	21.56
SEm (±)	0.409	0.210	0.470
CD (0.05)	1.206	NS	1.388
Foliar nutrition (F)			
F_0	10.17	15.23	16.91
F_1	12.56	16.29	20.97
F_2	10.54	15.39	19.70
F_3	11.08	15.66	21.12
F_4	10.67	16.54	21.07
F_5	12.99	15.86	20.58
SEm (±)	0.708	0.363	0.815
CD (0.05)	2.089	NS	2.404
Interaction effects (SxF)			
S_1F_0	9.33	15.23	16.25
S_1F_1	10.75	15.86	19.02
S_1F_2	9.83	15.23	17.41
S_1F_3	11.16	15.78	20.58
S_1F_4	8.833	16.03	19.08
S_1F_5	11.83	15.55	19.00
S_2F_0	11.00	15.83	17.58
S_2F_1	14.37	16.72	22.91
S_2F_2	11.25	15.55	22.00
S_2F_3	11.00	15.53	21.66
S_2F_4	12.50	17.05	23.07
S_2F_5	14.15	16.16	22.16
SEm (±)	1.001	0.514	1.152
CD (0.05)	NS	NS	3.76

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.2.3. Pod weight per plant

Pod weight per plant was significantly influenced by management systems, foliar fertilization and their interaction (Table 8). Pod weight per plant was significantly higher in S_2 (21.57g) where KAU POP was applied compared to S_1.

In the case of foliar application F_3 produced highest pod weight per plant (21.12g) followed by F_1, F_2, F_4 and F_5 which were on par and significantly superior to control.

Interaction of main treatments showed significant differences in pod weight per plant. The treatment combination S_2F_4 produced maximum pod weight per plant which was on par with $S_2F_{1,}$ $S_2F_{2,}$ $S_2F_{3,}$ S_2F_5 and S_1F_3 and significantly superior to other treatment combinations. In general, the treatment combinations including KAU POP recommendation with foliar nutrition recorded higher pod weight per plant compared to treatment combination with KAU adhoc organic POP recommendations.

4.2.4. Test weight

No significant differences was observed on test weight with regard to management system, foliar nutrition and their interaction (Table 9)

4.2.5. Pod yield

Pod yield was significantly affected by different treatments and their interaction (Table 9). KAU POP recommendations (S_2) recorded significantly higher pod yield (2475 kg ha^{-1}) than S_1 (2066 kg ha^{-1}) where KAU adhoc organic POP was followed.

Application of humic acid (F_4) recorded maximum pod yield (2534 kg ha^{-1}) followed by F_5 (2513 kg ha^{-1}) which were on par and significantly superior to other treatments.

Interaction effect of nutrient management system and foliar application was found to be significant and the treatment combination S_2F_4 recorded maximum pod yield per hectare (2743 kg ha^{-1}) and it was on par with S_2F_2, S_2F_3 and $S_2F_{5.}$ Application of adhoc organic POP recommendations without foliar fertilization recoded the lowest yield (1733 kg ha^{-1}).

4.2.6. Seed yield

The data on seed yield (Table 9) revealed that seed yield per hectare was significantly influenced by management systems, foliar application and their interaction. Highest seed yield was obtained in treatment S_2 (1733 kg ha^{-1}) compared to S_1 (1411 kg ha^{-1}).

Foliar application of fulvic acid (F_5) produced maximum seed yield (1730 kg ha^{-1}) which was on par with F_4 (1661 kg ha^{-1}) and F_2 (1624 kg ha^{-1}).

Interaction effects of nutrient management systems and foliar application significantly varied with seed yield. S_2F_5 produced highest seed yield (1783 kg ha^{-1}) and it was on par with S_1F_4, S_1F_5, S_2F_0, S_2F_1, S_2F_2, S_2F_3 and S_2F_4. The treatment combination S_1F_0 where adhoc organic POP recommendations without foliar fertilization was applied recorded the lowest yield (1115 kg ha^{-1}).

Table 9. Effect of management system, foliar nutrition and their interaction effects on test weight, pod yield and seed yield

Treatments	Yield and yield attributes		
Management systems (S)	Test weight (g)	Pod yield (kg ha^{-1})	Seed yield (kg ha^{-1})
S_1	12.36	2066	1411
S_2	12.37	2475	1733
SEm (±)	0.191	42	30
CD (0.05)	NS	125	90
Foliar nutrition (F)			
F_0	12.15	1966	1367
F_1	12.23	2110	1527
F_2	12.34	2214	1624
F_3	12.13	2288	1523
F_4	12.53	2534	1661
F_5	12.83	2513	1730
SE(m)±	0.330	73	53
CD (0.05)	NS	216	156
Interaction effects (SxF)			
S_1F_0	11.86	1733	1115
S_1F_1	11.88	1994	1287
S_1F_2	12.59	1915	1479
S_1F_3	12.15	2130	1362
S_1F_4	12.39	2325	1547
S_1F_5	13.32	2302	1676
S_2F_0	12.43	2200	1619
S_2F_1	12.58	2227	1768
S_2F_2	12.09	2512	1770
S_2F_3	12.12	2447	1684
S_2F_4	12.68	2743	1774
S_2F_5	12.35	2724	1783
SE(m)±	0.467	104	75
CD (0.05)	NS	377	272

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.3. PLANT ANALYSIS

4.3.1. Nutrient content of plant

Nutrient status of the plant at flowering and at harvesting stages are given in Table 10, 11 and 12.

4.3.1.1. Nitrogen

The effect of management systems, foliar nutrition and their interaction effects are presented in Table 10.

Nitrogen content in plant at flowering and at harvesting stage responded significantly to management systems and higher N content was obtained in treatment S_2 (3.13 % and 2.81% at flowering and harvesting stage respectively).

Nitrogen content of the plant was not significantly influenced by foliar application at both stages.

Among the interaction effects, S_2F_2 recorded maximum N content at flowering and S_2F_1 at harvesting stage without any significant differences.

4.3.1.2. Phosphorous

Nutrient management systems, foliar nutrition and their interaction significantly influenced the phosphorous content of plant at flowering stage (Table 10) and at harvesting stage no significant differences were observed. Nutrient management based on KAU adhoc organic POP (S_1) enhanced the P content of plant (0.303%) at flowering stage.

Highest phosphorous content (0.346%) was observed with foliar nutrition F_4 (humic acid) which was significantly superior to all other foliar nutrition treatments.

The treatment combination S_1F_4, where KAU adhoc organic POP and humic acid were combined, significantly increased the P content in plant and was on par with S_1F_2, S_1F_3 and S_1F_5.

Table 10. Effect of management system, foliar nutrition, and their interaction effects on N, P and K content in plant at flowering and harvesting stage

Treatment	N (%)		P (%)		K (%)	
Management systems (S)	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage
S_1	2.38	2.13	0.303	0.193	1.97	1.39
S_2	3.13	2.81	0.270	0.196	2.48	1.89
SEm (±)	0.136	0.135	0.003	0.004	0.137	0.108
CD (0.05)	0.403	0.398	0.008	NS	0.405	0.320
Foliar nutrition (F)						
F_0	2.44	1.72	0.241	0. 167	1.65	1.19
F_1	3.01	2.08	0.276	0.175	1.99	1.45
F_2	3.19	2.55	0.289	0.183	1.94	1.75
F_3	2.89	2.50	0.294	0.218	2.79	1.97
F_4	2.56	1.85	0.346	0.221	2.53	1.78
F_5	2.57	2.08	0.274	0.204	2.42	1.72
SEm (±)	0.236	0.234	0.005	0.004	0.238	0.188
CD (0.05)	NS	NS	0.015	NS	0.702	NS
Interaction effects (SxF)						
S_1F_0	1.90	1.72	0.221	0.150	1.72	0.89
S_1F_1	2.54	2.08	0.262	0.220	1.74	1.38
S_1F_2	2.75	2.55	0.316	0.210	1.75	1.48
S_1F_3	2.50	2.50	0.305	0.204	2.50	1.70
S_1F_4	2.30	1.85	0.318	0.181	2.05	1.52
S_1F_5	2.32	2.08	0.304	0.194	2.02	1.42
S_2F_0	2.98	3.21	0.261	0.113	1.58	1.48
S_2F_1	3.48	3.23	0.290	0.200	2.23	1.52
S_2F_2	3.64	3.02	0.261	0.155	2.13	2.02
S_2F_3	3.28	2.90	0.283	0.231	3.07	2.24
S_2F_4	2.82	2.36	0.283	0.261	3.01	2.03
S_2F_5	2.57	2.15	0.245	0.213	2.82	2.03
SEm (±)	0.334	0.331	0.007	0.009	0.336	0.188
CD (0.05)	NS	NS	0.021	NS	NS	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations

F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution

F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.3.1.3. Potassium

The effect of management systems, foliar nutrition and their interaction effects on K content in plant are presented in Table 10.

Potassium content of plant was significantly influenced by the management system at flowering and at harvesting stage. The treatment S_2 recorded maximum K content at flowering (2.48%) and at harvesting stage (1.89%) compared to S_1.

Foliar nutrition had significant influence on plant K at flowering stage only. Highest K content was observed in F_3 which was on par with F_4 and F_5.

Interaction effects of nutrient management system and foliar nutrition was not significant with K content in plant at both stages.

4.3.1.4. Calcium

Treatment effect on Ca content of plant with respect to management systems, foliar nutrition and their interaction are given in Table 11.

Calcium content in plant was not significantly influenced by any of the treatment or their combinations except treatment interaction at harvesting stage. At harvesting stage KAU organic POP along with *sampoorna* (S_1F_1) significantly increased the Ca content of plant (3.04 %) which was on par with S_1F_3, S_1F_0, S_1F_2, S_1F_4, S_2F_0, S_2F_1, S_2F_3, S_2F_4 and S_2F_5.

4.3.1.5. Magnesium

Nutrient management system and foliar nutrition had a significant influence on Mg content in plant both at flowering and at harvesting stages (Table 11). Interaction of nutrient management system and foliar nutrition produced a significant effect in Mg content of plant at flowering stage and failed to produce a significant effect at harvesting stage.

KAU POP recommendation (S_2) enhanced the Mg content in plant at flowering and at harvesting stage.

Table 11. Effect of management system, foliar nutrition and their interaction effects on Ca, Mg and S content in plant at flowering and harvesting stage

Treatment	Ca (%)		Mg (%)		S (%)	
Management systems (S)	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage
S_1	3.09	2.72	0.78	0.80	0.32	0.235
S_2	3.10	2.70	0.89	0.85	0.367	0.245
SEm (±)	0.101	0.063	0.014	0.007	0.004	0.012
CD (0.05)	NS	NS	0.041	0.022	0.012	NS
Foliar nutrition (F)						
F_0	2.97	2.63	0.73	0.75	0.307	0.217
F_1	3.30	2.82	0.81	0.82	0.325	0.274
F_2	3.09	2.59	0.86	0.82	0.308	0.266
F_3	3.25	2.85	0.81	0.80	0.352	0.225
F_4	2.95	2.72	0.89	0.87	0.375	0.229
F_5	3.02	2.66	0.94	0.86	0.400	0.230
SEm (±)	0.175	0.110	0.024	0.013	0.007	0.021
CD (0.05)	NS	NS	0.071	0.038	0.010	NS
Interaction effects(SxF)						
S_1F_0	3.04	2.60	0.61	0.69	0.200	0.250
S_1F_1	3.47	3.04	0.75	0.79	0.228	0.260
S_1F_2	3.10	2.68	0.80	0.80	0.310	0.263
S_1F_3	3.37	3.00	0.74	0.79	0.376	0.183
S_1F_4	2.79	2.67	0.85	0.89	0.416	0.229
S_1F_5	2.81	2.33	0.92	0.83	0.385	0.226
S_2F_0	2.89	2.65	0.85	0.81	0.413	0.184
S_2F_1	3.13	2.60	0.87	0.84	0.422	0.288
S_2F_2	3.09	2.50	0.93	0.84	0.306	0.269
S_2F_3	3.14	2.70	0.87	0.82	0.327	0.268
S_2F_4	3.10	2.77	0.93	0.89	0.321	0.229
S_2F_5	3.23	2.99	0.96	0.89	0.430	0.230
SEm (±)	0.247	0.155	0.034	0.018	0.010	0.030
CD (0.05)	NS	0.458	0.100	NS	0.028	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

Foliar application of fulvic acid (F_5) enhanced the Mg content (0.94 %) in plant at flowering stage and was on par with application of humic acid F_4 (0.89%). At harvesting stage humic acid (F_4) increased the Mg content which was on par with fulvic acid.

At harvesting stage, application of KAU POP along with fulvic acid (S_2F_5) application enhanced the Mg content of plant which was on par with S_2F_1, S_2F_2, S_2F_3, S_2F_4 and S_1F_5 and significantly superior to other treatment combinations.

4.3.1.6. Sulphur

Results on sulphur content in plant is recorded in Table 11 and the effect was significant only at flowering stage.

At flowering stage, S content was significantly enhanced by KAU POP recommendation (S_2) compared to S_1. In the case of foliar nutrition, application of fulvic acid (F_5) increased the S content (0.400%) and was significantly superior to other treatments.

Application of KAU POP along with fulvic acid spray (S_2F_5) significantly enhanced the S content of plant at flowering stage and was on par with S_2F_0, S_2F_1 and S_1F_4. Management system, foliar nutrition and their interaction effect failed to produce any significant effect on S content in plant at harvesting stage.

4.3.1.7. Micro nutrients

Treatment effect on micronutrients with respect to management system, foliar nutrition and interaction was presented in Table 12

At flowering and at harvesting stages, management system and interaction effects failed to produce significant influence on Fe content (Table 12) while foliar nutrition significantly influenced the Fe content at both stages. Foliar nutrition $F_{2,}$ where micronutrient solution was sprayed, recorded maximum Fe content (352.84 mg kg^{-1}) at flowering stage and which was on par with $F_{5,}$ F_3 and F_1 and significantly superior to F_0 and F_4. Foliar nutrition F_2 significantly increased the Fe content (352.84 mg kg^{-1}) of plant and was on par with F_1 and F_5 at harvesting stage.

Table 12. Effect of management system, foliar nutrition and their interaction effects on Fe, Mn Zn and Cu content in plant at flowering and harvesting stage

Treatment	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})		Cu (mg kg^{-1})	
Management systems (S)	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage	Flowering stage	Harvesting stage
S_1	301.79	277.06	235.26	201.04	77.61	59.74	23.58	22.79
S_2	324.06	295.12	252.39	191.14	78.46	61.93	24.19	22.87
SEm (±)	8.677	8.691	7.248	9.348	2.756	2.593	1.287	1.006
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Foliar nutrition (F)								
F_0	300.03	264.46	221.52	182.40	76.63	59.00	19.10	19.70
F_1	310.90	286.56	247.20	217.86	84.96	74.46	20.60	21.36
F_2	352.84	326.60	258.46	171.26	76.76	53.43	21.29	23.53
F_3	309.23	263.46	240.30	190.70	80.96	65.40	27.02	23.56
F_4	279.43	267.61	247.16	199.06	77.33	55.53	28.33	24.09
F_5	325.13	307.86	248.33	215.28	71.56	62.60	26.98	21.72
SEm (±)	15.029	15.053	12.554	16.192	4.773	4.491	2.229	1.742
CD(0.05)	44.363	44.433	NS	NS	NS	13.258	6.580	NS
Interaction effects (SxF)								
S_1F_0	312.66	244.60	187.44	164.26	74.73	65.13	18.69	20.39
S_1F_1	293.13	287.40	260.00	241.33	92.86	78.66	23.77	20.03
S_1F_2	330.95	313.46	264.73	162.46	73.00	53.06	21.30	25.63
S_1F_3	298.46	266.27	243.13	201.33	82.33	57.06	24.02	23.02
S_1F_4	247.73	234.20	227.60	201.66	73.06	52.73	28.81	23.20
S_1F_5	327.80	316.46	247.36	216.56	69.66	51.80	24.92	24.46
S_2F_0	287.40	284.33	255.60	200.53	78.53	52.86	19.51	19.02
S_2F_1	328.66	285.73	253.06	175.73	77.06	70.26	17.44	22.70
S_2F_2	374.73	339.73	252.20	180.06	80.53	53.80	21.28	21.42
S_2F_3	320.00	266.67	237.46	180.06	79.60	73.73	30.01	24.10
S_2F_4	311.13	301.02	266.73	196.46	81.60	58.33	27.8	24.98
S_2F_5	322.46	299.26	249.30	214.00	73.46	62.60	29.05	18.98
SEm (±)	21.254	21.288	17.753	22.899	6.75O	6.352	3.153	2.464
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

Management systems, foliar nutrition and their interaction effects on Mn was found to be insignificant both at flowering and at harvesting stage (Table 12).

Zinc content in plant (Table 12) was not significantly influenced by management system, foliar nutrition and their interaction effects at flowering stage. At harvesting stage only foliar nutrition showed significant difference and the treatment F_1 recorded highest Zn content (74.46 mg kg^{-1}) which was on par with F_3 and F_4 and superior to other treatments.

Copper content in plant was significantly influenced by foliar nutrition only (Table12). At flowering stage highest Cu content was observed with foliar nutrition F_4 (28.33 mg kg^{-1}) and was on par with F_3 and F_5.

4.3.2. Nutrient content of the grain

Nutrient content of the grain are presented in Table 13 and Table 14.

4.3.2.1 Nitrogen

In grain, nitrogen was significantly influenced by the management system, foliar nutrition and their interaction effects (Table 13). Highest N content (3.50 %) was observed with KAU POP recommendation (S_2).

Foliar nutrition with fulvic acid (F_5) significantly enhanced the nitrogen content of grain (3.58%) which was on par with humic acid application (F_4) and significantly superior to other treatments.

Among the treatment combinations, KAU POP recommendation along with fulvic acid (S_2F_5) recorded maximum N content of grain (3.65%) which was on par with S_2F_4 and significantly superior to other treatment combinations.

4.3.2.2. Phosphorous

Management system didn't significantly influence the P content of grain (Table 13).

Maximum P content (0.358 %) was observed with foliar nutrition of *sampoorna* (F_1) and was significantly superior to all other foliar applications.

Among the interactions, KAU organic POP management system along with *sampoorna* (S_1F_1) significantly increased the P content of grain followed by S_2F_5 and S_2F_4.

4.3.2.3. Potassium

Potassium content in grain (Table 13) was significantly influenced by individual treatments but not with their interactions.

Maximum K content was observed in S_1 (1.03 %) compared to S_2.

Foliar nutrition F_4 recorded the highest K content in grain (1.04 %) which was on par with F_0 and F_1 and significantly superior to other treatments.

Significant effect was not observed in K content with respect to interaction effects.

4.3.2.4. Calcium

Calcium content of grain was significantly influenced by management system, and foliar nutrition (Table 13). KAU POP recommendation (S_2) significantly increased the Ca content (0.45 %) of grain compared to S_1.

Maximum calcium content was observed with foliar nutrition, fulvic acid (F_5) and was on par with humic acid (F_4) and significantly superior to other foliar nutrition.

No significant effects were observed with interaction of main treatments on Ca content of grain.

4.3.2.5. Magnesium

Magnesium content in grain showed similar trend as in Ca (Table 13).

KAU POP recommendation (S_2) recorded maximum Mg content in grain (0.184%).

Application of fulvic acid (F_5) was superior among foliar nutrition treatments with regard to Mg content (0.189%) of grain which was on par with humic acid (F_4) application (0.187%).

Table 13. Effect of management system, foliar nutrition and their interaction effects on N, P, K, Ca, Mg and S in grain

Treatment	Nutrient Content (%)					
Management systems (S)	N	P	K	Ca	Mg	S
S_1	3.40	0.343	1.03	0.39	0.178	0.368
S_2	3.50	0.377	1.01	0.45	0.184	0.429
SE(m)±	0.012	0.000	0.005	0.010	0.000	0.001
CD (0.05)	0.035	NS	0.016	0.030	0.001	0.004
Foliar nutrition (F)						
F_0	3.29	0.322	1.02	0.37	0.170	0.365
F_1	3.41	0.358	1.03	0.38	0.179	0.412
F_2	3.42	0.330	1.01	0.41	0.183	0.414
F_3	3.48	0.353	1.00	0.42	0.180	0.377
F_4	3.51	0.337	1.04	0.46	0.187	0.410
F_5	3.58	0.355	1.01	0.49	0.189	0.413
SE(m)±	0.021	0.001	0.009	0.010	0.001	0.002
CD (0.05)	0.061	0.002	0.028	0.030	0.002	0.007
Interaction effects (SxF)						
S_1F_0	3.27	0.342	1.02	0.34	0.169	0.320
S_1F_1	3.36	0.384	1.03	0.39	0.177	0.390
S_1F_2	3.42	0.327	1.00	0.39	0.180	0.396
S_1F_3	3.43	0.356	1.01	0.38	0.175	0.384
S_1F_4	3.41	0.314	1.05	0.42	0.184	0.385
S_1F_5	3.51	0.332	1.04	0.45	0.187	0.388
S_2F_0	3.31	0.351	1.02	0.40	0.172	0.370
S_2F_1	3.46	0.331	1.02	0.38	0.181	0.433
S_2F_2	3.42	0.333	1.01	0.43	0.186	0.433
S_2F_3	3.54	0.301	0.98	0.46	0.185	0.410
S_2F_4	3.62	0.360	1.03	0.49	0.189	0.435
S_2F_5	3.65	0.377	0.98	0.53	0.191	0.454
SE(m)±	0.029	0.001	0.013	0.025	0.001	0.004
CD (0.05)	0.087	0.003	NS	NS	NS	0.011

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations

F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution

F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.3.2.6. Sulphur

Sulphur content of grain was significantly influenced by management system, foliar nutrition and their interaction Table 13.

Among the management systems, KAU POP management system enhanced the S content in grain (0.429%).

Foliar application of micronutrient solution (F_2) recorded maximum S content (0.414%) in grain which was on par with F_1, F_4 and F_5.

KAU POP management system along with fulvic acid (S_2F_5) showed maximum S content (0.454 %) in grain which was significantly superior to all other treatment combinations.

4.3.2.7. Micronutrients

Management system and foliar nutrition was found to be insignificant with Fe content (Table 14). Interaction effect on Fe content was significant and the treatment combination S_2F_5 produced the highest Fe content (225.00 mg kg^{-1}) which was on par with S_1F_3 and superior to all other treatment combinations.

Manganese content was significantly influenced by management system and foliar nutrition (Table 14) and was not influenced by their interaction. The management system S_2 significantly increased the Mn content (10.12 mg kg^{-1}) compared to S_1. Among the foliar nutrition, application of fulvic acid (F_5) recorded maximum Mn content and was on par with F_2 and F_4.

Similar to Mn content, the Zn content in grain was also significantly influenced by management system and foliar nutrition and not with their interaction (Table 14).

Table 14. Effect of management system, foliar nutrition and their interaction effects on Fe, Mn, Zn and Cu in grain

Treatment	Nutrient content (mg kg^{1})			
Management systems (S)	Fe	Mn	Zn	Cu
S_1	159.68	9.99	29.86	5.30
S_2	166.71	10.12	33.53	5.37
SEm (±)	6.054	0.030	0.689	0.019
CD (0.05)	NS	0.090	2.035	0.057
Foliar nutrition (F)				
F_0	149.00	9.83	28.40	5.18
F_1	152.45	10.01	33.90	5.36
F_2	153.25	10.16	32.80	5.37
F_3	169.45	9.94	30.95	5.33
F_4	165.90	10.14	33.70	5.41
F_5	189.15	10.26	30.45	5.36
SEm (±)	10.486	0.053	1.194	0.033
CD (0.05)	NS	0.156	3.524	0.099
Interaction effects (SxF)				
S_1F_0	157.30	9.75	25.40	5.17
S_1F_1	160.30	9.91	32.10	5.35
S_1F_2	133.70	10.01	30.90	5.29
S_1F_3	188.00	9.84	30.70	5.29
S_1F_4	165.50	10.17	30.60	5.32
S_1F_5	153.30	10.25	29.50	5.36
S_2F_0	140.70	9.90	31.40	5.18
S_2F_1	144.60	10.11	35.70	5.37
S_2F_2	172.80	10.31	34.70	5.44
S_2F_3	150.90	10.05	31.20	5.37
S_2F_4	166.30	10.11	36.80	5.50
S_2F_5	225.00	10.27	31.40	5.36
SEm (±)	14.829	0.075	1.688	0.047
CD (0.05)	43.772	NS	NS	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

The management system S_2 recorded significantly higher Zn content (33.53 mg kg^{-1}) than S_1. In foliar nutrition, F_1 recorded maximum Zn content (33.90 mg kg^{-1}) which was on par with all other treatment except F_0.

Significant influence on Cu content (Table 14) was observed with management system and foliar nutrition and not with their interaction. The management system S_2 significantly increased the Cu content in grain (5.37 mg kg^{1}). Application of humic acid (F_4) recorded significantly higher Cu content and was on par with all other treatment except control.

4.3.3. Nutrient uptake

4.3.3.1. Nutrient uptake by plant

Nutrient uptake by plant at harvesting stage was calculated for nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu and presented in Table 15 and Table 16.

Application of nutrients based on KAU POP recommendation (S_2) (68.26 kg ha^{-1}) increased the nitrogen uptake and the effect was significant (Table 15). Foliar nutrition and interaction effects of main treatments failed to produce any significant influence on nitrogen uptake by the plant.

KAU POP recommendation (S_2) significantly increased the P uptake (4.80 kg ha^{-1}) by the plant (Table 15) compared to KAU adhoc organic POP recommendation (S_1). In case of foliar nutrition, fulvic acid (F_5) application enhanced the P uptake (5.16 kg ha^{-1}) which was on par with F_3 and F_4. Among the interaction application of humic acid along with KAU POP recommendation (S_2F_5) significantly enhanced the P uptake (6.47 kg ha^{-1}) and was on par with S_2F_3 and S_2F_5.

In plant, K uptake (Table 15) was significantly enhanced by management system and the treatment S_2, where KAU POP recommendation was followed, recorded significantly higher uptake compared to S_1.

Table 15. Effect of management system, foliar nutrition and their interaction effects on N, P, K, Ca, Mg and S uptake of plant at harvest

Treatment	Nutrient Uptake (kg ha^{-1})					
Management systems (S)	N	P	K	Ca	Mg	S
S_1	38.94	3.47	25.66	48.23	14.41	4.22
S_2	68.26	4.80	46.49	65.96	20.78	5.97
SEm (±)	3.625	0.161	3.008	2.144	0.668	0.320
CD (0.05)	10.700	0.474	8.878	6.330	1.972	0.946
Foliar nutrition (F)						
F_0	49.68	3.40	23.46	50.14	14.49	4.00
F_1	55.94	3.10	29.52	55.36	16.49	5.51
F_2	55.84	3.54	35.36	51.19	16.34	5.32
F_3	61.30	4.85	44.51	62.49	17.77	5.08
F_4	44.80	4.74	38.58	55.67	18.57	4.85
F_5	54.05	5.16	44.99	67.72	21.89	5.81
SEm (±)	6.278	0.278	5.209	3.714	0.668	0.555
CD (0.05)	NS	0.821	NS	10.964	1.972	NS
Interaction effects (SxF)						
S_1F_0	25.45	2.20	12.70	39.17	10.38	3.78
S_1F_1	34.81	3.51	22.57	48.57	12.78	4.12
S_1F_2	44.76	3.71	26.02	47.39	14.15	4.72
S_1F_3	49.54	3.91	33.19	57.39	15.09	3.49
S_1F_4	30.41	3.01	26.64	43.30	14.88	4.04
S_1F_5	48.69	4.46	32.81	53.54	19.15	5.15
S_2F_0	73.91	4.60	34.22	61.12	18.60	4.22
S_2F_1	77.07	2.69	36.47	62.14	20.20	6.89
S_2F_2	66.92	3.41	44.71	54.98	18.52	5.92
S_2F_3	73.06	5.78	55.84	67.59	20.44	6.68
S_2F_4	59.18	6.47	50.52	68.03	22.25	5.65
S_2F_5	59.41	5.87	57.18	81.91	24.63	6.48
SEm (±)	8.879	0.393	7.367	5.253	1.636	0.785
CD (0.05)	NS	1.161	NS	NS	NS	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

Foliar nutrition and interaction effects failed to produce any significant effect on K uptake by the plant

Uptake of Ca (Table 15) by plant was highest in KAU POP recommendation (S_2) (65.96 kg ha^{-1}). In foliar nutrition, application of fulvic acid **(**F_5) enhanced the Ca uptake (67.72 kg ha^{-1}) and was on par with F_3 (*jeevamrutham* application). Interaction of main treatments failed to produce any significant effect on Ca uptake.

Magnesium uptake was significantly influenced by management system and foliar nutrition but not by their interaction (Table 15). Crop management with KAU POP recommendation (S_2) significantly enhanced the Mg uptake (20.78 kg ha^{-1}) compared to S_1. In case of foliar nutrition, foliar nutrition of fulvic acid (F_5) significantly increased the Mg uptake compared to other treatments.

Uptake of S by plant was significantly influenced by the management system (Table 15). KAU POP recommendation (S_2) enhanced the S uptake. Foliar nutrition and the interaction effects were not significant with respect to S uptake.

Iron uptake (Table 16) was highest in KAU POP based management system (S_2) which was significantly superior to S_1. In case of foliar nutrition, fulvic acid application (F_5) enhanced the Fe uptake (0.787 kg ha^{-1}) and was on par with micronutrient solution spray (F_2).

Uptake of Mn (Table 16) was highest in KAU POP management system (S_2). Foliar nutrition and interaction effects were not significant.

Zinc uptake was influenced by both management system and foliar nutrition. The management system (S_2) where KAU POP was followed recorded the highest uptake compared to S_1. Foliar nutrition where *sampoorna* (F_1) was applied enhanced the highest Zn uptake (0.149 kg ha^{-1}) and was on par with F_3, F_4 and F_5.

Copper uptake by plant was influenced by management system only and the treatment KAU POP based management system (S_2) recorded the highest uptake (0.055 kg ha^{-1}).

Table 16. Effect of management system, foliar nutrition and interaction effects on Fe, Mn, Zn and Cu uptake of plant at harvest

Treatments	Nutrient uptake (kg ha^{-1})			
Management systems (S)	Fe	Mn	Zn	Cu
S_1	0.502	0.365	0.106	0.041
S_2	0.722	0.467	0.151	0.055
SEm (±)	0.033	0.027	0.007	0.003
CD (0.05)	0.097	0.080	0.020	0.008
Foliar nutrition (F)				
F_0	0.518	0.353	0.109	0.037
F_1	0.571	0.423	0.149	0.043
F_2	0.649	0.343	0.106	0.046
F_3	0.582	0.419	0.146	0.052
F_4	0.567	0.411	0.115	0.054
F_5	0.787	0.545	0.145	0.055
SEm (±)	0.057	0.047	0.012	0.005
CD (0.05)	0.168	NS	0.035	NS
Interaction effects (SxF)				
S_1F_0	0.373	0.247	0.097	0.030
S_1F_1	0.460	0.428	0.127	0.032
S_1F_2	0.551	0.289	0.094	0.045
S_1F_3	0.512	0.384	0.110	0.044
S_1F_4	0.391	0.343	0.087	0.039
S_1F_5	0.725	0.498	0.120	0.056
S_2F_0	0.663	0.459	0.121	0.044
S_2F_1	0.681	0.419	0.170	0.054
S_2F_2	0.746	0.397	0.118	0.047
S_2F_3	0.652	0.454	0.183	0.061
S_2F_4	0.742	0.480	0.144	0.069
S_2F_5	0.849	0.592	0.171	0.054
SEm (±)	0.081	0.066	0.017	0.007
CD (0.05)	NS	NS	NS	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.3.3.2. Nutrient uptake by grain

Data on nutrient uptake by grain are presented in Table 17 and Table 18

Nitrogen uptake by grain was highest (81.83 kg ha^{-1}) in KAU POP based management system (Table 17) and was significantly superior to KAU adhoc organic POP management system. With regard to foliar nutrition, fulvic acid (F_5) was significantly superior to all other treatments. Among the interaction, KAU POP recommendation along with fulvic acid (S_2F_5) recorded maximum N uptake (83.48 kg ha^{-1}) which was on par with S_2F_4 and S_2F_2.

Nutrient management system, foliar nutrition and their interaction significantly influenced the phosphorous uptake (Table 17) by grain. Maximum P uptake (8.16 kg ha^{-1}) was observed with KAU POP management system (S_2). Application of fulvic acid (F_5) as foliar nutrition was on par with F_3, F_2 and F_4 and significantly superior to all other foliar nutrition. KAU POP along with humic acid (S_2F_4) significantly enhanced the P uptake (8.93 kg ha^{-1}) and was on par with S_2F_5, S_2F_2, S_2F_0 and S_1F_5.

The data on K uptake (Table 17) showed that maximum K uptake (26.19 kg ha^{-1}) was observed with KAU POP management system (S_2). Foliar nutrition F_4 where humic acid was given as foliar spray recorded the highest K uptake which was on par with F_5 and significantly superior to all other treatments. Application of KAU POP based management system along with humic acid significantly enhanced the K uptake (29.47 kg ha^{-1}) and was on par with S_2F_5 S_2F_2 and S_2F_0.

Calcium uptake (Table 17) by grain was highest (15.60 kg ha^{-1}) in KAU POP management (S_2). Foliar nutrition with fulvic acid (F_5) enhanced the Ca uptake (16.52 kg ha^{-1}) by grain and was on par with humic acid (F_4).

Magnesium uptake was significantly influenced by the management system, foliar nutrition and their interaction effects. KAU POP (S_2) enhanced the Mg uptake (4.16 kg ha^{-1}). Fulvic acid application significantly increased the magnesium uptake (4.15 kg ha^{-1}) and was on par with humic acid. Highest Mg uptake was observed with S_2F_4 and was on par with S_2F_2 and S_2F_5.

Table 17. Effect of management system, foliar nutrition and interaction effects on N, P, K, Ca, Mg and S uptake of grain at harvest

Treatment	Nutrient uptake (kg ha^{-1})					
Management systems (S)	N	P	K	Ca	Mg	S
S_1	76.85	6.653	21.51	11.00	3.26	7.59
S_2	81.83	8.163	26.19	15.604	4.16	10.71
SEm (±)	0.117	0.153	0.475	0.463	0.076	0.190
CD (0.05)	0.346	0.452	1.403	1.365	0.224	0.561
Foliar nutrition (F)						
F_0	76.35	6.63	21.72	12.03	3.44	8.09
F_1	78.53	7.45	22.32	11.08	3.38	8.651
F_2	80.33	8.19	21.72	11.94	3.59	8.676
F_3	78.79	7.96	22.68	12.86	3.57	8.77
F_4	80.38	7.61	26.10	15.39	4.10	10.02
F_5	81.67	8.31	25.58	16.52	4.15	10.69
SEm (±)	0.203	0.265	0.824	0.801	0.132	0.329
CD (0.05)	0.599	0.783	2.431	2.365	0.389	0.971
Interaction effects (SxF)						
S_1F_0	73.39	5.07	16.63	9.99	2..61	6.258
S_1F_1	75.21	6.87	19.88	9.91	2.96	7.22
S_1F_2	77.88	7.32	22.47	8.676	3.24	6.35
S_1F_3	77.12	6.46	20.63	10.33	3.10	8.16
S_1F_4	77.28	6.31	22.73	11.93	3.47	8.01
S_1F_5	80.23	7.88	24.46	15.17	4.14	9.52
S_2F_0	79.31	8.61	26.79	14.06	3.95	9.38
S_2F_1	81.84	7.45	24.76	12.26	3.80	10.08
S_2F_2	82.78	8.19	26.79	15.20	4.27	11.02
S_2F_3	80.46	7.05	24.37	15.38	4.05	9.94
S_2F_4	83.11	8.93	29.47	18.84	4.72	12.03
S_2F_5	83.48	8.75	26.70	17.87	4.17	11.86
SEm (±)	0.287	0.375	1.165	1.133	0.186	0.465
CD (0.05)	0.847	1.107	3.438	NS	0.550	1.373

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

KAU POP management system (S_2) significantly increased the S uptake by grain (10.71 kg ha^{-1}). Foliar application of fulvic acid recorded maximum S uptake which was on par with humic acid foliar spray (F_4) and significantly superior to other foliar applications. KAU POP management system along with humic acid (S_2F_4) was observed with maximum S uptake (12.03 kg ha^{-1}) and was on par with S_2F_5 and S_2F_2.

Management system, foliar nutrition and their interaction effect significantly influenced the Fe uptake (Table18). Highest Fe uptake was observed with KAU POP management system (S_2). In case of foliar nutrition, F_5 significantly enhanced the iron uptake and was superior to all other treatments. Interaction effects of main treatments were not significant.

Manganese uptake (Table 18) by grain was found to be highest (0.024 kg ha^{-1}) in KAU POP management system (S_2). Foliar application of humic acid (F_4) and fulvic acid (F_5) recorded significantly higher Mn uptake and were on par with F_2. KAU POP recommendation combined with humic acid foliar spray (S_2F_4) increased the Mn uptake (0.027 kg ha^{-1}) and was on par with S_2F_2, S_2F_5, S_2F_0 and S_1F_5.

Zinc uptake (Table 18) was highest (0.108 kg ha^{-1}) in KAU POP management system (S_2). Foliar nutrition of humic acid (F_4) increased the Zn uptake by grain and was on par with fulvic acid (F_5). Interaction effect was significant with regard to Zn uptake and the treatment combination S_2F_4 recorded maximum Zn uptake which was on par with S_2F_2.

Copper uptake by grain (Table 18) was highest in S_2 (KAU POP management system). Foliar nutrition with humic acid (F_4) increased the Cu uptake (0.016 kg ha^{-1}) and was on par with *sampoorna* (F_1) and fulvic acid (F_5). In the case of interaction, maximum Cu uptake was observed with KAU POP recommendation along with humic acid (0.019 kg ha^{-1}) and was on par with S_2F_1.

Table 18. Effect of management system, foliar nutrition and interaction effects on Fe, Mn, Zn and Cu uptake of grain at harvest

Treatment	Nutrient uptake (kg ha^{-1})			
Management systems (S)	Fe	Mn	Zn	Cu
S_1	0.194	0.019	0.077	0.012
S_2	0.243	0.024	0.108	0.016
SEm (±)	0.008	0.000	0.002	0.000
CD (0.05)	0.024	0.001	0.007	0.001
Foliar nutrition (F)				
F_0	0.185	0.020	0.086	0.013
F_1	0.202	0.020	0.092	0.014
F_2	0.208	0.022	0.089	0.013
F_3	0.215	0.021	0.087	0.013
F_4	0.234	0.024	0.106	0.016
F_5	0.268	0.024	0.095	0.014
SEm (±)	0.008	0.001	0.004	0.001
CD (0.05)	0.024	0.002	0.013	0.013
Interaction effects (SxF)				
S_1F_0	0.172	0.015	0.064	0.010
S_1F_1	0.196	0.018	0.076	0.011
S_1F_2	0.160	0.020	0.070	0.010
S_1F_3	0.216	0.019	0.077	0.012
S_1F_4	0.198	0.020	0.081	0.012
S_1F_5	0.220	0.024	0.093	0.014
S_2F_0	0.208	0.024	0.096	0.015
S_2F_1	0.197	0.023	0.107	0.016
S_2F_2	0.257	0.025	0.114	0.017
S_2F_3	0.213	0.023	0.102	0.014
S_2F_4	0.270	0.027	0.130	0.019
S_2F_5	0.316	0.024	0.097	0.015
SEm (±)	0.020	0.001	0.006	0.001
CD (0.05)	NS	0.003	0.018	0.003

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.4. SOIL ANALYSIS

The available nutrient status of the soil was analyzed after the harvest of the crops and presented in Table 19 and Table 20.

Organic carbon content of the soil was significantly influenced by the management system, foliar nutrition and their interaction effects. Highest OC content was obtained in treatment S_2 (1.17 %). Foliar nutrition with fulvic acid (F_5) produced higher OC content (1.27 %) which was on par with F_2 and F_3 and significantly superior to other treatments. The Interaction S_2F_5 where application of KAU POP management combined with foliar spray of fulvic acid recorded higher OC content in soil which was on par with S_2F_1 and S_2F_2.

Available N content of the soil did not vary significantly with management system, foliar nutrition and their interaction effects. However, management system S_1 (289.17 kg ha^{-1}) and foliar nutrition F_4 (339.33 kg ha^{-1}) resulted in higher N content without any significant differences.

Available P content of the soil after the harvest of the crop was significantly influenced by management system, foliar nutrition and their interaction effects. Management system S_2 significantly increased the P content (45.79 kg ha^{-1}) in soil. In case of foliar nutrition maximum P content was observed with F_2 (micro nutrient solution) which was significantly superior to all other treatments. The treatment combination S_1F_2 resulted in maximum P content (61.07 kg ha^{-1}) in soil and was significantly superior to all other treatment combinations.

Available K content in the soil was significantly increased by the management system S_2 (247.49 Kg ha^{-1}) compared to S_1. Foliar nutrition and interaction effects were not significant with respect to available K content in soil.

Different management systems did not have any significant influence on available Ca content of the soil. Among the foliar nutrition F_0 where no foliar spray was given recorded significantly higher Ca content in soil.

Table 19. Effect of management system, foliar nutrition and their interaction effects on OC, available N, P, K, Ca, and Mg in soil after harvest

Treatments	Available nutrient in soil					
Management systems (S)	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
S_1	0.95	289.17	45.79	177.7	151.42	43.79
S_2	1.17	272.08	36.75	247.49	159.17	48.19
SEm (±)	0.040	12.127	0.549	20.528	6.53	2.026
CD (0.05)	0.117	NS	1.621	60.596	NS	NS
Foliar nutrition (F)						
F_0	1.04	240. 36	37.12	196.87	218.00	53.30
F_1	0.78	267.40	39.62	268.31	177.00	36.29
F_2	1.19	296.23	47.70	143.04	137.50	54.10
F_3	1.09	264.38	37.90	238.65	124.50	48.05
F_4	1.00	339.33	42.68	218.17	139.25	43.65
F_5	1.27	276.05	42.96	210.63	135.50	53.90
SEm (±)	0.069	12.127	0.951	35.556	11.31	3.51
CD (0.05)	0.202	NS	2.807	NS	33.38	10.36
Interaction effects (SxF)						
S_1F_0	1.04	242.28	34.43	183.64	250.00	33.85
S_1F_1	0.75	259.00	47.17	186.03	153.00	37.00
S_1F_2	1.08	283.97	61.07	138.46	135.00	48.500
S_1F_3	1.15	296.87	35.23	161.37	118.00	46.55
S_1F_4	0.98	376.55	48.38	183.41	127.500	44.50
S_1F_5	1.15	276.32	48.47	155.49	125.00	52.35
S_2F_0	1.04	238.45	39.81	210.11	186.00	53.30
S_2F_1	1.27	275.79	31.35	350.59	201.00	35.19
S_2F_2	1.30	308.49	34.33	147.61	140.00	54.10
S_2F_3	1.03	231.88	40.58	257.93	131.00	48.05
S_2F_4	1.02	302.11	36.98	252.93	151.00	43.65
S_2F_5	1.39	275.79	37.45	265.77	146.00	53.90
SEm (±)	0.097	29.705	1.345	50.284	15.99	4.96
CD (0.05)	0.286	NS	3.970	NS	47.21	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

Interaction effect S_1F_0 recorded maximum Ca content in soil and was significantly superior to other treatment combinations.

Available Mg content in soil was significantly influenced by foliar nutrition whereas nutrient management system and interaction of main treatments failed to produce any significant effect. Foliar nutrition F_2 recorded maximum available Mg content in soil which was on par with F_5, F_3 and F_0.

Available S content in soil (Table 20) was significantly influenced by management system and foliar nutrition. Interaction effects failed to produce any significant effects on available S content. Nutrient management system S_1 recorded significantly higher S content in soil (5.97 mg kg^{-1}) than S_2. The treatment without any foliar spray (F_0) was significantly superior (6.33 mg kg^{-1}) compared to other foliar nutrition treatments and was on par with F_1 and F_2.

Available Fe, Zn and Cu content of the soil (Table 20) after the harvest of the crop were not significantly influenced by the management system foliar nutrition and their interaction effects.

KAU adhoc organic POP management system (S_1) recorded the highest amount of available Mn content in soil (15.47 mg kg^{-1}) compared to S_2 (Table 20). Foliar nutrition with *jeevamrutham* (F_3) produced maximum available Mn content (18.33 mg kg^{-1}) which was significantly superior to F_4 and F_5. Effect of interactions were not significant on available Mn content of the soil.

4.5. DISEASES AND PEST INCIDENCE

The major pests noticed during the entire crop period were aphids, leaf roller and pod borer. Aphids (*Aphis craccivora*) was observed from the initial stage to harvesting stage of crop. It affected all the plots. Leaf roller *(Omiodes indicata)* was found during the flowering stage. Pod borer *Maruca vitrata* was observed during the pod formation stage. *Sclerotium* stem rot was the major disease observed in plants during the cropping period.

Table 20. Effect of management system, foliar nutrition and their interaction effects on available S, Fe, Mn, Zn and Cu in soil after harvest

Treatments	Available nutrient in soil (mg kg[1])				
Management systems (S)	S	Fe	Mn	Zn	Cu
S_1	5.97	24.04	15.47	2.11	2.19
S_2	5.33	26.60	12.02	2.67	2.19
SEm (±)	0.131	5.653	0.722	0.221	0.065
CD (0.05)	0.385	NS	2.132	NS	NS
Foliar nutrition (F)					
F_0	6.33	16.80	17.33	2.40	2.16
F_1	6.06	20.27	17.23	1.89	2.24
F_2	5.67	34.03	16.90	2.66	2.02
F_3	5.45	32.42	18.33	2.28	2.24
F_4	5.21	34.71	11.60	2.24	2.24
F_5	5.17	13.71	11.45	2.86	2.25
SEm (±)	0.226	9.790	1.251	0.384	0.113
CD (0.05)	0.668	NS	3.693	NS	NS
Interaction effects (SxF)					
S_1F_0	6.87	23.06	17.33	2.28	2.24
S_1F_1	6.45	24.40	17.23	1.49	2.42
S_1F_2	5.93	42.36	16.90	2.41	2.14
S_1F_3	5.71	19.42	18.33	1.86	2.18
S_1F_4	5.49	21.99	11.60	2.33	2.14
S_1F_5	5.33	13.02	11.45	2.27	2.02
S_2F_0	5.79	10.54	15. 16	2.52	2.09
S_2F_1	5.67	16.13	11.83	2.29	2.06
S_2F_2	5.39	25.70	13.01	2.92	1.90
S_2F_3	5.18	45.43	10.47	2.70	2.30
S_2F_4	4.935	47.43	10.94	2.15	2.35
S_2F_5	5.00	14.40	10.70	3.45	2.48
SEm (±)	0.320	13.846	1.769	0.542	0.159
CD (0.05)	NS	NS	NS	NS	NS

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

4.6. ECONOMICS

4.6.1. Gross income

The gross income was significantly influenced by the management systems, foliar nutrition (Table 21).

KAU POP recommendations (2016) recorded maximum gross return (₹ 173221 ha^{-1}) and was significantly superior to KAU adhoc organic POP recommendations (2017) (₹ 141636 ha^{-1}). Foliar nutrition F_5 produced higher gross return (₹ 173292 ha^{-1}), which was on par with F_4 and F_2. With respect to interactions S_2F_5 recorded maximum gross return (₹ 178987 ha^{-1}) without any significant differences from other combinations.

4.6.2. Net return

The data on net income (Table 21) showed that net income was significantly influenced by the management system, foliar nutrition and their interactions.

Maximum net return (₹ 70141 ha^{-1}) was obtained from management system $S_{2,}$ where KAU POP was followed. With respect to foliar nutrition, F_5 recorded maximum net return (₹ 66055 ha^{-1}) and was on par with all other treatments except F_0, F_1 and F_3. Net return did not vary significantly with interaction effects. S_2F_5 produced maximum net return (₹ 74157 ha^{-1})

4.6.3. BCR

Influence of management systems, foliar nutrition and their interactions on BCR are presented in Table 21.

Management system S_2 significantly enhanced the BCR (1.69). Foliar nutrition F_5 recorded maximum BCR (1.62) and was on par with F_4 and F_2. With respect to interaction of management system and foliar nutrition, significant effects was present with BCR. Maximum BCR was obtained from S_2F_5 (1.75) and was on par with S_2F_1, S_2F_2, S_2F_3 and S_2F_4

Table 21. Effect of management system, foliar nutrition and their interaction effects on gross income, net return and BCR

Treatments	Economics			
Management systems (S)	Cost of cultivation (₹ ha^{-1})	Gross income (₹ ha^{-1})	Net return (₹ ha^{-1})	BCR
S_1	103975	141636	33741	1.31
S_2	99160	173221	70141	1.69
SEm (±)		2983	2983	0.028
CD (0.05)		8806	8806	0.083
Foliar nutrition (F)				
F_0	3180	138273	36705	1.36
F_1	3000	152538	47790	1.46
F_2	4980	162095	57528	1.55
F_3	6690	152315	45768	1.43
F_4	5670	166058	57800	1.54
F_5	3180	173292	66055	1.62
SEm (±)		5167	5167	0.049
CD (0.05)		15253	15253	0.144
Interaction effects (SxF)				
S_1F_0	103975	114640	10665	1.10
S_1F_1	107155	128736	21580	1.20
S_1F_2	106975	147893	40918	1.38
S_1F_3	108955	136235	27280	1.20
S_1F_4	110665	154716	44051	1.39
S_1F_5	109645	167598	57953	1.52
S_2F_0	99160	161906	62746	1.54
S_2F_1	102340	176340	74000	1.72
S_2F_2	102160	176298	74138	1.72
S_2F_3	104140	168396	64255	1.61
S_2F_4	105850	177400	71550	1.68
S_2F_5	104830	178987	74157	1.75
SEm (±)		7308	7308	0.069
CD (0.05)		NS	NS	0.192

S_1- KAU Adhoc organic POP Recommendations S_2- KAU POP Recommendations
F_0 – Without foliar application F_1 – *Sampoorna* F_2 – Micronutrient solution
F_3 – *Jeevamrutham* F_4 – Humic acid F_5 – Fulvic acid

Plate.12. harvested pods

Plate. 13. Seeds after threshing and cleaning

Plate. 14. *Sclerotium* stem rot disease

DISCUSSION

5. DISCUSSION

An investigation entitled “Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems” was undertaken during 2019-20 to evaluate the effect of foliar nutrition under organic and integrated nutrient management practices in cowpea and the results presented in the previous chapter are discussed below.

5.1. EFFECT OF MANAGEMENT SYSTEM AND FOLIAR NUTRITION ON GROWTH PARAMETERS OF COWPEA

5.1.1. Plant height

At harvesting stage, foliar application of fulvic acid and “*sampoorna”* has significantly enhanced the plant height. Abdel-Baky *et al*. (2019) reported that application of fulvic acid enhanced the vegetative growth by increasing the root growth, leaf area and chlorophyll accumulation in faba beans. Enhanced root growth promotes the availability of nutrients to plants and may resulted in increased plant height. Increased plant height by application of micronutrient mixture “*sampoorna*” might be due to its effect on physiological activities such as cell division and cell elongation which is regulated by the enzyme IAA. Similar results were observed by Jhon (2019) and Eisa and Ali (2014). Zinc is directly involved in IAA synthesis (Srivastava and Gupta, 1996) and Fe plays a prominent role in photosynthesis (Taiz and Zeiger, 2002). Manganese is the major component of hill reaction, which is necessary for photosynthesis and due to varying oxidation state, became a part of electron transport system of chloroplast (Srivastava and Gupta, 1996). Molybdenum is important for the nitrate reduction and nitrogen fixation due to its involvement in nitrate reductase enzyme and nitrogenase enzyme respectively (Deb *et al*., 2006; Bhuiyan *et al*., 2008). These functions of micro nutrients might be the reason for enhanced the vegetative characters of the cowpea.

At flowering stage KAU POP Recommendations along with *sampoorna* as a foliar spray produced maximum plant height and was on par with all treatments except KAU adhoc organic POP recommendations+ without foliar application, KAU adhoc organic POP recommendations+ micro nutrient solution, KAU adhoc organic POP recommendations+ humic acid and KAU POP recommendations + *jeevamrutham.* At harvesting stage KAU adhoc organic POP recommendations along with fulvic acid spray significantly enhanced the plant height, which was on par with KAU POP recommendations + *sampoorna*. KAU adhoc organic POP recommendations+ fulvic acid and KAU POP recommendations + *sampoorna e*nhanced the plant height significantly both at flowering and at harvesting stage. Similar findings were reported by Paliwal *et al.,* 1999; Ahmed and Elzaawely, 2010. Macro and micro nutrients are effectively supplied by farm yard manure (Babaji *et al*., 2011) that helps to enhance vegetative growth characters. Fulvic acid application as foliar spray increase chlorophyll production and more photosynthates accumulation will be possible (Abdel-Baky *et al*., 2019). Combination of these effects are the reason behind the interaction effect of KAU adhoc organic POP recommendations+ fulvic acid. Application of NPK as inorganic fertilizers and micro nutrients availability through micro nutrient mixture *sampoorna* triggers the vegetative growth in treatment KAU POP recommendations + *sampoorna*.

5.1.2. Number of branches per plant

Number of branches per plant was significantly influenced by the foliar nutrition. At flowering stage foliar application of humic acid and micronutrient solution increased the number of branches per plant. The foliar application of humic acid and *sampoorna* has increased number of branches per plant and was significantly superior to other treatments at harvesting stage.

Humic acid application enhanced the number of branches per plant. This may be due to the nutrient uptake by the crops. Similar results were reported by Sani (2014) and Malik and Azam (1985). Liu *et al.* (1998) suggested that application of humic acid stimulated the root growth. Stimulation and proliferation of roots helps in enhanced nutrient uptake and production of more number of branches per plant. Increased number of branches per plant with respect to micro nutrient solution and *sampoorna* may be due to the involvement of micronutrients in physiological aspects of crop growth. Eisa and Ali (2014) observed that application of micro nutrient mixture enhanced the number of branches per plant in cowpea. Gad and El-Moez (2013) also reported similar results.

5.1.3. Number of nodules per plant

Application of *jeevamrutham* significantly enhanced the number of nodules per plant. Olayinka *et al.* in 1998 proved that application of cow dung increased nitrogen fixation by enhanced availability of nutrients like P, K and Ca, which promotes the rhizobial growth (Hiltbold *et al*., 1985). The increased number of nodules per plant in this treatment might be due to the increased content of cow dung in the preparation of *jeevamrutham*. Among the interaction effects, foliar application of *jeevamrutham* along with KAU POP recommendations produced more number of nodules per plant

5.1.4. Leaf area of the plant

Leaf area of the plant was significantly influenced by the nutrient management systems both at flowering and at harvesting stage. KAU POP recommendations significantly increased the leaf area both at flowering and at harvesting stage. It may be due to the increased availability of major nutrients N, P and K (Table 10) which enhances the vegetative growth. This result was in conformity with Ahmed and Elzaawely, 2010; Paliwal *et al.,* 1999; and Vachhani and Patel, 1993.

5.1.5. Total dry matter production

KAU POP recommendations significantly increased the total dry matter production of the plant. This may be due to the increased leaf area and better growth observed in this treatment. Application of inorganic fertilizers ensure the availability of nutrients to plants in time. This results was in accordance with the findings of Ahmed and Elzaawely, (2010). Foliar nutrition significantly influenced the dry matter production. At flowering stage micro nutrient solution, *jeevamrutham*, fulvic acid and humic acid were on par and significantly superior over other treatments. Foliar nutrition *jeevamrutham* and fulvic acid enhanced the total dry matter production at both stages. Vemaraju (2014) reported that application of *jeevamrutham* enhanced the total dry matter production in oriental pickling melon. Increased dry matter production achieved by fulvic acid application may be due to the capacity of fulvic acid to enhance vegetative growth, which results from the enhanced chlorophyll production that triggered the photosynthates accumulation (Abdel-Baky *et al*., 2019)

5.2. EFFECT OF MANAGEMENT SYSTEM AND FOLIAR NUTRITION ON YIELD AND YIELD ATTRIBUTES OF COWPEA

The treatment with fulvic acid foliar application recorded the highest number of pods per plant (12.99) followed by application of *sampoorna* and *jeevamrutham* which were on par and significantly superior to other treatments. The positive influence of fulvic acid on number of pods per plant was reported earlier by Al-Jana *et al.* (2018). This may be due to the enhanced chlorophyll and protein synthesis, which resulted in more carbohydrate accumulation. The results were in line with the findings of Suh *et al.,* 2014; Abdel-Baky *et al.*, 2019. Application of *sampoorna* as foliar nutrition was on par with the fulvic acid application. Similar results were noted by Eisa and Ali, 2014. According to them increment in number of pods per plant was due to the improvement in vegetative growth and chlorophyll accumulation leads to increase in photosynthesis. According to Bhuiyan *et al.* (2008) micro nutrients helps in the pigment formation, photosynthesis activation and more phosynthates get accumulated in the seeds. Vemaraju (2014) reported that application of *jeevamrutham* enhanced the number fruits per plant in oriental pickling melon. He concluded that the growth regulators present in the *jeevamrutham* such as GA and IAA are needed for cell elongation and other physiological activities, which helps to achieve higher yield.

Pod weight per plant was significantly increased by the KAU POP recommendations. This may be due to the increased availability of nutrients resulted in enhanced vegetative growth which leads to the increased pod weight per plant. Foliar nutrition of *jeevamrutham* enhanced the pod weight per plant and was on par with all other foliar nutrition. This was in line with the findings of Vemaraju (2014). He said that application of liquid organic manures enhanced the nutrient availability and enhanced the growth parameters and later more vegetative phase get converted to reproductive phase.

KAU POP Recommendations recorded the highest pod yield compared to KAU adhoc organic POP recommendations. Application of nutrients through inorganic fertilizer increased the availability and uptake of nutrients which in turn enhanced the vegetative growth and increased the yield by allocating more photosynthates to plant parts. Similar results were reported by Sannigrahi *et al. (*2001) in cowpea.

Pod yield was highest in humic acid followed by fulvic acid, which were on par and superior to other treatments. This may be due to increased number of seeds per pod, pods per plant and pod weight (Table 8). Increased pod yield obtained from humic acid was in line with the findings of El-Bassiony *et al.,* 2010. Abbas (2013) reported that humic acid have the capacity to enhance vegetative growth and nutrient uptake, there by the competition between the pods for nutrient uptake can be decreased and also it influences the carbohydrate and protein biosynthesis in plants, which further increased the pod yield of the plant. Abdel-Baky *et al*. (2019) confirmed that application of fulvic acid enhanced the pod yield by increasing photosynthetic activity, vegetative growth, and translocation of photosynthates to reproductive parts of plants. Similar results were reported by Rauthan and Schnitzer (1981) and they suggested that increase in yield may be due to the increase in flower production by activating the enzyme responsible for flower production.

As in the case of pod yield, seed yield was also higher in the treatment $S_{2,}$ where KAU POP recommendations was followed. This may be due to the increased availability of major nutrients (Table 10) by application of inorganic fertilizers which enhanced the vegetative growth, produced more number of pods per plant, seeds per pod and pod yield (Table 8). This was in conformity with the findings of Ali *et al.,* 2006; Daramy *et al*., 2017; Joshi *et al*., 2016.

Foliar application of fulvic acid produced maximum seed yield which was on par with application of humic acid and micronutrient solution. Increased seed yield with fulvic acid was in line with the findings of Abdel-Baky *et al* (2019) in faba bean. Fulvic acid application as foliar spray increased the photosynthesis (Anjum *et al.,* 2011) by increasing the chlorophyll content (Chen *et al.,* 2004) and enhanced the photosynthates and transport of photosyntates to reproductive parts. Among the interactions, KAU POP recommendations along with all foliar application increased the pod yield compared to other treatment. This results collaborates the findings of Waqas *et al.* (2014); Khan *et al.* (2010); Vanitha and Mohandass (2014); Thenmozhi *et al.* (2004) and David and Samule (2002).

5.3. EFFECT OF MANAGEMENT SYSTEM AND FOLIAR NUTRITION ON PLANT NUTRIENT CONTENTS

KAU POP Recommendation includes the application of major nutrients *viz.* nitrogen, phosphorus and potassium through inorganic fertilizers while KAU adhoc organic POP recommendations follow the application of nutrients through organic manures. Nitrogen content in plant, grain and N uptake was highest in treatment with KAU POP recommendation both at flowering and harvesting stage. This may be due to the increased availability of N from inorganic fertilizer like urea and efficient translocation of N from vegetative parts to reproductive parts. Similar results were reported by Pandya and Bhatt, 2007; Verma *et al.* (2015). High N content and dry matter production may lead to higher N uptake compared to KAU adhoc organic POP.

Foliar application of fulvic acid enhanced the N content and uptake in grain and this was in line with the findings of Khalil, *et al.* (2011). They concluded that fulvic acid application enhanced the protein content in cucumber.

Phosphorous content was highest in KAU adhoc organic POP at flowering stage and this may be due to the application of farm yard manure. Minhas and Sood (1994) confirms this result. The nutrient uptake was more in KAU POP recommendation at harvesting stage, this may be due to the higher dry matter production associated with KAU POP recommendation at harvesting stage (Table 7)

KAU POP Recommendation significantly increased the K content in plant and K uptake by plant and grain. This may be due to the increased availability of K from inorganic fertilizer like MOP and efficient translocation of K from vegetative parts to reproductive parts (Table 10, 13, 15 and 17). Significantly high dry matter production and high K content in plant leads to highest nutrient uptake in KAU POP recommendation. Experiment conducted by Pandya and Bhatt (2007) also reported similar results.

Maximum K content of plant was recorded in *jeevamrutham* foliar spray, which was on par with application of humic acid and fulvic acid at flowering stage. Sutar *et al*. (2017) and Palekar (2006) found that *jeevamrutham* foliar spray has enhanced plant K content. El-Bassiony *et al.* (2010) recorded that the application of humic acid enhanced the potassium content of plant in snap bean. KAU adhoc organic POP recommendations enhanced the K content of the grain but the uptake was highest in KAU POP. This may be due to the enhanced grain yield in KAU POP. Potassium content of the grain was significantly influenced by the foliar nutrition except micro nutrient solution and *jeevamrutham.*

Even though individual effect of foliar nutrition and management system were not significant with respect to Ca content of plant, interaction effects except KAU POP along with fulvic acid and KAU POP along with micro nutrient solution were significant at harvesting stage. KAU POP management enhanced the calcium uptake of plant. Foliar nutrition fulvic acid and *jeevamrutham* were on par and significantly superior over other treatments with respect to calcium uptake of plant. This may be due to the enhanced dry matter production at harvesting stage (Table 7) which provides an opportunity for more uptake.

Individual effect of management system and foliar nutrition were significant in the case of Mg content in plant, grain and Mg uptake. Maximum dry matter production and Mg content of plant leads to higher Mg uptake by plant. KAU POP enhanced the S content of plant. Foliar nutrition fulvic acid enhanced the S content of plant because the fulvic acid contains 0.25 % S. KAU organic POP with humic acid, KAU POP without foliar application, KAU POP along with *sampoorna* and KAU POP with fulvic acid were on par and significantly superior over other treatments.

Maximum Fe content was observed with inorganic micro nutrient formulation both at flowering and at harvesting stage and was on par with *sampoorna a*nd fulvic acid at both stages. Micro nutrient formulation and *sampoorna* contains Fe as a constituent. The findings are in accordance with the results obtained by Jhon (2019). Interaction of foliar nutrition and management system influenced the Fe content in grain and KAU POP recommendation along with fulvic acid foliar spray enhanced the iron content of grain and it was on par with KAU organic POP with *jeevamrutham.*

Sampoorna, *jeevamrutham* and fulvic acid were on par and significantly enhanced the Zn content of plant at harvesting stage. Zinc uptake was enhanced by all treatments except micro nutrient solution and control. *Sampoorna* consists of Zn 3.5-

5% and due to this, application of *sampoorna* as foliar spray increased the Zn content and uptake in plant. Rauthan and Schnitzer (1981) found that application of fulvic acid enhanced the Zn uptake in cucumber. They found that fulvic acid increased the root branching and improves the surface area for nutrient absorption. In case of grain KAU POP Recommendation enhanced the Zn content of grain. In foliar nutrition, all treatments except control significantly influenced the Zn content of grain.

Copper content of the plant was influenced by the foliar nutrition at harvesting stage. Foliar nutrition with humic acid recorded maximum Cu content and was on par with *jeevamrutham* and fulvic acid. Sharif *et al.* (2002) also reported similar results with respect to humic acid in maize. Humic acid attracts Cu ions due to chelation and prevent them from leaching and make it more available for plants thus increases the accumulation (Yingei, 1988) similar effects were also observed with fulvic acid and *jeevamrutham.* In grain, Cu content was highest for KAU POP recommendation. All foliar nutrition except control influenced the Cu content.

5.4. EFFECT OF MANAGEMENT SYSTEM AND FOLIAR NUTRITION ON SOIL ANALYSIS

KAU POP recommendation enhanced the organic carbon content in soil. In foliar nutrition, fulvic acid application was on par with micro nutrient solution and *jeevamrutham*. Fulvic acid increased the organic carbon content in soil. Khalil *et al* (2011) found that application of fulvic acid as soil and foliar application enhanced the organic matter content of the soil as the fulvic acid itself is a major component of organic substances (Mecan and Petrovic, 1995). With respect to interactions, application of fulvic acid along with KAU POP recommendation increased the organic carbon content of the soil which was on par with S_2F_1 and S_2F_2.

Available N content of the soil did not vary significantly with management system, foliar nutrition and their interaction effects. However, management system, KAU adhoc organic POP and foliar nutrition of humic acid resulted in higher N content without any significant differences. Application of humic acid enhanced the N content of the soil. These findings are supported by the results obtained by Guminski (1968).

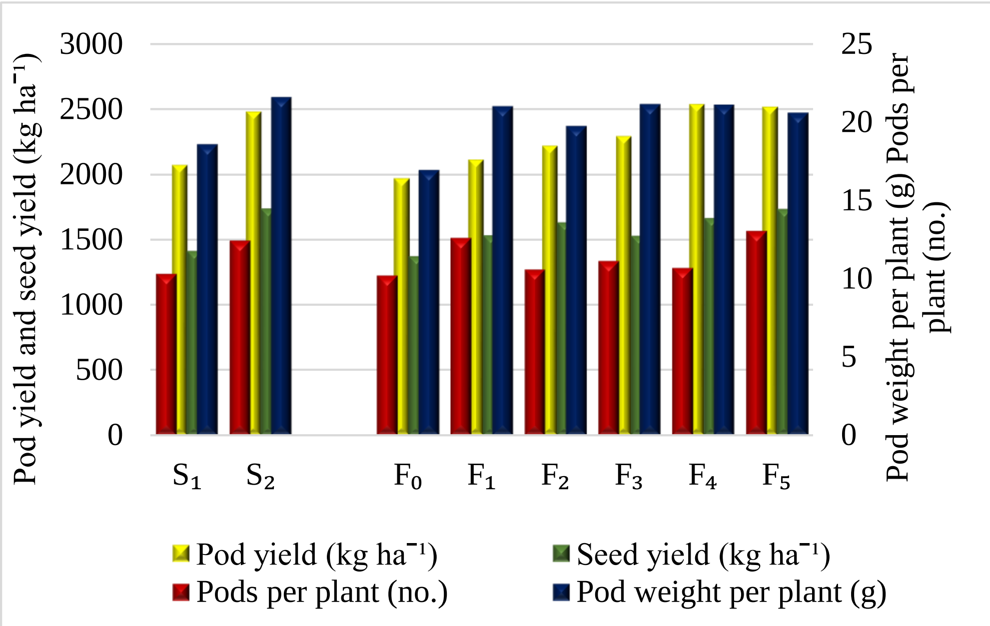

Fig 3. Effect of management system and foliar nutrition on yield and yield attributes

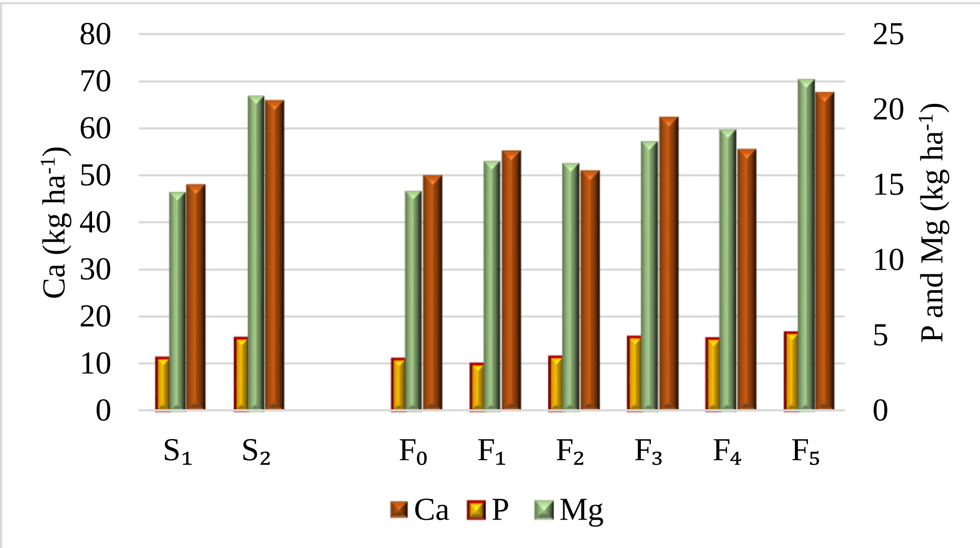

Fig 4. Effect of management system and foliar nutrition effects on nutrient uptake of P, Ca and Mg

After the harvest of crops, maximum P content was observed with KAU adhoc organic POP. This may be due to the residual effect. The removal and uptake of P by the plant and grain was highest in KAU POP compared to KAU adhoc organic POP.

Available K content in the soil was significantly increased by the management system KAU POP recommendation. Soil application of MOP enhanced the K content of soil. Similar results were obtained by Santhosh (2008). He found that 100% recommended dose of fertilizer enhanced the available K content of soil.

The nutrient content, dry matter production and uptake of Ca by plant was found to be lowest in control and hence more amount of Ca may be left in the soil as unabsorbed. This might have resulted in increased Ca content of soil after harvest of crops. Similar trend was observed in treatment interactions where, KAU adhoc organic POP with no foliar nutrition showed higher Ca content in soil.

Available Mg content in soil was significantly influenced by foliar nutrition. Application of micronutrient solution recorded maximum available Mg content in soil which was on par with fulvic acid, *jeevamrutham* and no foliar application.

Since the lowest uptake of S by plant was associated with KAU organic POP and no foliar nutrition, so maximum S content in soil was recorded in these treatments.

Manganese content of the soil was found higher in KAU adhoc organic POP recommendations. All foliar nutrition except fulvic acid and humic acid enhanced the Mn content in soil.

5.5. PEST AND DISEASE INCIDENCE

The Influence of pests and diseases on growth and yield of cowpea was negligible and this may be due to better climatic conditions prevailed during the growth period of the crop and proper and timely adaptation of management practices.

5.6. ECONOMICS

Nutrient management system and foliar nutrition significantly influenced the gross income, net return and BCR. KAU POP enhanced the gross income compared to

KAU organic POP. Foliar nutrition- Fulvic acid, humic acid and micronutrient solution were on par and significantly superior over other treatments with respect to gross return. This may due to the increased seed yield associated with these treatments. KAU POP enhanced the net return and BCR. Fulvic acid application enhanced the net return and BCR and was on par with micro nutrient solution and humic acid.

KAU POP along with fulvic acid enhanced the BCR and was on par with treatment combinations consisting KAU POP management system and foliar nutrition except control.

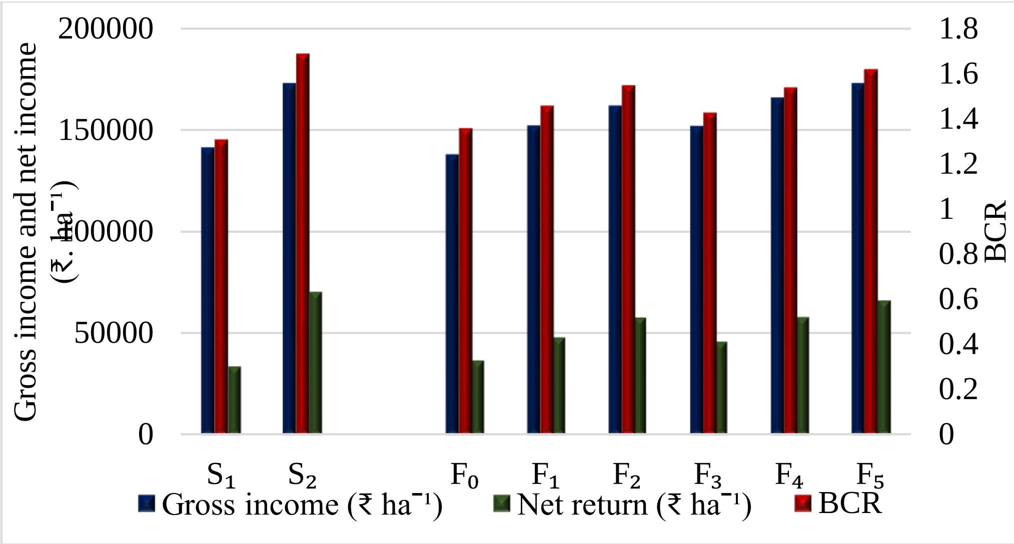

Fig 5. Effect of management system and foliar nutrition on gross return, net return and BCR

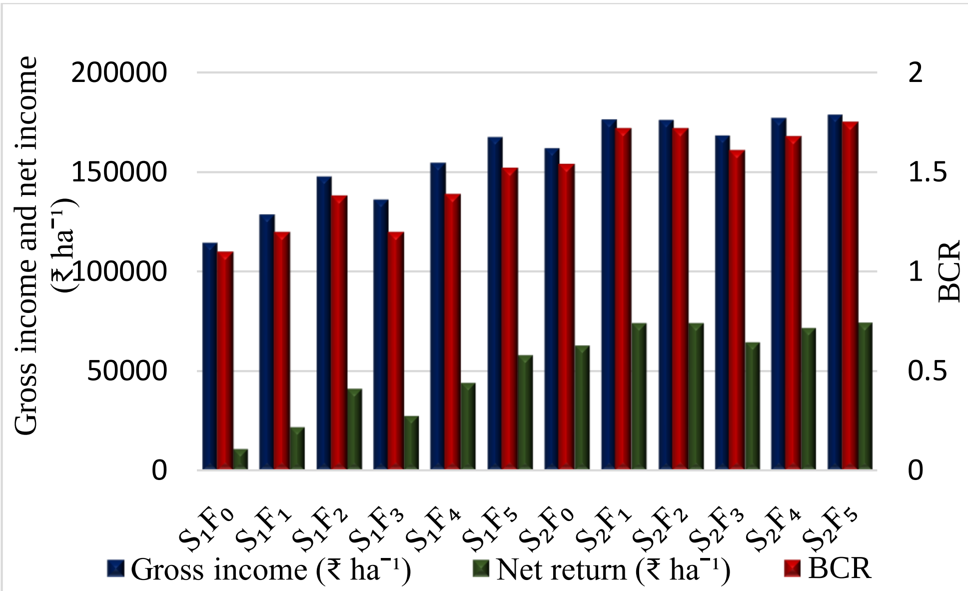

Fig 6. Interaction effects on gross return, net return and BCR

SUMMARY

6. SUMMARY

An investigation entitled "Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems" was undertaken during 2019-2020. The field experiment was conducted during October- December 2019 at Regional Agricultural Research Station, Pilicode and College of Agriculture, Padannakkad.

The experiment was laid out in factorial RBD with two factors, management system and foliar nutrition with three replication. Management system consists of KAU adhoc organic POP recommendations and KAU POP recommendations. Five foliar nutritions *viz*. '*sampoorna*- KAU multi nutrient mix', micro nutrient solution, *jeevamrutham,* humic acid and fulvic acid were included in the study. The treatment combinations were, KAU adhoc organic POP recommendations (S_1F_0), KAU adhoc organic POP recommendations+ *sampoorna* (S_1F_1), KAU adhoc organic POP recommendations+ micronutrient solution (S_1F_2), KAU adhoc organic POP recommendations+ *jeevamrutham* (S_1F_3), KAU adhoc organic POP recommendations+ humic acid (S_1F_4), KAU adhoc organic POP recommendations+ fulvic acid (S_1F_5), KAU POP recommendations (S_2F_0), KAU POP recommendations + *sampoorna* (S_2F_1), KAU POP recommendations+ micronutrient solution (S_2F_2), KAU POP recommendations + *jeevamrutham* (S_2F_3), KAU POP recommendations + humic acid (S_2F_4) and KAU POP recommendations + fulvic acid (S_2F_5). The crop variety used for the study was cowpea var. PGCP 6. The results of the experiments are summarized below.

1) Foliar nutrition influenced the plant height at harvesting stage. Fulvic acid foliar spray enhanced the plant height and was on par with *sampoorna*. At flowering stage KAU POP recommendation along with *sampoorna* significantly increased the plant height and was on par with all treatments except S_1F_0, S_1F_2, S_1F_4 and S_2F_3. At harvesting stage KAU organic POP along with fulvic acid enhanced the plant height and was on par with KAU POP along with *sampoorna.*

2) Humic acid enhanced the number of branches per plant both at flowering and harvesting stages followed by micro nutrient solution at flowering and *sampoorn*a at harvesting stage.

3) Number of nodules per plant was highest in *jeevamrutham* treated plots. KAU POP along with *jeevamrutham* enhanced the number of nodules per plant.

4) Among the management systems, KAU POP increased the leaf area and total dry matter production both at flowering and harvesting stages. Maximum dry matter production obtained from fulvic acid and was on par with F_2, F_3 and F_4 at flowering and F_3 at harvesting stage.

5) In cowpea, pod weight per plant, number of pods per plant, pod yield and seed yield were enhanced by KAU POP management system compared to KAU adhoc organic POP recommendation.

6) Number of pods per plant was increased by fulvic acid foliar spray and was on par with *jeevamrutham* and *sampoorna.*

7) KAU POP recommendation along with humic acid spray increased the pod weight per plant and was on par with S_2F_1, S_2F_2, S_2F_3, S_2F_5 and S_1F_3.

8) Pod yield was found to be highest in humic acid spray and was on par with fulvic acid foliar spray. Seed yield was enhanced by the fulvic acid foliar spray, which was on par with humic acid and micro nutrient solution.

9) With regard to nutrient content and uptake by the plant, N content and uptake was increased by KAU POP recommendation at flowering and harvesting stages. Same trend was observed with Potassium and magnesium content of plant compared to KAU adhoc organic POP.

10) Application of humic acid as foliar spray enhanced the K content and was on par with *jeevamrutham* and fulvic acid at flowering stage. In magnesium content of plant was humic acid and fulvic acid were on par and superior over other foliar nutrition.

11) At flowering stage, KAU POP management system with fulvic acid recorded maximum S content and was on par with S_2F_0, S_2F_1 and S_1F_4.

12) Iron content of plant was significantly increased by foliar nutrition and application of micro nutrient solution recorded the maximum both at flowering and harvesting stages. At flowering stage micro nutrient solution was on par with *sampoorna*, *jeevamrutham* and fulvic acid and at harvesting stage it was on par with *sampoorna* and fulvic acid.

13) Zinc content of plant was increased by *sampoorna* and was on par with *jeevamruthm* and fulvic acid. Humic acid increased the Cu content of pant at flowering stage and was on par with *jeevamrutham* and fulvic acid

14) In grain, N, Ca, Mg, S, Mn, Zn and Cu contents were enhanced by KAU POP compared to KAU adhoc organic POP.

15) Fulvic acid increased the N content of grain. Humic acid increased the K content of grain and was on par with F_0 and F_1. Fulvic acid and humic acid were on par and significantly superior over other treatments with respect to Ca content of grain. Similar effect was observed with Mg content of grain also.

16) Sulphur content of grain was highest in micro nutrient solution and was on par with *sampoorna*, fulvic acid and humic acid. Zinc content of grain was found to be highest in *sampoorna*, which was on par with micronutrient solution, *jeevamrutham*, fulvic acid and humic acid. Humic acid enhanced the Cu content of grain and was on par with all foliar nutrition except control

17) Nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, iron, manganese, zinc and copper uptake by plant and grain were enhanced by KAU POP nutrient management system.

18) Fulvic acid foliar spray significantly increased the N uptake by grain. KAU POP along with micro nutrient solution, humic acid and fulvic acid were on par and significantly superior over other treatment combination.

19) Maximum P uptake by plant and grain was obtained from fulvic acid and was on par with *jeevamrutham* and humic acid in plant, and with *jeevamrutham*, humic acid and micro nutrient solution in grain.

20) Highest uptake of Ca and Mg were obtained from fulvic acid foliar spray in plant. Fulvic acid was on par with *jeevamrutham* with respect to Ca uptake by plant.

21) Uptake of S by grain was found to be highest in fulvic acid foliar spray. KAU POP along with humic acid enhanced the Mg and S uptake by grain and was on par with S_2F_2 and S_2F_5.

22) Application of Fulvic acid enhanced the Fe uptake by plant and grain. In plant it was on par with micro nutrient solution. In grain manganese uptake by plant was improved by fulvic acid , micro nutrient solution and humic acid.

23) KAU POP along with humic acid increased Mn uptake of grain and was on par with S_1F_5 S_2F_0, S_2F_2 and S_2F_5. Maximum Zn uptake by plant was observed in *sampoorna* foliar application and was on par with *jeevamrutham*, fulvic acid and humic acid.

24) With regard to Cu uptake in grain, *Sampoorna*, fulvic acid and humic acid were on par and superior to other treatments.

25) KAU POP along with humic acid enhanced the uptake of Zn and Cu by grain and was on par with KAU POP with micronutrient solution in the case of Zn and KAU POP with *sampoorna* in Cu.

26) KAU POP recommendation significantly increased the OC content of soil after harvest of cowpea. Maximum OC content was obtained from fulvic acid, which was on par with micro nutrient solution and *jeevamrutham*. KAU POP along with fulvic acid enhanced the OC content of soil and was on par with S_2F_1 and S_2F_2.

27) Humic acid increased the available N content of soil. Maximum P content was obtained from KAU adhoc organic POP. Foliar nutrition, micro nutrient solution and the combination of KAU organic POP along with micro nutrient solution enhanced the available P content of soil. Available K content of soil was found highest in KAU POP management system.

28) Foliar nutrition, F_0 and interaction effect S_1F_0 enhanced the calcium content of soil after harvest. Highest Mg content of the soil was observed with foliar nutrition of micronutrient solution and was on par with F_0, F_3 and F_5. In soil maximum S content was observed with management system, S_1 and foliar nutrition, F_0. Maximum Mn content was observed with KAU organic POP. Foliar nutrition F_0, F_2, F_1 and F_3 significantly enhanced the Mn content of soil after harvest of cowpea.

29) With regard to economics, KAU POP management system enhanced the gross income, net return and BCR compared to KAU adhoc organic POP. Among foliar nutrition, maximum gross income, net return and BCR were associated with fulvic acid foliar spray and was on par with humic acid and micro nutrient solution.

30) KAU POP recommendation along with fulvic acid significantly increased the BCR and was on par with S_2F_1, S_2F_2, S_2F_3 and S_2F_4

Future line of work

- Further research is required to explore the microbial growth associated with management systems and foliar nutrition.
- Experiments on effect of organic and inorganic foliar nutrition should be conducted in different crops.

REFERENCES

7. REFERENCES

Abayomi, Y. A., Ajibade, T. V., Sammuel, O. F., and Sa'adudeen, B. F. 2008. Growth and Yield Responses of Cowpea (*Vigna unguiculata* (L.) Walp). *Asian J. plant sci.* 7(2): 170-176.

Abbas, S. M. 2013. The influence of biostimulants on the growth and on the biochemical composition of *Vicia faba* CV. Giza 3 beans. *Romanian Biotechnol. Lett.* 18(2): 8061-8068.

Abdel-Baky, Y. R., Abouziena, H. F., Amin, A. A., El-Sh, M. R., and El-Sttar, A. A. 2019. Improve quality and productivity of some faba bean cultivars with foliar application of fulvic acid. *Bull. Natl. Res. Cent.* 43: 1-11.

Adeoye, P. A., Adebayo, S. E., and Musa, J. J. 2011. Growth and yield response of cowpea (*Vigna unguiculata*) to poultry and cattle manure as amendments on sandy loam soil plot. *Agric. J.* 6(5): 218-221.

Ahmed, A. A., Abd El-Baky, M. M. H., Zaki, M. F., and Abd El-Aal, F. S. 2011. Effect of foliar application of active yeast extract and zinc on growth, yield and quality of potato plant (*Solanum tuberosum* L.). *J. Appl. Sci. Res*. 7(12): 2479-2488.

Ahmed, M. E. and Elzaawely, A. A. 2010. Growth and yield of cowpea plants in response to organic fertilization. *Australian J. Basic Appl. Sci.* 4(8): 3244-3249.

Ali, A., Nadeem, M., and Ejaj, M. 2006. Effect of different levels of potash on growth and yield of mungbean varieties. *J. Agric. Res*. 44(2): 121-126.

Al Jana, M. H. N., Radhi, M. A., and Rahy, E. 2018. Effects of foliar application with fulvic acid on the growth, yield and protein content of three genotypes of faba bean (Vicia faba L.). *J. Res. Ecol.* 6(2): 1965-1975.

Amareswari, P. U. and Sujathamma, P. 2014. *Jeevamrutha* as an alternative chemical ferilizers in rice production. *Agric. Sci. Dig*. 34(3): 240-242.

Anitha, S., Sreenivasan, E., and Purushothaman. 2005. Response of cowpea (*Vigna unguiculata* L.) to foliar nutrition of zinc and iron in the oxisols of Kerala. *Legume Res.* 28 (4): 294-296.

Anjum, S. A., Wang, L., Farooq, M., Xue, L., and Ali, S. 2011. Fulvic acid application improves the maize performance under well-watered and drought conditions. *J. Agron. Crop Sci.* 197(6): 409-417.

Anwar, M., Patra, D. D., Chand, S., Alpesh, K., Naqvi, A. A., and Khanuja, S. P. S. 2005. Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation, and oil quality of French basil. *Commun. Soil Sci. plant Anal.* 36(13-14): 1737-1746.

Atiyeh, R. M., Lee, S., Edwards, C.A., Arancon, N. Q., and Metzger, J. D. 2002. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresour. Technol.* 84(1): 7-14.

Azarpour, E., Danesh, R. K., Mohammadi, S., Bozorgi, H. R., and Moraditochaee, M. 2011. Effects of nitrogen fertilizer under foliar spraying of humic acid on yield and yield components of cowpea (*Vigna unguiculata*). *World Appl. Sci. J.* 13(6): 1445-1449.

Babaji, B. A., Yahaya, R. A., Mahadi, M. A., Jaliya, M. M., Sharifai, A. I., Kura, H. N., Arunah, U. L., Ibrahim, A., and Ajeigbe, H. 2011. Growth attributes and pod yield of four cowpea (*Vigna unguiculata* (L.) Walp.) varieties as influenced by residual effect of different application rates of farmyard manure. *J. Agric. Sci.* 3(2): 165-171.

Bahrani, A. and Pourreza, J. 2014. Effects of micronutrients on seed yield and oil content of *Brassica napus* L. cv. Talayeh. *Bangladesh J. Bot.* 43(2: 231-233.

Bama, K. S. and Selvakumari, G. 2005. Effect of humic acid and fertilizers on yield and nutrition of rice in alfisol. *J. Ecobiol*. 17(1): 41-47.

Balachandar, D., Nagarajan, P., and Gunasekaran, S. 2003. Effect of organic amendments and micronutrients on nodulation and yield of blackgram in soil. *Legume Res.* 26(3): 192-195.

Banger, K., Kukal, S. S., Toor, G., Sudhir, K., and Hanumanthraju, T. H. 2009. Impact of long-term additions of chemical fertilizers and farm yard manure on carbon and nitrogen sequestration under rice-cowpea cropping system in semi-arid tropics. *Plant soil* 318(1-2): 27-35.

Basavaraj, K., Devakumar, N. and Sheshadri, T., 2016. Influence of farm yard manure, jeevamrutha and panchagavya on growth and yield of french bean (Phaseolus vulgaris L.). *Mysore J. Agric. Sci*. 50(2): 279-283.

Basole, V. D., Deotale, R. D., Ilmulwar, S. R., Raut, S. S., and Kadwe, S. B. 2003. Effect of hormone and nutrients on morphological characters and yield of soybean. *J. Soils Crops* 13(1): 135-139.

Bhargava, B. S. and Raghupathi, H. B. 1995. Analysis of plant material for macro and micronutrients. In: Tandon, H.L.S. (ed.), *Methods of analysis of soils, plants, water and fertilizers*. Malhotra publishing house, New Delhi, pp. 61-62.

Bhuiyan, M. M. H., Rahman, M. M., Afroze, F., Sutradhar, G. N. C., and Bhutyan, M. S. I. 2008. Effect of phosphorus,molybdenum and rhizobium inoculation on growth and nodulation on mungbean. *J. Soil Nature* 2(2): 25-30.

Black, C. A., Evans, D. D., Ensminger, L. E., White, J. L., and Clark, F. E. 1965. *Methods of soil analysis*. *Am. Soc. Agron.* Madison, USA, 156p.

Bocanegra, M. P., Lobartini, J. C., and Orioli, G. A. 2006. Plant uptake of iron chelated by humic acids of different molecular weights. *Commun. Soil sci. Plant anal.* 37(1-2): 239-248.

Boraiah, 2013. Effect of organic liquid formulations and manures on growth and yield of capsicum (*Capsicum annuum* L. var. grossum). Ph.D. (Ag) thesis, University of Agricultural Sciences, Bangalore, 472p.

Borkar, M. S. 2019. Influence of foliar application of organic products on growth nutrient uptake and yield of okra *(Abelmochus esculentus)* in inceptisol. Ph. D. (Ag) thesis. Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, 109p.

Bressani, R. 1985. Nutritive value of cowpea. In: Singh, S. R. and Rachie, K. O. (eds), *Cowpea Research, Production and Utilization.* John Wiley and Sons Ltd., Chichester, pp. 353–359.

Buisiness line. 2011. Kasaragod declared organic farming district [On-line]. Available:https://www.thehindubusinessline.com/economy/policy/kasaragod-declared-organic-farming-district/article23056113.ece. [06 June 2020].

Burkhardt, J., Dreitz, S., Goldbach, H. E., and Eichert, T. 1999. Stomatal uptake as an important factor for foliar fertilization. In: Soil and Fertilizer Society (ed.), *Technology and Application of Foliar Fertilizers.* Proceedings of the Second International Workshop on Foliar Fertilization, Thailand, Bangkok. Soil and Fertilizer Society of Thailand, Bangkok, pp. 63–72.

Cantisano, A. 2000. What to use for foliar feeding. In: Byczynski, L. (ed.), *Growing for the Market*. Fairplain Publications, Lawrence, pp. 4–6.

Chandrakala, M. 2008. Effect of FYM and fermented manures on yield and quality of chilli. M.Sc. (Ag) thesis, University of Agricultural Sciences, Dharwad, 85p.

Chatterjee, R. and Bandyopadhyay, S. 2017. Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea (*Vigna unguiculata* L. Walp.) in acid soil of eastern Himalayan region. *J. Saudi Soc. Agric. Sci.* 16(4): 332-336.

Chen, Y., De Nobili, M., Aviad, T. 2004. Stimulatory effects of humic substances on plant growth. In: Magdoff, F. and Weil, R. R. (eds), *Soil Organic Matter in Sustainable Agriculture. C*RC Press, Boca Raton, pp. 103-129.

Chen, Y., Clapp, C. E., Magen, H., and Cline, V. W. 1999 Stimulation of Plant Growth by Humic Substances: Effects of Iron Availability. In: Ghabbour, E. A. and Davies, G. (eds), *Understanding Humic Substances. Advances Methods, Properties and Applications.* Royal Society of Chemistry, Cambridge, pp. 255–263.

Daramy, M. A., Sarkodie-Addo, J., and Dumbuya, G. 2016. The effects of nitrogen and phosphorus fertilizer application on crude protein, nutrient concentration and nodulation of cowpea in Ghana. *J. Agric. Biol. Sci.* 11(12): 470-480.

Daramy, M. A., Sarkodie-Addo, J., and Dumbuya, G. 2017. Effect of nitrogen and phosphorus fertilizers application on growth and yield performance of cowpea in Ghana. *J. Agric. Biol. Sci*. 5: 31-44.

Daur, I. 2013. Comparative study of farm yard manure and humic acid in integration with inorganic-N on wheat (*Triticum aestivum* L.) growth and yield. *J. Agric. Sci.* 19: 170-177.

David, R. A. and Samuel, M. 2002. Plant growth stimulation of lignite humic acid. Part-II. Effect of lignite derived ammonium humate on mustard (*Brassica juncea* L.) using different levels of phosphate fertilizer. *Pakistan Counc. Sci. Ind. Res.* 45: 273-276.

Deb, R., Poddar, P., and Banerjee, S. 2006. Effect of various modes of application of molybdenum on nodulation yield and economics of groundnut cultivation under terai region of West Bengal. *Environ. Ecol.* 24(4): 1081-1084.

Debnath, P., Pattanaaik, S. K., Sah, D., Chandra, G., and Pandey, A. K. 2018. Effect of boron and zinc fertilization on growth and yield of cowpea (*Vigna unguiculata* Walp.) in Inceptisols of Arunachal Pradesh. *J. Indian Soc. Soil Sci.* 66(2): 229-234.

Denelan, P. 1988. Foliar feeding. *Mother Earth's News* 111: 58–61.

Dikhit, P. R. and Khatik, S. K. 2002. Influence of organic manure in combination with chemical fertilizer on production, quality and economic feasibility of soybean in typic hapludalf of Jabalpur. *Legume Res.* 25(1): 53-56.

Divyashree, K. S. 2018. Effect of different methods of micronutrients mixture application on growth and yield of mungbean in Cauvery command area. *J. Pharmacognosy Phytochem.* 7(3): 3578- 3582.

Dybing, C. D. and Currier, H. B. 1961. Foliar penetration by chemicals. *Plant Physiol.* 36(2): 169-174.

Eichert, T. and Burkhardt, J. 2001. Quantification of stomatal uptake of ionic solutes using a new model system. *J. Exp. Bot.* 52(357): 771-781.

Eichert, T., Goldbach, H. E., and Burkhardt, J. 1998. Evidence for the uptake of large anions through stomatal pores. *Botanica Acta* 111(6): 461-466.

Eisa, G. S. A. and Ali, T. B. 2014. Impact spraying of some microelements on growth, yield, nitrogenase activity and anatomical features of cowpea plants. *World J. Agric. Sci.* 10(2): 57-67.

Emmel, R. H., Solera, J. J., and Stux, R. L. 1977. *Atomic absorption methods manual.* Instrumentation Laboratory Inc., Wilmington, pp. 67-190.

EL-Afifi, S. T., Zaghloul, M. M., EL-Saady, W. A., and EL-Gammal, R. E. 2016. Effect of different levels of NPK fertilizers with the foliar application of iron, zinc and boron on vegetative growth and yield of cowpea. *J. Plant Prod.* 7(12): 1245-1254.

El-Bassiony, A. M., Fawzy, Z. F., El-Baky, M. A., and Mahmoud, A. R. 2010. Response of snap bean plants to mineral fertilizers and humic acid application. *Res. J. Agric. Biol. Sci*. 6(2): 169-175.

El-Ghamry, A. M., Abd El-Hai, K. M., and Ghoneem, K. M. 2009. Amino and humic acids promote growth, yield and disease resistance of faba bean cultivated in clayey soil. *Aust. J. Basic Appl. Sci*. 3(2): 731-739.

El-Hak, S. G., Ahmed, A. M., and Moustafa, Y. M. M. 2012. Effect of foliar application with two antioxidants and humic acid on growth, yield and yield components of peas (*Pisum sativum* L.). *J. Hort. Sci. Ornam. Plants* 4(3): 318-328.

Ezzat, M., Lateef, A. E., Tawfik, M. M, Hozyin, M., Bakry, B. A., Elewa, T.A., Farrag, A. A., and Amany. 2012. Soil and foliar fertilization of mungbean (*Vigna radiata* (L) wilczek) under Egyptian conditions. *Elixir Agric.,* 47: 8622-8628.

Franke, W. 1967. Mechanisms of foliar penetration of solutions. *Annu. Rev. Plant Physiol.* 18(1): 281-300.

Gad, N. and El-Moez, M. A. 2013. Influenced of molybdenum on nodulation, nitrogen fixation and yield of cowpea. *J. App. Sci. Res*. 9: 1498-1504.

Gad, N. and Kandil, H. 2013. Evaluate the effect of molybdenum and different nitrogen levels on cowpea (*Vigna unguiculata*). *J. Appl. Sci. Res. 9*(3): 1490-1497.

Gettier, S. W., Martens, D. C., and Brumback, T. B. 1985. Timing of foliar manganese application for correction of manganese deficiency in soybeans. *Agron. J.* 77: 627–629.

Girma, K., Martin, K. L., Freeman, K. W., Mosali, J., Teal, R. K., Raun, W. R., Moges, S. M., and Arnall, D. B. 2007. Determination of optimum rate and growth for foliar applied phosphorus in corn. *Commun. Soil Sci. Plant Anal.* 38: 1137–1154.

Gore, N. S. 2010. Influence of liquid organic manures on microbial activity, growth, lycopene content and yield of tomato (*Lycopersicon esculentum* MILL) in the sterilized soil. M.Sc. (Ag) thesis, University of Agricultural Sciences, Dharwad, 78p.

Guminski, S. 1968. Present-day views on physiological effects induced in plant organisms by humic compounds. *Soviet soil sci.* 9: 1250- 1255.

Gupta, S. C., Singh, R. P., and Verma, R. 2009. Response of chickpea to P levels from different sources with various PSB species. *Legume Res*. 32: 212-214.

Hiltbold, A. E., Patterson, R. M., and Reed, R. B. 1985. Soil population of *Rhizobium japonicum* in a cotton-corn-soybean rotation. *Soil Sci. Soc. Am. J*. 49: 343-344.

IFOAM [International Federation of Organic Agriculture Movements]. 2005 Definition of organic agriculture [On-line]. Available: http://www.ifoam.bio/en/organic-landmarks/definition-organic agriculture. [06 June 2020].

Issac, R. A. and Kerber, J. D. 1971. Atomic absorption and flame photometry techniques and uses in soil, plant and water analysis. In: Walsh, L. M. (ed.). *Instrumental methods for analysis of soil and plant tissue*. Soil Science Society America, Madison, USA, pp. 17-37.

Jackson, M. L. 1958. Soil chemical analysis. In Cliffs, E. N. J. (ed.). Soil Science University of Wisconsin, USA, Madison, pp. 89-102.

Jhon, R. 2019. Evaluation of micronutrient formulation in cowpea (*Vigna unguiculata* L. Walp). M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 124p.

Joshi, D., Gediya, K. M., Patel, J. S., Birari, M. M., and Gupta, S., 2016. Effect of organic manures on growth and yield of summer cowpea [*Vigna unguiculata* (L.) Walp] under middle Gujarat conditions. *Agric. Sci. Digest Res. J.* 36(2): 134-137.

Kabse, S. S., Joshi, M., and Bhasker, S. 2009. Charecterization of farmer´s *jeevamrutha* formulations with respect to aerobic rice. *Mysore Agric. J.* 43(3): 570-573.

Kadam, R. S. 2006. Effect of organic nitrogen sources and fulvic acid application on yield and quailty of soybean in inceptisol Ph.D (Ag) thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, 137p.

Kadam, R. S., Amrutsagar, M. V., and Deshpande, N. A. 2010. Influence of organic nitrogen sources with fulvic acid spray on yield and nutrient uptake of soybean in inceptisol. *J. Soils Crops* 20(1): 58-63.

Kahraman, A. 2017. Effect of humic acid doses on yield and quality parameters of cowpea [*Vigna unguiculata* (L.) Walp] cultivars. *Legume Res.* 40(1): 155-159.

Kanwar, A. and Sharma, S. R. 2014. Effect of organic and inorganic nutrition on fertility status of soil and yield of vegetable cowpea. *Ann. Arid Zone* 53(1): 17-20.

KAU (Kerala Agricultural University). 2016. *Package of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, 392p.

KAU (Kerala Agricultural University). 2017. *Package of Practices Recommendations: (ad hoc) for Organic Farming: Crops.* Kerala Agricultural University, Thrissur, 392p.

Kazi, S. S., Ismail. S., and Joshi, K. G. 2012. Effect of multi-micro nutrient on yield and quality attributes of the sweet orange. *Afr. J. Agric. Res.* 7 (29): 4118-4123.

Khaled, H. and Fawy, H. A. 2011. Effect of different levels of humic acids on the nutrient content, plant growth, and soil properties under conditions of salinity. *Soil Water Res.* 6(1): 21-29.

Khalil, H. M., Ali, L. K., and Mahmoud, A. A. 2011. Impact of applied humic and fulvic acids on the soil physic-chemical properties and cucumber productivity under protected cultivation conditions. *J. Soil Sci. Agric. Eng.* 2 (2): 183-201.

Khan, R. U., Rashid, A., Khan, M. S., and Ozturk, E. 2010. Impact of humic acid and chemical fertilizer application on growth and grain yield of rainfed wheat (*Triticum aestivum* L.). *Pak. J. Agric. Res.* 23: 113-121.

Liu, E., Yan, C., Mei, X., He, W., Bing, S.H., Ding, L., Liu, Q., Liu, S., and Fan, T. 2010. Long-term effect of chemical fertilizer, straw, and manure on soil chemical and biological properties in northwest China. *Geoderma* 158(3-4): 173-180.

Liu, C., Cooper, R. J. and Bowman, D. C., 1998. Humic acid application affects photosynthesis, root development, and nutrient content of creeping bentgrass. *Hort. Sci.* 33(6): 1023-1025.

Maheshbabu, H. M., Ravi, H., Biradar, P. N. K., and Babalad, H. B. 2008. Effect of organic manures on plant growth, seed yield and quality of soybean. *Karnataka J. Agric. Sci*. 21(2): 219-222.

Malik, K. A. and Azam, F. 1985. Effect of humic acid on wheat (*Triticum aestivum* L.) seedling growth. *Environ. Exp. Bot.* 25(3): 245-252.

Mecan, M. K. and Petrovic M. 1995. Competitive sorption of phosphate and marine humic substances on suspended particulate matter. *Water Sci. Technol.* 32: 349-355.

Mengel, K., and Kirkby, E. A. 2001. *Principles of Plant Nutrition*. Springer, Dordrecht, 849p.

Middleton, L. J. and Sanderson, J. 1965. The uptake of inorganic ions by plant leaves. *J. Exp. Bot.* 16(2): 197-215.

Minhas, R.S. and Sood, A. 1994. Effect of inorganics and organics on soil yield and nutrient uptake by three crops in rotation on an acid alfisol. *J. Indian Soc. Soil Sci.* 42(2): 257-260.

Motaghi, S. and Nejad, T. S. 2014. The effect of different levels of humic acid and potassium fertilizer on physiological indices of growth. *Int. J. Biosci.* 5(2): 99-105.

Musa, M. and Singh, A. 2015. Influence of cow dung application on the yield and yield components of two Groundnut (*Arachis hypogaea* L.) varieties in Sokoto, semi-arid zone of Nigeria. *Agric. Trop. Subtrop.* 48(3-4): 75-81.

Ninan, J., Sasidharan, N. K., Biji, C., Ambikadevi, D., and Venugopal, V. 2013. Evaluation of organic flternatives to Fertilizers for the medicinal rice variety-Njavara. In: Vinod, T. R., Sabu, T., and Ambat, B. (eds) *Kerala Environment Congress 2013,* 9-11 October 2013, Thiruvananthapuram. Centre for Environment and Development, pp. 288- 292.

Olayinka, A., Adetunji, A., and Adebayo, A. 1998. Effect of organic amendments on nodulation and nitrogen fixation by cowpea. *J. plant Nutr. 21*(11): 2455-2464.

Oldham, J. L. 2008. *Inorganic fertilizers for crop production*. Mississippi State University Extension Service. 7p.

Olsen, R. j., Henslar, R. F., and Alloe, O. J. 1970. Effect of manure application, aeration and soil pH on soil nitrogen transformations and on cotton soil test values. *Soil Sci. Soc. Am. Proc*. 34: 222-225.

Palekar, S. 2006. *Text book on Shoonya Bandovalada Naisargika Krushi.* Published by Swami Anand, Agri Prakashana, Bangalore, 65p.

Paliwal, R., Naruka, I. S., and Yadav, J. K. 1999. Effect of nitrogen on growth and yield of cowpea (*Vigna unguiculata*) cv. 'pusa –komal'. *Prog. Hort*. 31(1-2): 94-97.

Papadakis, I. E., Sotiropoulos, T. E., and Therios, I. N. 2007. Mobility of iron and manganese within two citrus genotypes after foliar applications of iron sulfate and manganese. *J. Plant Nutr.* 30: 1385– 1396.

Parmar, D. K., Sharma, T. R., Sajni, J. P., and Sharma, V. 1999. Responses of French bean (*Phaseolus vulgaris*) to nitrogen and phosphorus in cold desert area of H.P. *Indian J. Agron*. 444(4): 787-790.

Pandya, C. B. and Bhatt, V. R. 2007. Effect of different nutrient levels on yield and nutrient content of fodder cowpea. *Legume Res.* 30 (3): 218-220.

Pandya, C. B. and Bhatt, V. R. 2009. Effect of fertilizer levels and FYM on yield, nutrient content, soil nutrient status and quality of fodder cowpea [*Vigna unguiculata* (L.) Walp]. *Crop Res.* 38(1/3): 226-229.

Panse, V .G. and Sukhatme, P. V. 1985. Statistical methods for agricultural Research. *ICAR*, New Delhi, 8: 308-318.

Pascual, J. A., Garcia, C., and Hernandez, T. 1999. Comparison of fresh and composted organic waste in their efficacy for the improvement of arid soil quality. *Bioresour. Technol*. 68: 255–264.

Patidar, M. and Mali, A. L. 2004. Effect of farmyard manure, fertility levels and biofertilizer on growth, yield and quality of sorghum. *Indian J. Agron*. 49(2): 117-120.

Pawar, J. B. 2004. Ffect of different composts and their fulvic acid sprays on tomato in inceptisols. Ph.D (Ag) thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, 154p.

Piper. 1966. Aging of crystalline precipitates. *Analyst* 77: 1000-1001.

Poongothai, S. and Chitdeshwari, T. 2003. Response of blackgram to multi micronutrients mixture. *Madras Agric. J*. 90(7-9): 442-443.

Pratt, P. F. 1965. *Potassium in methods of soil analysis*. (2^{nd} Ed.). American Society of Agronomy, Madison, USA, pp. 1019-1021.

Rajashekhar, D., Srilatha, M., Rao, P. C., Sharma, S. H. K., and Rekha, K. B. 2017. Effect of zinc-humate and zinc-fulvate complexes on rice drymatter and availability of zinc. *Bull. Env. Pharmacol. Life Sci.* 6(3): 56-60.

Rajkhowa, D. J., Saikia, M., and Rajkhowa, K. M. 2003. Effect of vermicompost and levels of fertilizer on greengram. *Legume Res.* 26(1): 63-65.

Ram, N. 2000. Long-term effects of fertilizers on rice-wheat-cowpea productivity and soil properties in mollisols. In: Abrol, I. P., Bronson, K. F., Duxbury, J. M., and Gupta, R. K. (eds.). *Long-term soil fertility experiments with rice-wheat* *rotations in South Asia.* Rice-Wheat Consortium Research Series 6. Rice-Wheat Consortium for the Indo- Gangetic Plains, New Delhi, India, pp. 50-55.

Rameeza, E. A. 2011. Shelf life of liquid organic formulations. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 97p.

Rao, M. R., Kumar, M. S., and Jha, N. K. 2015. Comparitive yield analysis of chilli by application of vermicompost and *panchagavya*. *J. Chem. Pharmaceutical Res.* 7(9): 91-98.

Rao, T. S. S. and Shankar, C. R. 2001. Effect of organic manures on growth and yield of brinjal. *S. Indian Hortic*. 49: 288-291.

Rauthan, B. S, and Schnitzer, M. 1981. Effects of a soil fulvic acid on the growth and nutrient content of cucumber (*Cucumis sativus*) plants. *Plant Soil* 63: 491–495.

Rezazadeh, M. K., Nejad, T. S., and Shokouhfar, A. 2014. The effect of different levels of humic acid fertilizer on components of biological nitrogen fixation in cowpea cultivars in Ahvaz. *Int. J. Biosci.* 5(2): 167-174.

Safiullah, K., Durani, A., Durrani, H., and Ansari, M.A. 2018. Effect of solid and liquid organic manures on growth, yield and economics of sweet corn (*Zea mays* L. Var. Saccharata Sturt) under south Gujarat condition. *Int. J. Pure App. Biosci*. 6(2): 567-574.

Sangeetha, M., Singaram, P., and Devi, R. D. 2006. Effect of lignite humic acid and fertilizers on the yield of onion and nutrient availability. In: *Proceedings of 18th World Congress of Soil Science*, 9-15 July 2006, Philadelphia. International Union of Soil Science, pp 9-15.

Sannigrahi, A. K. and Borah, B. C. 2001. Response of cowpea (*Vigna unguiculata*) to varying level of FYM and chemical fertilizers. *Agric. Sci. Digest* 21(1): 67-68.

Santhy, P., Muthuvel, P., and Selvi, D. 2001. Status and impact of organic matter fractions on yield, uptake and available nutrients in a long-term fertilizer experiment. *J. Indian Soc. Soil Sci. 49*(2): 281-285.

Salih, H. O. 2013. Effect of Foliar Fertilization of Fe, B and Zn on nutrient concentration and seed protein of Cowpea "*Vigna unguiculata*". *J. Agric. Vet. Sci.* 6(3): 42-46.

Sani, B. 2014. Foliar application of humic acid on plant height in canola. *APCBEE procedia,* 8: 82-86.

Santhosh, S. C. 2008. Integrated nutrient management for cowpea in southern dry zone of Karnataka (*Vigna unguiculata* L.) M. Sc. (Ag) thesis, University of Agricultural Sciences GKVK, Bengaluru. 122p.

Shanke, B. R., Jadao. B. J., Ghadwe, S. M., and Maharkar, V. K. 2003. Effect of different levels nitrogen on growth and yield of French bean under Akola condition. *Orrisa J. Hort*. 31(1): 123-124.

Sharma, S. R., Bhandari, S. C., and Purohit, H. S. 2002. Effect of organic manure and mineral nutrients on nutrient uptake and yield of cowpea. *J. Indian Soc. of Soil Sci.* 50(4): 475-480.

Sharif, M., Khattak, R. A., and Sarir, M. S. 2002. Effect of different levels of lignitic coal derived humic acid on growth of maize plants. *Commun. Soil Sci. Plant Anal.* 33: 3567–3580.

Shukla, A. K., Behera, S. K., Pakhre, A., and Chaudhari, S. K. 2018. Micronutrients in soils, plants, animals and humans. *Indian J. Fertil. 14*(3): 30-54.

Sims, J. R. and Johnson, G. V. 1991. Micronutrient soil tests. In: Mortvedt, J. J. (ed.), *Micronutrients in Agriculture* (2^{nd} ed.). Soil Science Society of America, Madison, USA, pp. 427-476.

Singh, R. R. and Prasad, K. 2011. Effect of bio-fertilizers on growth and productivity of wheat (*Triticum aestivum*). *J. Farm Sci.*1 (1): 1-8.

Singh, A., Singh, V. K., Rana, N. S., Kumar, S., Panwar, G. S., and Kumar, Y. 2008, Response of urdbean to farmyard manure and phosphorus application under urdbean wheat cropping sequence. *J. Food Legumes* 21 (2): 119-121.

Sing, N. B. and Verma, K. K. 2002. Effect of Phosphorus nutrition on French bean grown in Easer U.P. under late sown condition. *Indian J. Agron*. 479(1): 89-93.

Sreenivasa, M. N., Naik, N., and Bhat, S. N. 2011. Nutrient status and microbial load of different organic liquid manures. *Karnataka J. Agric. Sci*. 24(4): 583-585.

Srivastava, O. P. 1985. Role of organic matter in soil fertility. *Indian J. Agric. Chem.* 18: 257-269.

Srivastava, P. C. and Gupta, U. C. 1996. *Trace Elements in Crop Production*. Science Pub. Inc. Lebanon, NH03766 USA, 366p.

Stevenson, F. J. 1994. *Humus Chemistry: Genesis, Composition, Reactions.* John Wiley and Sons, New York, 242p.

Subbiah, B. V. and Asija, G. L. A. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci*. 32: 325-327.

Suh, H. Y., Yoo, K. S., and Suh, S. G. 2014. Effect of foliar application of fulvic acid on plant growth and fruit quality of tomato (*Lycopersicon esculentum* L.). *Hortic. Environ. Biotechnol.* 55(6): 455-461.

Sutar, R., Sujith, G. M. and Devakumar, N. 2017. Nutrient status and microbial activity as influenced by jeevamrutha and panchagavya in cowpea [*Vigna unguiculata* (L.) Walp.] grown on Alfisols. *Crop Res.* 52(6): 218-223.

Sutar, R., Sujith, G. M., and Devakumar, N. 2019. Growth and yield of Cowpea [*Vigna unguiculata* (L.) Walp] as influenced by *jeevamrutha* and *panchagavya* application. *Legume Res. 42*(6): 824-828.

Tan, K .H. and Tantiwiramanond, D. 1983. Effect of humic acids on nodulation and dry matter production of soybean, peanut, and clover. *Soil Sci. Soc. Am. J.* 47(6): 1121-1124.

Taiz, L. and Zeiger, E. 2002. *Plant Physiology* (3rd Ed.). Sinauer Associates Inc Publishers, Sunderland, 690p.

Tenisha, J. S. V. and Singaram, P. 2008. Influence of humic acid on yield nutrient avilaility and uptake of tomato. *J. Pl. Nutr*. 21(3): 51-575.

Thenmozhi, S., Natarajan, S., and Selvakumari, G. 2004. Effect of humic acid on quality parameters of groundnut. *Crop Res.* 27: 210-213.

Tiwari, A. K. and Shivhare, A. K. 2016. Pulses in India: Retrospect and prospects. Directorate of pulses development, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, Vindhyachal Bhavan, Bhopal, India.

Türkmen, Ö., Dursun, A., Turan, M., and Erdinç, Ç. 2004. Calcium and humic acid affect seed germination, growth, and nutrient content of tomato (*Lycopersicon esculentum* L.) seedlings under saline soil conditions. *Acta Agric. Scandinavica, Section B-Soil Plant Sci.* 54(3): 168-174.

Udode-Haes, H. A., Voortman, R. L., Bastein, T., Bussink, D. W., Rougoor, C. W., and Weijden, V. W. J. 2012. Scarcity of micronutrients in soil, feed, food, and mineral reserves - urgency and policy options. *Platform Agric. Innovation Soc.* 2: 546–554.

Vanitha, K. and Mohandass, S. 2014. Effect of humic acid on plant growth characters and grain yield of drip fertigated aerobic rice (*Oryza Sativa* L.). *Bioscan*. 9: 45-50.

Varanini, Z. and Pinton, R. 2001. Direct versus indirect effects of soil humic substances on plant growth and nutrition. In: Pinton R., Varanini Z., Nannipieri P. (eds). *The Rhizosphere: Biochemistry and Organic Substances at the Soil-Plant Interface.* Marcel Dekker Inc, New York, pp. 141-157.

Vachhani, M. U. and Patel, Z. G. 1993. Growth and yield of onion (*Allium cepa* L.) as influenced by nitrogen, phosphorus, and potash under south Gujarat condition. *Prog. Hort.* 25 (3-4): 166-167.

Vemaraju, A. 2014. Liquid formulations for production of organic oriental pickling melon. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, 80p.

Verma, H. P., Chovatia, P. K., and Sanwal, R. C. 2015. Effect of nitrogen and phosphorus levels on uptake by cowpea (*Vigna unguiculata* (L.) Walp) and residual N, P and K content in soil. *Asian J. Soil Sci.* 10(1): 173-175.

Vidyavathi, V., Dasog, G. S., Babalad, H. B., Hebsur, N. S., Gali, S. K., Patil, S. G., and Alagawadi, A. R. 2012. Nutrient status of soil under different nutrient and crop management practices. *Karnataka J. Agric. Sci.* 25(2): 193-198.

Vieira, R. F., Vieira, C., Cardoso, E. J. B. N., and Mosquim, P. R. 1998. Foliar application of molybdenum in common bean. II. Nitrogenase and nitrate reductase activities in a soil of low fertility. *J. Plant nutr.* 21(10): .2141-2151.

Walkley, A. J. and Black, I. A. 1934. Estimation of soil organic carbon by chromic acid and titration method. *Soil Sci*. 31: 21-38.

Waqas, M., Ahmad, B., Arif, M., Munsif, F., Khan, A. L., Amin, M., Kang, S. M., Kim, Y. H., and Lee, I. J. 2014. Evaluation of humic acid application methods for yield and yield components of mungbean. *Am. J. Plant Sci.* 5: 2269-2276.

Wright, D. and Lenssen, A. W. 2013. Humic and fulvic acids and their potential in crop production. *Agric. and Environ. Ext. Publ.*187. Available: https://lib.dr.iastate.edu/ extension_ag_pubs/187. [January 2013].

Yingei, W. 1988. HA resin treatment of copper and nickle. *Haunjing Bashu* (7): 21-22.

Zhao, Y. Wang. P., Li, L., Chen, Y., Ying, X., and Liu, S. 2009. The effects of two organic manures on soil properties and crop yields on a temperate calcareous soil under a wheat- maize cropping system. *Eur. J. Agron.* 31: 36-42.

Zimmerli, L., Hou, B. H., Tsai, C. H., Jakab, G., Mauch-Mani, B., and Somerville, S. 2008. The xenobiotic beta-aminobutyric acid enhances Arabidopsis thermotolerance. *Plant J.* 53: 144–156.

APPENDICES

Appendix 1. Weather parameters during the crop season in standard weeks

Standard week	Maximum temperature (°C)	Minimum temperature (°C)	Relative humdity (%)	Rainfall (mm)	Rainy days (no.)	Evaporation (mm)
43 (Oct 22 – Oct 28)	27.5	23.2	92	326.4	6	14.40
44 (Oct 29 – Nov 4)	29.8	23	83	99	3	23.20
45 (Nov 5 – Nov 11)	31.2	24.1	82	5.8	1	26.00
46 (Nov 12 – Nov 18)	31.1	23.7	79	1.7	0	27.10
47 (Nov 19 – Nov 25)	31.1	23.5	80	0	0	25.95
48 (Nov 26 – Dec 02)	32.7	23.7	77	75.7	1	28.30
49 (Dec 02 – Dec 09)	31.7	22.3	75	7.3	1	26.20
50 (Dec 10 – Dec 16)	32	22.5	74	0	0	26.00
51 (Dec 17 – Dec 23)	31.8	22.1	73	0	0	27.60
52 (Dec 24 – Dec 31)	31	23.7	81	8	1	23.19

Appendix II: Cost of cultivation

Cost of cultivation without foliar nutrition

KAU adhoc POP recommendation system		
Sl. No.	**Contents**	**Cost (₹ ha^{-1})**
1	Ploughing	2000
2	Seed	9000
3	Lime	12500
4	FYM	57200
5	Rock phosphate	1500
6	labour	19150
7	Plant protection	2625
8	Total	103975
KAU POP recommendation system		
Sl. No.	**Contents**	**Cost (₹ ha^{-1})**
1	Ploughing	2000
2	Seed	9000
3	Lime	12500
4	FYM	52000
5	Chemical fertilizer	3530
6	Human labour	18750
7	Plant protection	1380
8	Total	99160

Cost of cultivation with foliar nutrition

Treatments	General cost (₹ ha^{-1})	Foliar spray cost (₹ ha^{-1})	Spraying cost (₹ ha^{-1})	Total cost (₹ ha^{-1})
T_1	103975	0	0	103975
T_2	103975	1680	1500	107155
T_3	103975	1500	1500	106975
T_4	103975	2730	2250	108955
T_5	103975	4440	2250	110665
T_6	103975	3420	2250	109645
T_7	99160	0	0	99160
T_8	99160	1680	1500	102340
T_9	99160	1500	1500	102160
T_{10}	99160	2730	2250	104140
T_{11}	99160	4440	2250	105850
T_{12}	99160	3420	2250	104830

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FOLIAR NUTRITION OF COWPEA (*Vigna unguiculata* L.) UNDER DIFFERENT MANAGEMENT SYSTEMS

by

SUGINA P.

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ABSTRACT OF THE THESIS

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ABSTRACT

Abstract

Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems

An investigation entitled "Foliar nutrition of cowpea [*Vigna unguiculata* (L.)] under different management systems" was carried out at College of Agriculture, Padannakkad and Regional Agricultural Research Station (RARS), Pilicode, during 2018 - 20 with an objective to evaluate the effect of foliar nutrition under organic and integrated nutrient management practices in cowpea.

The field experiment was carried out in randomized block design with 12 treatments and 3 replications. The 12 treatments include the factorial combination of two management system and six foliar nutrition. Management system includes KAU adhoc organic POP recommendations (2017) (S_1) and KAU POP recommendations (2016) (S_2). Six foliar nutrition, *viz*. '*sampoorna*- KAU multi nutrient mix' (F_1), micro nutrient solution (F_2), *jeevamrutham* (F_3), humic acid (F_4), fulvic acid (F_5) and a control without foliar spray (F_0), were tested in the study. Multi nutrient mixture '*sampoorna*- KAU multi mix' @ 5 g L^{-1} and micro nutrient solution (2 %) were applied as foliar spray at 15, 30, and 45 DAS. Fulvic acid @ 2 g L^{-1}, humic acid @ 250 ml ha^{-1} and *jeevamrutham* (100 %) as foliar spray were given at weekly interval up to 45 DAS.

Fulvic acid foliar spray enhanced the plant height and was on par with *sampoorna* at harvesting stage. Humic acid enhanced the number of branches per plant followed by micro nutrient solution at flowering stage and *sampoorn*a at harvesting stage. Among the foliar sprays, *jeevamrutham* treated plots recorded the highest number of nodules per plant and the interaction effect of *jeevamrutham* with KAU POP recorded the same result. KAU POP enhanced the leaf area and total dry matter production both at flowering and harvesting stages as well.

Considering the yield and yield attributes, pod weight per plant, number of pods per plant, pod yield and seed yield were enhanced by S_2 compared to S_1. Number of pods per plant was increased by application of fulvic acid (F_5) and was on par with F_3 and F_1. KAU POP along with humic acid spray increased the pod weight per plant and was on par with S_1F_3, S_2F_1, S_2F_2, S_2F_3 and S_2F_5. Pod yield was found highest in humic

acid and was on par with fulvic acid foliar application. Seed yield was maximum in fulvic acid sprayed plots and was on par with that of humic acid and micro nutrient solution.

Nitrogen, potassium and magnesium contents of the plant were significantly enhanced by S_2 at flowering and at harvesting stage compared to S_1. Foliar nutrition of humic acid enhanced the phosphorous content of plant at flowering stage. *Jeevamrutham* enhanced the K content of plant at flowering stage and was on par with humic acid and fulvic acid spray. At harvesting stage, S_1F_1 enhanced the calcium content of plant and was on par with all treatments except S_1F_5 and S_2F_2. Foliar nutrition of fulvic acid and humic acid increased the magnesium content of plant at both stages. Micro nutrient solution increased the Fe content of plant and was on par with F_1, F_3 and F_5 at flowering and F_1 and F_5 at harvesting stage.

After the harvest of crops, maximum available P content was observed with management system S_1, foliar nutrition F_2, and interaction effect S_1F_2. Available K content was found to be maximum with S_2 compared to S_1. Foliar nutrition F_0 enhanced the available Ca content and interaction effect S_1F_0 was found to be superior over other treatment combinations. Sulphur and manganese contents of soil were increased by S_1.

Highest gross income, net return and BCR were recorded in KAU POP management system (S_2). Foliar nutrition F_5 recorded the highest gross income, net return and BCR which was on par with F_4, and F_2 and significantly superior to other treatments. Combined application of KAU POP recommendation with fulvic acid significantly increased the BCR and was on par with the combinations of KAU POP with other foliar sprays except F_0.

Results of the study revealed that integrated nutrient management system was significantly superior to organic management system with respect to yield and net returns. Foliar nutrition of fulvic acid, humic acid and micro nutrient solution are beneficial for getting higher yield and economic returns.

സംക്ഷിപ്തം

വിവിധ വിള പരിപാലന രീതികളിൽ വെള്ളപ്പയറിലെ (*വിഗ്ന അംഗികുലേറ്റ* (എൽ.) വോൾപ്പ്.). പർണപോഷണം

ശരീരത്തിന്റെ നിർമാണ ഘടനയിൽ ഏറ്റവും വലിയ പങ്കു വഹിക്കുന്നത് മാംസ്യങ്ങളാണ്. മാംസ്യത്തിന്റെ അഭാവം കുറയ്ക്കുവാൻ ഏറ്റവും നല്ല മാർഗമാണ് ഭക്ഷണക്രമത്തിൽ പയർ വർഗങ്ങൾ ഉൾപ്പെടുത്തുക എന്നത്. പയർ വിളകളിൽ നമ്മുടെ നാടിനും കാലാവസ്ഥയ്ക്കും ഏറ്റവും അനുയോജ്യമായത് *വിഗ്ന അംഗികുലേറ്റ* എന്ന ശാസ്ത്രീയ നാമത്തിൽ അറിയപ്പെടുന്ന വെള്ളപ്പയറാണ്. വളരെ കുറഞ്ഞ പരിപാലനവും രോഗങ്ങളും കീടങ്ങളും മണ്ണിലെ സൂക്ഷ്മ മൂലകങ്ങളുടെ അഭാവവും ഈ വിളയുടെ വിളവ് കുറയുന്നതിന് കാരണമാകുന്നു. വിളവ് വർധിപ്പിക്കുന്നതിനായി ജൈവ അജൈവ വളങ്ങൾ പർണപോഷണം വഴി കൊടുക്കാവുന്നതാണ്. ജൈവ കൃഷി രീതികൾക്ക് പ്രാധാന്യം ഇന്ന് വർധിച്ചു വരികയാണ് പ്രത്യേകിച്ചും വടക്കൻ കേരളത്തിൽ. പരിസ്ഥിതിയോട് നീതി പുലർത്തുന്നുവെങ്കിലും ഇത്തരം കൃഷിരീതികളുടെ കാര്യക്ഷമത ഇപ്പോഴും ഒരു ചോദ്യമായി അവശേഷിക്കുകയാണ്. കാർഷിക കോളേജ്, പടന്നക്കാട് കാർഷിക ഗവേഷണ കേന്ദ്രം, പിലിക്കോട് എന്നിവിടങ്ങളിലായി 2018- 2020 കാലഘട്ടത്തിൽ നടന്ന പരീക്ഷണത്തിന്റെ പ്രധാന ലക്ഷ്യം ജൈവ, സംയോജിത പോഷക പരിപാലന രീതികളിൽ പർണപോഷണത്തിന്റെ ഫലം വെള്ളപ്പയറിൽ വിലയിരുത്തുക എന്നതായിരുന്നു.

ശാസ്ത്രീയമായി രൂപകൽപന ചെയ്ത പരീക്ഷണത്തിൽ കാർഷിക സർവകലാശാല വികസിപ്പിച്ചെടുത്ത സൂക്ഷ്മ മൂലക മിശ്രിതങ്ങളായ സമ്പൂർണ, സൂക്ഷ്മ മൂലക ലായനി എന്നിവയുടെയും ജീവാമൃതം, ഫൾവിക് ആസിഡ്, ഹ്യൂമിക് ആസിഡ് എന്നിവയുടെയും കാര്യക്ഷമത ജൈവ, സംയോജിത പോഷക പരിപാലന രീതികളിൽ വിലയിരുത്തി. ജൈവ കൃഷി രീതികൾക്ക് കേരള കാർഷിക സർവകലാശാലയുടെ ജൈവ കൃഷി പരിപാലന ശുപാർശകളും (2017) സംയോജിത കൃഷി രീതികൾക്ക് കേരള കാർഷിക സർവകലാശാലയുടെ കൃഷി പരിപാലന ശുപാർശകളും (2016) ആണ് അനുവർത്തിച്ചിരുന്നത്. സമ്പൂർണ - കെഎയു മൾട്ടി മിക്സ്' (5 ഗ്രാം ഒരു ലിറ്റർ വെള്ളത്തിൽ എന്ന തോതിൽ) , സൂക്ഷ്മ മൂലക ലായനി (2%) എന്നിവ വിത്ത് പാകി 15, 30, 45 ദിവസങ്ങൾക്ക് ശേഷം പർണപോഷണം വഴി നൽകുകയുണ്ടായി. ഫൾവിക് ആസിഡ് (2 ഗ്രാം ഒരു ലിറ്റർ വെള്ളത്തിൽ) ഹ്യൂമിക് ആസിഡ് (250 മില്ലി ഒരു ഹെക്ടർ എന്ന തോതിൽ), ജീവാമൃതം (100%) എന്നിവ പർണപോഷണമായി വിത്ത് പാകി 45 ദിവസങ്ങൾ വരെ പ്രതിവാര ഇടവേളയിൽ നൽകി.

വിളവെടുപ്പ് സമയത്ത് ഫൾവിക് ആസിഡ്, സമ്പൂർണ എന്നിവ ചെടിയുടെ ഉയരം വർദ്ധിപ്പിച്ചു. ഹ്യൂമിക് ആസിഡ് ചെടിയിലെ ശാഖകളുടെ എണ്ണം വർദ്ധിപ്പിച്ചു. ഇതിനു

തുല്യമാകാര്യക്ഷമത പൂവിടുമ്പോൾ സൂക്ഷ്മ മൂലക ലായനിയിൽ നിന്നും വിളവെടുപ്പിന്റെ സമയത്ത് സമ്പൂർണയിൽ നിന്നും ലഭിച്ചു. വേരുകളിൽ കാണുന്ന മുഴകൾ ഏറ്റവും കൂടുതലായി രേഖപ്പെടുത്തിയത് ജീവമൃതം തളിച്ച ചെടികളിലാണ്. സംയോജിത കൃഷി രീതിയും ജീവമൃതവും ഒരുമിച്ച് ഉപയോഗിക്കുന്നതും വളരെ ഫലപ്രദമായി കാണുകയുണ്ടായി.

സംയോജിത കൃഷി കായകളുടെ തൂക്കം, എണ്ണം, വിളവ്, വിത്തിന്റെ വിളവ് എന്നിവ ഗണ്യമായി വർദ്ധിപ്പിച്ചു. ഫൾവിക് ആസിഡ് കായകളുടെ എണ്ണം വർദ്ധിപ്പിച്ചപ്പോൾ ഹ്യൂമിക് ആസിഡും ഫൾവിക് ആസിഡും കായകളുടെ വിളവ് വർദ്ധിപ്പിച്ചു. വിത്തിന്റെ വിളവ് ഏറ്റവും കൂടുതൽ ഫൾവിക് ആസിഡ് നൽകിയ ചെടികളിൽ നിന്നായിരുന്നു. ഹ്യൂമിക് ആസിഡും സൂക്ഷ്മ മൂലക ലായനിയും ഏകദേശം അതേ വിളവ് തന്നെ നൽകുകയുണ്ടായി.

ചെടികളിലെ പോഷക മൂലകങ്ങളുടെ തോത് പരിശോധിച്ചതിൽ നൈട്രജൻ, പൊട്ടാസ്യം, മഗ്നീഷ്യം എന്നിവ സംയോജിത കൃഷിയിൽ വളർച്ചയുടെ രണ്ട് ഘട്ടങ്ങളിലും കൂടുതലായി കാണുകയുണ്ടായി. ഹ്യൂമിക് ആസിഡ് നൽകിയ ചെടികളിൽ പൂവിടുന്ന സമയത്ത് ഫോസ്ഫോറസിന്റെ അളവ് കൂടുതലായിരുന്നു.. ജീവമൃതം തളിച്ച ചെടികളിൽ പൊട്ടാസ്സ്യം കൂടുതലായി കാണപ്പെട്ടു. ഇതേ ഫലം ഹ്യൂമിക് ആസിഡിലും ഫൾവിക് ആസിഡിലും ലഭിക്കുകയുണ്ടായി.

സംയോജിത കൃഷിയും ജൈവ കൃഷിയും താരതമ്യം ചെയ്യുമ്പോൾ മൊത്ത വരുമാനം, ചെലവ് കിഴിച്ചുള്ള വരുമാനം, വരവ് ചെലവ് അനുപാതം എന്നിവ സംയോജിത കൃഷിയിൽ വർദ്ധിച്ചു. പർണ പോഷണങ്ങളിൽ, ഫൾവിക് ആസിഡ് തളിച്ചവയിൽ മൊത്ത വരുമാനം, ചെലവ് കിഴിച്ചുള്ള വരുമാനം, വരവ് ചെലവ് അനുപാതം എന്നിവ വർദ്ധിക്കുന്നതായി കാണപ്പെട്ടു. ഇതിനു തുല്യമായ ഫലം ഹ്യൂമിക് ആസിഡും സുക്ഷ്മ മൂലക ലായനിയും നൽകിയപ്പോൾ ലഭിച്ചു. സംയോജിത കൃഷിയിൽ ഫൾവിക് ആസിഡിന്റെ ഉപയോഗം വരവ് ചെലവ് അനുപാതം വർധിപ്പിച്ചു. തത്തുല്യമായ ഫലം സംയോജിത കൃഷിയോടൊപ്പം മറ്റു പർണ പോഷണങ്ങൾ ഉപയോഗിച്ചപ്പോഴും ലഭിക്കുകയുണ്ടായി.

പഠന ഫലങ്ങൾ സംഗ്രഹിച്ചാൽ, പയറുകൃഷിയിൽ വിളവ്, വരുമാനം എന്നിവ കൂട്ടുന്നതിനായി സംയോജിത പോഷക പരിപാലനമുറകളാണ് ജൈവ പരിപാലനത്തേക്കാൾ മെച്ചം എന്ന നിഗമനത്തിൽ എത്തിച്ചേരുവാൻ സാധിക്കും.. പർണപോഷണം ഫൾവിക് ആസിഡ് ആണ് ഏറ്റവും ഉത്തമം. ഹ്യൂമിക് ആസിഡ്, സുക്ഷ്മ മൂലക ലായനി എന്നിവയും മെച്ചപ്പെട്ടത് തന്നെയാണ്. കൂടുതൽ വിളവ് ലഭിക്കുന്നതിനും സാമ്പത്തിക വരുമാനം വർദ്ധിപ്പിക്കുന്നതിനും സംയോജിത പരിപാലന രീതിയോടൊപ്പം ഫൾവിക് ആസിഡ് പർണപോഷണം നൽകുന്നത് ഏറ്റവും ഉചിതമാണ്.