STUDIES ON FOLIAR APPLICATION OF NUTRIENTS ON PRODUCTIVITY OF SOYBEAN [*Glycine max* (L.) Merrill]

BRANDON LYNGDOH

PALB 5182

DEPARTMENT OF AGRONOMY

UNIVERSITY OF AGRICULTURAL SCIENCES

GKVK, BENGALURU

2018

STUDIES ON FOLIAR APPLICATION OF NUTRIENTS ON PRODUCTIVITY OF SOYBEAN [*Glycine max* (L.) Merrill]

BRANDON LYNGDOH

PALB 5182

Thesis submitted to the

UNIVERSITY OF AGRICULTURAL SCIENCES, BENGALURU

in partial fulfilment of the requirements

for the award of the Degree of

MASTER OF SCIENCE (Agriculture)

in

AGRONOMY

BENGALURU **OCTOBER, 2018**

Affectionately Dedicated to My Family

DEPARTMENT OF AGRONOMY
UNIVERSITY OF AGRICULTURAL SCIENCES
GKVK, BENGALURU-560065

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON FOLIAR APPLICATION OF NUTRIENTS ON PRODUCTIVITY OF SOYBEAN [*Glycine max* (L.) Merrill]"** submitted by **Mr. BRANDON LYNGDOH, ID No. PALB 5182,** in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture) in AGRONOMY** to the University of Agricultural Sciences, Bengaluru is a record of research carried out by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
October, 2018

(N. KRISHNAMURTHY)
Major Advisor

Approved by:

Chairman : **(N. KRISHNAMURTHY)**

Members : 1. **(JAYARAME GOWDA)**

2. **(H. M. JAYADEVA)**

3. **(C. SEENAPPA)**

ACKNOWLEDGEMENT

It is my privilege to express my sense of gratitude, reverence and thanks to ***Dr. N. Krishnamurthy,*** *Dean (PGS retd.), College of Agriculture, University of Agricultural Sciences, Bengaluru and presently working as Chairman, Karnataka State Food Commission, Govt. of Karnataka, the esteemed chairman of my Advisory committee for his valuable guidance, suggestions and constructive criticism without which I, would not have reached this mile stone in my life.*

This thesis must surely bear the imprint of the criticism and ideas of ***Dr. Jayarame Gowda****, Head of AICRP on Soybean, ZARS, Bengaluru,* ***Dr. H. M. Jayadeva,*** *Professor, Department of Agronomy College of Agriculture, University of Agricultural Sciences, Bengaluru and* ***Dr. C. Seenappa,*** *Associate Professor, College of Agriculture, University of Agricultural Sciences, Bengaluru the esteemed members of my advisory committee who provided me with a continuing meaningful ideas throughout the period of Research.*

I would like to express my deep sense of gratitude and thanks to ***Dr. Kalyana Murthy****, Professor & Head, Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Bengaluru for the faith which he reposed in me and also for the suggestions, systematic ideas and fruitful criticism during the course of my research.*

I am also thankful to ***Dr. Ravishankar, C. R., Dr. Ramappa, H. K., Dr. Shubasree, Dr. Gangadaraiah, Dr. Mahadevaiah, K. R., Dr. Revanna, M. L., Dr. Mohan Raju, Dr. Murali, K.*** *and* ***Dr. Atheekur Rehaman*** *for their constant encouragement and good will.*

I am ever indebted to the teaching and non teaching staff of the Department of Agronomy, College of Agriculture, University of Agricultural Sciences, Bengaluru

With utmost pleasure and sincerity I, am grateful to University of Agricultural Sciences, Bengaluru for granting me one and half year internal deputation and further part time facility during my Ph.D. programme.

A word of apology to those I have not mentioned in person and a note of thanks to one and all who helped me for the successful completion of this endeavour.

Bengaluru

October, 2018 **(BRANDON LYNGDOH)**

STUDIES ON FOLIAR APPLICATION OF NUTRIENTS ON PRODUCTIVITY OF SOYBEAN [*Glycine max* (L.) Merrill]

BRANDON LYNGDOH

ABSTRACT

A field experiment was conducted during the *kharif* season of 2016 at the Zonal Agricultural Research Station, University of Agricultural Sciences, Bengaluru to evaluate the effect of foliar nutrition on productivity of soybean crop (Variety MAUS -2). The experiment was laid out in Randomized Block Design with three replications. There were ten treatments consisting of various combinations of nutrient application viz. RDF + water spray, RDF + Urea @ 2 % spray, RDF + DAP @ 2 % spray at pod initiation, RDF + MOP @ 0.5 %spray, RDF + NPK(19:19:19) @ 2% spray, RDF+ Molybdenum @ 0.5% spray, RDF + Boron @ 0.5% spray, RDF + Zinc chelated @ 0.5% spray, RDF + bio-digester liquid spray and RDF through organic source (FYM) @ 13.44 kg plot^{-1}. The treatments were imposed during pod initiation stage of crop growth (45 DAS). The application of RDF + DAP @ 2% spray resulted in significantly higher plant height at harvest (40.32 cm), number of leaves plant^{-1} at 60 DAS and at harvest (37.73 and 10.46, respectively), leaf area plant^{-1} at 60 DAS and at harvest (850.00 cm^2 and 394.34 cm^2, respectively), number of pods plant^{-1}(43.00), number of seeds pod^{-1} (3.00), number of seeds plant^{-1} (88.37), higher grain yield (3772 kg ha^{-1}) and higher uptake of NPK (302.95, 35.42 and 108.88 kg ha^{-1}, respectively) compared to the other treatments. Foliar application of DAP @ 2 % also recorded significantly higher oil content (22.01 %), protein content (40.41 %), higher net return of ₹ 55,808 ha^{-1} and BC ratio of 2.84.

October, 2018

Department of Agronomy
University of Agricultural Sciences
GKVK, Bengaluru – 65

Dr. N. Krishnamurthy
(Major Advisor)

ಸೋಯಾಅವರೆಯ ಉತ್ಪಾದಕತೆಗೆ ಎಲೆಗಳ ಮೇಲೆ ಪೋಷಕಾಂಶಗಳ ದ್ರಾವಣವನ್ನು ಸಿಂಪಡಿಸುವ ಕುರಿತು ಅಧ್ಯಯನ

ಬ್ರಾಂಡನ್ ಲಿಂಡೊ

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಬೆಂಗಳೂರಿನ ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ವಲಯ ಕೃಷಿ ಸಂಶೋಧನೆ ಕೇಂದ್ರದಲ್ಲಿ ಪೋಷಕಾಂಶಗಳ ದ್ರಾವಣವನ್ನು ಸೋಯಾಅವರೆಯ ಎಲೆಗಳಿಗೆ ಸಿಂಪಡಿಸುವ ಮೂಲಕ ಸೋಯಾಅವರೆಯ ಉತ್ಪಾದಕತೆಯ ಮೇಲಿನ ಪರಿಣಾಮಗಳನ್ನು ಅಧ್ಯಯನ ಮಾಡಲಾಯಿತು. ಈ ಪ್ರಯೋಗವು ಹತ್ತು ವಿವಿಧ ಉಪಚಾರಗಳನ್ನು ಒಳಗೊಂಡಿದ್ದು ಸಂಪೂರ್ಣ ಯಾದೃಚ್ಛಿಕ ತಾಕು ವಿನ್ಯಾಸದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಬೆಳೆಯ ವಿವಿಧ ಹಂತಗಳಲ್ಲಿ ಬೆಳವಣಿಗೆಯನ್ನು ದಾಖಲಿಸಲಾಯಿತು. ಪೋಷಕಾಂಶಗಳನ್ನು ಹೀರಿಕೊಂಡ ಪ್ರಮಾಣ, ಸಸಾರಜನಕದ ಪ್ರಮಾಣ, ಎಣ್ಣೆಯ ಪ್ರಮಾಣ, ಎಲ್ಲಾ ಅಗತ್ಯ ಪರಿಣಾಮಗಳನ್ನು ದಾಖಲಿಸಿಕೊಂಡು ತುಲನೆ ಮಾಡಲಾಯಿತು. ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರಗಳ ಜೊತೆ ಶೇ ೨ ರಷ್ಟು ಡಿಎಪಿ ಯನ್ನು ಕಾಯಿಕಟ್ಟುವ ಹಂತದಲ್ಲಿ ಸಿಂಪಡಿಸಿದಾಗ ಗರಿಷ್ಟ ಎತ್ತರದ (೪೦.೩೨ ಸೆಂ.ಮಿ.) ೬೦ನೆ ದಿನದ ಕಟಾವಿನ ಹಂತದಲ್ಲಿ (೧೦.೪೬) ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯ ಎಲೆಗಳು (೩೭.೭೩), ಎಲೆಗಳ ವಿಸ್ತೀರ್ಣ (೮೫೦ ಚ. ಸೆಂ.ಮಿ.) ಕಟಾವಿನ ಹಂತದಲ್ಲಿ ೩೯೪.೩೪ ಚ. ಸೆಂ. ಮಿ, ಹೆಚ್ಚಿನ ಕಾಯಿಗಳು (೪೩.೦೦ ಗಿಡಕ್ಕೆ$^{-1}$), ಪ್ರತಿ ಕಾಯಿಗು ಹೆಚ್ಚಿನ ಬೀಜಗಳು (೩.೦೦), ಪ್ರತಿಗಿಡಕ್ಕೆ (೮೮.೩೦ ರಷ್ಟು) ಬೀಜಗಳು ಕಂಡುಬಂದಿರುತ್ತವೆ. ಉತ್ತಮಗೊಂಡ ಬೆಳವಣಿಗೆ ಪರಿಣಾಮವಾಗಿ ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ ಹೆಚ್ಚಿನ ಇಳುವರಿ (೩೭೭೨ ಕಿ. ಗ್ರಾಂ.) ಕಂಡುಬಂದಿರುತ್ತದೆ. ಇದೆ ಉಪಚಾರದಲ್ಲಿ ಗಣನೀಯ ಪ್ರಮಾಣದಲ್ಲಿ ಪೋಷಕಾಂಶಗಳು ಹೀರಿಕೊಂಡಿದ್ದು (೩೦೨.೯೫, ೩೫.೪೨ ಮತ್ತು ೧೦೮.೮೫ ಕಿ. ಗ್ರಾಂ/ ಹಕ್ಟೇರಿಗೆ$^{-1}$ ಅನುಕ್ರಮವಾಗಿ) ಸಹ ಕಂಡುಬಂದಿದೆ. ಹಾಗೂ ಗಣನೀಯ ಪ್ರಮಾಣದಲ್ಲಿ ಸಸಾರಜನಕ (ಶೇ. ೪೦.೪) ಎಣ್ಣೆಯ ಪ್ರಮಾಣ (ಶೇ. ೨೨.೦೧) ಕಂಡುಬಂದಿದ್ದು ಇದೆ ರೀತಿಯ ಉಪಚಾರದಲ್ಲಿ ಪ್ರತಿ ಹೆಕ್ಟೇರಿಗೆ ಹೆಚ್ಚಿನ ನಿವ್ವಳ ಆದಾಯ ₹.೫೫,೮೦೮ ಹಾಗೂ ಖರ್ಚು: ಆದಾಯ ಅನುಪಾತವು ೧:೨.೮೪ ಕಂಡುಬಂದಿರುತ್ತದೆ. ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರಗಳ ಜೊತೆ ಶೇ. ೨ ರಷ್ಟು ಡಿಎಪಿ ಯನ್ನು ಎಲೆಗಳಿಗೆ ಸಿಂಪಡಿಸುವುದರಿಂದ ಸೋಯಾಅವರೆಯಲ್ಲಿ ಇಳುವರಿಯನ್ನು ಸುಧಾರಿಸಬಹುದೆಂದು ಈ ಪ್ರಯೋಗದಿಂದ ಕಂಡುಕೊಳ್ಳಲಾಗಿದೆ.

ಅಕ್ಟೊಬರ್, ೨೦೧೮

ಬೇಸಾಯ ಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ, ಜಿ.ಕೆ.ವಿ.ಕೆ, ಬೆಂಗಳೂರು

ಡಾ. ಎನ್. ಕೃಷ್ಣಮೂರ್ತಿ
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

"Studies of application of nutrients on productivity of soybean (*Glycine max*)"

BRANDON LYNGDOH AND N. KRISHNAMURTHY

Department of Agronomy

College of Agriculture, UAS, GKVK, Bengaluru-560065

INTRODUCTION

- ✓ Soybean (*Glycine max*) is a dual purpose, most important rainy season crop to meet the pulse and oil requirements. It has 40 per cent protein and 20 per cent oil and recognized as a potential supplementary source of oil.
- ✓ It is also highly adaptable to varying soil and climatic conditions, giving fairly higher yields compared to other pulse crops.
- ✓ In India, soybean is cultivated in an area of 10.27 million hectares with a production of 11 million tonnes and productivity of 1070 kg ha^{-1}.
- ✓ Soil application of nutrients often results in lower efficiency of concerned nutrients due to several changes and losses due to leaching and volatilization.
- ✓ Adverse conditions such as water logging, lack of adequate moisture, acidity and alkalinity also affects the availability of nutrients.
- ✓ Foliar spray is the fastest way to boost the plant growth because the nutrients are directly available to the plants.
- ✓ Under rainfed agriculture, where availability of moisture is low, application of nutrients by foliar results in efficient absorption and usage which are economical with respect to the others ways of fertilization.
- ✓ Flower senescence and ill pod filling are the major problems faced in soybean and this can rectified or reduced by foliar application of nutrients and growth regulators.

Objectives:

- ✓ To study the effect of foliar nutrition on growth and yield of soybean.
- ✓ To study the effect of foliar nutrition on nutrient uptake of soybean.
- ✓ To work out the economics of foliar nutrition on soybean.

MATERIALS AND METHODS

Experimental details:

Crop : Soybean (MAUS-2) Season : *Kharif*

Treatments : 10 Replication : 3

Design : RCBD Net plot size : 5.6 x 2.4 m

Location : AICRP on dry land, UAS, GKVK, Bengaluru

Treatment details: (Imposing 4-5 DAF)

T_1 : Water spray at pod initiation + RDF

T_2: Urea 2% spray at pod initiation + RDF

T3: DAP 2% spray at pod initiation + RDF

T_4: MOP 0.5% spray at pod initiation + RDF

T_5: 19:19:19(NPK) 2% spray at pod initiation + RDF

T_6: Molybdenum 0.5% spray at pod initiation + RDF

T_7: Boron 0.5% spray at pod initiation + RDF

T_8: Zinc chelated 0.5% spray at pod initiation + RDF

T_9: Bio-digester liquid spray + RDF

T_{10}: RDF through organic source

RDF: 25:60:25 NPK Kgha^{-1}

RESULTS

Table 1 : Number of pods per plant, number of seeds per pod, test weight (g) and seed yield per hectare (kg ha^{-1})as influenced by different treatments.

Treatments	Pods Plant^{-1}	Seeds Pod^{-1}	Seed yield (kg ha^{-1})
T_1	29	2.00	672.21
T_2	26	2.75	696.63
T_3	33	3.00	711.81
T_4	39	2.67	695.31
T_5	36	2.58	673.53
T_6	39	2.63	599.94
T_7	28	2.52	650.43
T_8	25	2.48	656.37
T_9	32	2.02	640.23
T_{10}	24	1.98	629.47
S.Em	0.83	0.022	55.37
C.D at 5%	2.24	0.067	153.48

- ✓ Among the various treatments the values of pods per plant were significantly higher with the application of RDF + spray of 0.5% molybdenum and application of RDF + spray of 0.5% MOP at pod initiation, with values of 39 pods per plant each. Lowest was observed with the application of RDF through organic source(24 pods per plant).
- ✓ For seeds per pod, highest was observed in application of RDF + spray of 2% DAP at pod initiation(3.00 seeds per pod) and lowest was observed with application of RDF through organic source(1.98 seeds per pod).
- ✓ For seed yield, highest was observed in application of RDF + spray of 2% urea at pod initiation(696.63 kg ha^{-1}) and lowest was observed with application of RDF through organic source(629.47 kg ha^{-1}).

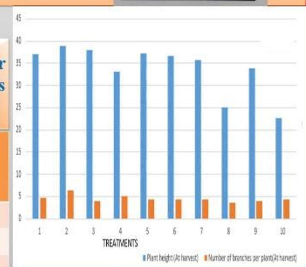

Fig. 1: Plant height and number of branches observed at harvest.

Plate.1 General view of an experimental plot (60 DAS)

DISCUSSION

- ✓ The foliar sprays of 2% DAP at flower initiation and pod formation stage might have helpful to reduced flower drop, which turn in significantly increased in number pods plant^{-1} as reported by Ganapathy et al. (2008). Optimum availability of all nutrients at flower initiation and pod formation stages of crop growth might have caused efficient translocation of photosynthates from source to sink. Decrease in flower drop due to prolonged assimilatory activity of leaves might be another possible reason for higher number of pods plant^{-1}.
- ✓ The application of RDF + spray of DAP @ 2% spray also increased the seeds plant^{-1}, which was significantly superior to the other treatments.. The lowest number of pods plant^{-1} (24), seeds pod^{-1} (1.98) was recorded from the plot where RDF through organic source was applied alone. The similar result was also reported by Kumar et al., (2013).
- ✓ The highest pods plant^{-1} was produced by foliar application of RDF + spray of DAP @ 2% at flowering and pod initiation stage increase the number of pods per plant could be attributed due to significant effect of microelements on reproductive organs, such as stamens and pollens. Soybean is a self-pollinated crop and application of Mo help to develop flower in more number and also help to complete fertilization process as it is self-pollinated crop and finally registered more number of pods per plant in soybean reported by Nadergholi et al., (2011).

SUMMARY

- ✓ The foliar sprays of 2% DAP at flower initiation and pod formation stage might have helpful to reduced flower drop, which turn in significantly increased in number pods plant^{-1}
- ✓ Soybean is a self-pollinated crop and application of Mo help to develop flower in more number and also help to complete fertilization process as it is self-pollinated crop and finally registered more number of pods per plant in soybean.
- ✓ The lowest number of pods plant^{-1} (24), seeds pod^{-1} (1.98) was recorded from the plot where RDF through organic source was applied alone.

REFERENCES

➢ ABDEL, E., LATIF, M. A. AND HAGGAN, E., 2014. Effect of micronutrients foliar application on yield and quality traits of soybean cultivars. *Intl. J. Agri. Crop Sci.*.**7**(11):908-914.

➢ BEHROUZI, F. G., 2012. Effect of micro-nutrient fertilizer application on soybean yield and yield components. *Amer. J. Agril. Biol. Sci.* 7 (4):412-41

Advisory committee:

Chairperson: Dr. N. Krishnamurthy

Members: Dr. H.M. Jayadeva

Dr. Jayarame Gowda

Dr. C. Seenappa

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

Abbreviation	Expansion
%	Per cent
@	At the rate
°C	Degree Celsius
B:C	Benefit cost ratio
C.D.	Critical difference
Cm	Centimetre
CPE	Cumulative pan evaporation
DAS	Days after sowing
dSm^{-1}	Deci Siemens per meter
Epan	Pan evaporation
Fig.	Figure
FYM	Farmyard manure
G	Grams
Ha	Hectare
Hr	Hour
Hrs	Hours
i.e.	That is
K_2O	Potassium
Kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAI	Leaf area index
M	Meter
m ha	Million hectare
m t	Million tones
N	Nitrogen
NS	Non significant
P, P_2O_5	Phosphorus
q ha^{-1}	Quintals per hectare
RH	Relative humidity
₹	Rupees
S. Em ±	Standard error mean
t ha^{-1}	Tonnes per hectare
viz.,	Namely
Litre	l

I INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is popularly known as the “Golden bean” or “Miracle crop” of the 21^{st} century because of its versatile nutritional qualities. It contains 20 per cent of oil and 40 per cent of protein with high levels of essential amino acids such as lysine (5 %), minerals (4 %), phospholipids (2 %) and the vitamins viz. thiamine and riboflavin (Harkal *et al*., 1989). The edible oil extracted from soybean contains about 1.6 to 3.1 per cent lecithin, which is essential for building nerve tissue and the oil can also be used as a raw material for production of antibiotics, paints, varnishes, adhesives, lubricants, etc. The protein quality of soybean is equivalent to that of meat, milk products and eggs. Being a leguminous crop, it is able to fix atmospheric nitrogen in the soil to an extent of 65 to 100 kg ha^{-1}, depending on the soil type and climatic conditions during rhizobial symbiosis (Srivastava *et al.*,1994). It is generally grown as a rainy season crop under rainfed situation.

In India, soybean occupies an area of 12.2 million hectares with the production of 89.19 lakh tonnes and an average productivity of 983 kg ha^{-1} (Anon., 2015). The productivity of soybean is comparatively very less in India as compared to world average (2484.1 kg ha^{-1}). Global area and production of soybean is 111.27 million hectares and 276.4 million tonnes, respectively (Anon., 2015). The major soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka. In Karnataka, soybean occupies an area of 0.29 million hectares with a production of 0.24 million tonnes and productivity of 868 kg ha^{-1} (Anon., 2015). Belagavi, Bidar, Dharwad, Haveri and parts of Bagalkot are the major soybean growing districts of Karnataka.

Foliar spraying is one alternative approach through which micronutrients are made available to the crop in liquid form through foliage application (Nasiri *et al.*, 2010). Foliar application of micronutrients is more beneficial than soil application. Since application rates are lesser as compared to soil application, it can be obtained immediately by the crop (Zayed *et al*., 2011). Foliar spraying of micronutrients is very helpful when the roots cannot provide essential micronutrients to the crop (Kinaci and Gulmezoglu, 2007 and Babaeian *et al*., 2011). Moreover, soil pollution would be a major problem by micronutrients through soil application. As people are concerned about the environment, foliar sprays of nutrients are better than soil application (Bozorgi *et al*., 2011).

Crop roots are unable to absorb some essential nutrients because of many reasons such as high pH, light or heavy texture, and due to these reasons, foliar spraying is considered better as compared to soil application (Kinaci and Gulmezoglu, 2007). Narimani *et al.* (2010) reported that foliar application of micronutrients is equal or in some case more effective as compared to micronutrients applied in soil. They also found that based on soil properties, foliar application could be 6 to 20 times more effective as compared to soil application. Tolerant to different stresses will be increased by foliar application of micronutrients (Ghasemian *et al.*, 2010). Since the soil features and environmental factors which affect nutrient absorption in field situation are extremely changeable, the foliar application could be an advantage for crop growth. Also, the effectiveness of foliar spraying is higher and the cost of foliar application is lower as compared to soil application. micronutrients play a major role in cell division and development of meristematic tissues, photosynthesis, respiration and acceleration of plant maturity. Zinc plays a special role in synthesizing proteins, RNA and DNA (Kobraee *et al.*, 2011). The adequate amount of zinc required by the crops is not clear for growth and yield of the plant up to a certain level. Although zinc is an essential element for crop growth, it could be poisonous in a large amount (Nasiri *et al.*, 2010). Profitability of micronutrients will be obtained in combination with macro elements such as nitrogen and potassium.

Foliar application of macro and micronutrients was more beneficial to legumes (Zayed *et al.*, 2011). However, adequate information on the effect of foliar application of Nitrogen, Phosphorus, Potassium, Molybdenum, Boron, and Zinc on soybean in agro-climatic conditions of Karnataka was not available. Considering the above stated important facts, the present investigation entitled “Studies on the foliar application of nutrients on the productivity of soybean [*Glycine max* (L.) Merrill]” will be carried out during the *kharif* season of 2016 at Zonal Agricultural Research Station, GKVK, Bengaluru with the following objectives.

1. To study the effect of foliar nutrition on growth, yield, and quality of soybean.
2. To study the effect of foliar nutrition on nutrient uptake of soybean.
3. To work out the economics of foliar nutrition in soybean.

II REVIEW OF LITERATURE

The field experiment entitled "Studies on the foliar application of nutrients on the productivity of soybean [*Glycine max* (L.) Merrill]" was carried out during *kharif* season, 2016 at the Zonal Agricultural Research Station, GKVK, Bengaluru. The reviews pertaining to the present investigation are presented in the following sub-headings:

2.1 Effect of foliar nutrition on crops

2.2 Effect of foliar application of nutrients on growth and yield parameters

2.3 Effect of foliar application of nutrients on quality parameters

2.4 Effect of foliar application of nutrients on nutrient uptake

2.5 Effect of foliar application of nutrients on economics

2.1 Effect of foliar nutrition on crops

Among the various fertilizer application methods, foliar application of nutrients is more important and advantageous because it facilitates easy and quick consumption of nutrients by penetrating through stomata or leaf cuticle and entering the cell (Girma *et al.*, 2007). Application of micro and macro nutrients at critical stages of crops resulting efficient translocation and absorption of nutrients to the developing pods and will generate more filled grains and a number of pods in soybean (Jayabal *et al.*, 1999).

Foliar application is most effective when the roots are unable to absorb required amounts of nutrients from the soil due to reasons such as high degree of fixation, lack of soil moisture, losses from leaching and low soil temperature. Application of nutrients through foliar spray at appropriate stages of crop growth becomes important for their utilization and better performance (Anadhakrishnaveni *et al.*, 2004). Girma *et al.* (2007) observed that the foliar application of nutrients eliminates the problems of nutrients fixation and immobilization and thus, increases fertilizer use efficiency. Foliar application of nutrients would be more appropriate, efficient and economical than soil application. The interest of foliar fertilizer arose due to multiple advantages such as rapid and efficient response to the plant needs, fewer products needed and independence from soil condition.

It is also recognized that supplementary foliar fertilization during crop growth improves the mineral status of the plant and increase crop yield (Elayaraja and Angayakanni, 2005).

2.2 Effect of foliar application of nutrients on growth and yield parameters

Oplinger *et al.* (1993) reported that foliar applied boron could stimulate the yield of soybean by increasing pods on lateral branches, seed number and overall seed yield over a wide range of growing conditions. Boron treatments include 0.25, 0.50, and 1.00 lb applied as foliar and 3.0 lb applied to the soil prior to planting. Boron applied at 0.25 lb as foliar at initial flowering stage increases the grain yield. The higher rates of boron either foliar or soil application had no significant effect on yield or yield components. Foliar applications of boron to soybean as a single nutrient may be significantly profitable.

Srivastava and Srivastava (1994) found that foliar application of 2 per cent urea at 50 per cent flowering stage gave significantly highest seed yield of chickpea (1.7 t ha^{-1}) due to higher plant height, no of branches $plant^{-1}$, seeds pod^{-1} and water use efficiency compared with other treatment combinations in chickpea.

Phosphorus application at three rates (20, 40 and 60 P_2O_5 kg ha^{-1}), foliar application of zinc (0.4 g l^{-1} at 300 l ha^{-1}), and irrigation intervals of 15 days during the whole growing season. Irrigation at 15-day interval throughout the growing season resulted in best growth and yield of soybean. Application of zinc fertilizer did not significantly affect the seed yield, but yield increased with increasing phosphorus rate of soybean (Osman *et al.*, 2000)

Manivannan *et al.* (2002) conducted a field experiment on the foliar application of NPK and chelated micronutrients with and without Rhizobium seed treatment on growth and yield of rice- fallow urd bean. It was found that combined application of Rhizobium seed treatment and foliar application of NPK and chelated micronutrients (Microsol) at 15, 30 and 45 DAS resulted in significant increase in growth characters viz., plant height, number of branches $plant^{-1}$, LAI, dry matter production, yield parameters viz., number of pods $plant^{-1}$, number of grains pod^{-1}, 100 grain weight and grain yield ha^{-1} in both rice-fallow urd bean crops.

Kalpana *et al.* (2003) observed that foliar spraying of DAP (2 %), KCl (1 %), boron (0.2 %) and NAA 40 mg recorded significantly higher grain yield of soybean (1612 kg ha^{-1}) than DAP (2 %) alone and water spraying.

Significantly highest growth parameters i.e., plant height, leaf area index, number of branches $plant^{-1}$ and yield attributes viz., number of pods $plant^{-1}$, pod length, number of grains pod^{-1} were recorded with the foliar spray of DAP (2 %) + KCI (1 %) + $ZnSO_4$ (0.5. %) sprayed at 15, 30 and 45 DAS, respectively, followed by two sprays of DAP (2 %) + KCI (1 %) + $ZnSO_4$ (0.5 %) given at 30 and 45 DAS in green gram (Krishnaveni *et al.*, 2004).

Thakare *et al.* (2006) studied the effects of two foliar sprays of DAP (2 %), urea (2 %), cow urine (21 %) and IAA (50 ppm) and NAA, along with a half dose of RDF to the soil. They reported that application of half dose of RDF along with foliar application of 2 % DAP with 50 ppm IAA or NAA resulted in significantly higher leaf chlorophyll and nitrogen content, seed protein, and oil content and yield contributing parameters, i.e. number and dry weight of pods $plant^{-1}$, 100 seed weight, and seed yield ha^{-1}.

Odeleye *et al.* (2007) opined that N, NPK, and NPK with magnesium, applied as foliar at the early flowering and early pod-filling growth stages of soybean responded significantly and enhanced the growth and yield of the soybean at both stages. However, the highest yield of soybean was obtained by spraying NPK and NPK with magnesium, but the optimum yield of soybean was obtained by the foliar spray of NPK at the pod filling stage.

Pradeep and Elamathi (2007) reported that application of potassium nitrate (2 %) + zinc sulphate (1 %) and boric acid (50 ppm) recorded significantly higher number of pods $plant^{-1}$, test weight and seed yield over control in soybean and a similar result was observed in green gram.

Ghosh and Joseph (2008) concluded that inoculation of Rhizobium + PSB, application of sulphur (30 kg ha^{-1}) through gypsum and foliar application of DAP (2 %) in green gram recorded significantly higher number of pods plant^{-1}, fertility coefficient, number of seeds pod^{-1}, seed yield, stalk yield and test weight in green gram.

Effect of zinc + iron treatment on grain yield, number of pods plant^{-1} and 1000 grain weight of soybean were studied in the field experiment. The time of foliar application on a number of pods plant^{-1} and 1000 grain weight was also significant. In general, the highest yield was produced with combined application of zinc and iron in soybean (Heidaria *et al.*, 2011).

Kobraee *et al.* (2011) reported that application of zinc, iron, and manganese in soybean responded significantly with respect to a number of pods plant^{-1} and seeds pod^{-1}. The highest grain yield was obtained by applying $ZnSO_4$ (40 kg ha^{-1}), $FeSO_4$ (50 kg ha^{-1}) and $MnSO_4$ (40 kg ha^{-1}). They have also observed that high concentration of manganese and iron in the soil had negative effects on zinc absorption in soybean.

Moosavi and Ronaghi (2011) recorded that soil and foliar applications of iron significantly increased shoot iron concentration and iron uptake in the plant. However, the foliar application was more effective. Foliar spray of ferrous sulphate (1 %) improved plant iron content and had no significant effect on shoot dry matter production in soybean.

Nadergoli *et al.* (2011) observed that the highest plant height, number of seeds pods^{-1}, number of pods plant^{-1}, shelling percentage, yield and harvest index (37.07 %, 44.74%, 45.43 %, 7.04 %, 75.1 % and 13.69 %, respectively) were associated with foliar application at shooting, flowering and pod formation stages, respectively. The highest 100 kernel weight was obtained by foliar application at shooting, flowering and pod formation stages with the application of manganese sulphate.

Behrouzi *et al.* (2012) recorded significantly highest seed yield with 3 ppm or 10 kg ha^{-1} of complete micronutrient of the spray of 8-12 leaf stage caused 88.88 per cent increase in seed yield compared to control. The highest 100 kernel weight was obtained by using 30 kg ha^{-1} of complete micronutrient in soil application form, causing an increase in seed yield (14.90 %) compared to control in groundnut.

Garud *et al.* (2012) found that application of phosphorus (60 kg P_2O_5 ha^{-1}) and foliar application of BOOST-52 (0: 52: 34 NPK) at 35 and 50 DAS was significantly recorded highest productive, profitable and better growth parameters, i.e., plant height, leaf area index, biological yield, number of branches $plant^{-1}$ and yield attributes viz., number of pods $plant^{-1}$, pod length, number of grains pod^{-1} with the foliar spray in soybean over the control.

Kobraee and Shamsi (2013) inferred that foliar application of manganese under moisture deficit condition increased grain yield of soybean by 29.6 per cent as compared to molybdenum treatment. Application of manganese decreased the adverse effects of drought stress in soybean.

Foliar application of micronutrients on a number of pods $plant^{-1}$, 100 grain weight, and seed yield was significantly highest with the treatments of iron as compared to control. The foliar application of iron at the flowering stage produced a maximum number of seed pod^{-1} (2.36). However, maximum 100 grain weight (168.3 g) was found the combined foliar application of zinc and iron was reported by Mostafavi (2012).

Kumar *et al.* (2013) revealed that foliar spray of DAP (2 %) at flowering initiation and pod formation stage of soybean resulted in significantly higher number of pods (62), number of seeds $pods^{-1}$, seed index and grain yield (1460 kg ha^{-1}) and it was on par with application of urea (2 %) and TNAU pulse wonder spray.

Kumar *et al.* (2013) reported that the foliar application of soluble starter NPK (2 %) + sulphur spray (2 %) at 45 DAS and soluble booster NPK (2 %) + boron spray (0.15 %) at 65 DAS resulted significantly higher seed yield (33.84 q ha^{-1}) which was 48 per cent higher over the control and only water spray. This treatment was also on par with the foliar application of boron (0.15 %) at pod initiation stage (31.95 q ha^{-1}).

Popovic *et al.* (2013) observed that the plant plants had on an average stem height of 81.94 cm and average plant weight of 16.00 g with foliar nutrition and it showed to be a feasible method of soybean productivity improving in the intensive cropping system.

Rezaei *et al.* (2013) were observed that the foliar application of iron and defoliation of soybean influenced significantly on the characteristics of plant height, number of pods plant^{-1}, 100 seed weight, seed yield, biological yield, oil percentage and protein percentage. However, there was no significant influence on a number of seeds pod^{-1} with iron foliar application and defoliation.

The application of RDF as a basal dose and foliar spray of NAA (40 ppm) + chelated (0.5 %) micronutrient + DAP (2 %) given at 35 and 50 DAS recorded significantly higher growth parameters like plant height (37.11 cm), number of branches (8.27 plant^{-1}), leaf area index (4.18) and total dry matter production (15.98 g plant^{-1}) and also higher grain yield (1298 kg ha^{-1}), net returns and B:C ratio (₹ 52,900 ha^{-1} and 3.03, respectively) over rest of the treatments but it was at par with RDF + foliar spray of DAP (2 %) + chelated micronutrient (0.5 %) were observed by Shashikumar *et al.* (2013).

Choudhary *et al*. (2014) reported that highest grain yield of 14.59 and 14.25 g pot^{-1} was obtained when S (40 ppm) and Zn (5 ppm) were applied individually. The highest yield (15.30 g pot^{-1}) and the yield attributes viz; plant height (43.5 cm), branches plant^{-1} (6.7), capsule plant^{-1} (13.0), grains capsule^{-1} (3.2) and 100 grain weight (9.96 g) were obtained with combined application of sulphur (40 ppm) and with zinc (5 ppm) and the highest protein (38.64 %) and oil (21.54 %) content was observed to the foliar application of sulphur (60 ppm), while zinc (5 ppm) of soybean grain. Therefore, it was concluded that application of sulphur (60 ppm) and zinc (5 ppm) should be used for the improvement of yield and quality traits of soybean grain.

Costa *et al.* (2014) reported that the calcium rates applied on the leaves were 0, 150, 300 and 600 g ha^{-1} for the first year of the investigation (2005) and 0, 300, 600 and 900 g ha^{-1} for the second year (2006). In both years, the molybdenum rates applied to the leaves were 0 g ha^{-1} (without) and 75 g ha^{-1}. The results showed that the foliar application of calcium with or without molybdenum did not improve yield. Foliar application of calcium alone improved seed yield potential in common bean when applied at the full bloom stage.

Gowthami and Rao (2014) revealed that foliar application of potassium nitrate (2 %) + boric acid (50 ppm) + zinc sulphate (1 %) at 30 and 60 DAS was found to be superior in increasing plant height, number of branches, number of leaves, leaf area, total dry matter, number of pods $plant^{-1}$, test weight and seed yield followed by potassium nitrate (2 %) + boric acid (50 ppm) at 30 and 60 DAS.

Kobraee and Shamsi (2014) opined that except 100 seed weight $plant^{-1}$, other evaluated traits were affected by irrigation regimes and foliar application of micronutrients. Soil water deficit at flowering stage reduced plant height, a number of nodes, pods, seeds $plant^{-1}$ and grain yield (21.5 %, 24.9 %, 24.9 %, 33.8 % and 29.3 %, respectively) as compared to control. In the other side, a spray of manganese increased grain yield (29.6 %) as compared to molybdenum treatment. Whereas, application of manganese decreased the adverse effects of drought stress in soybean.

Sadeghi and Noorhosseini (2014) reported that the combined foliar application of iron and zinc treatment significantly recorded highest lentil yield (37.71 %) compared to the foliar application of iron alone (27.12 %) over the control. The interaction between fertilizer and time of fertilizer application showed that iron + zinc treatment at two times of fertilizer application (10 leaf and flowering stages) recorded a maximum number of seed pod^{-1} (2.28) and 100 grain weight.

Mandic *et al.* (2015) revealed that foliar nutrition significantly increased the values of all quantitative parameters Ferticare-I (5 kg ha^{-1}) is more effective than Wuxal super (5 l ha^{-1}) in soybean because this fertilizer contains a higher concentration of macronnutrients.

Rao *et al.* (2015) reported that foliar spray of KNO_3 (1 %) has significantly superior over the control. Foliar sprays of KNO_3 (1 %) has recorded more plant height, leaf area, shoot dry weight and photosynthetic rate by maintaining high chlorophyll content and leaf water potential. KNO_3 (1 %) gave higher yields under receding soil moisture condition compared to other foliar sprays. Under irrigated conditions, urea (2 %) recorded significantly higher yield over the control. Among all treatments controlled (no spray) under un-irrigated conditions recorded lower yields due to moisture stress and nutrient deficiency in moong bean.

2.3 Effect of foliar application of nutrients on quality parameters

Nasef *et al.* (2006) observed that highest oil and protein percentage of peanut seeds in both the seasons were obtained when the highest level of 300 ppm boron was used followed by 200 ppm and 100 ppm in descending order.

Adkine *et al.* (2011) inferred that there was a significant increase in protein and oil yield of soybean with the application of RDF + boron (1 kg ha^{-1}) + molybdenum (0.5 kg ha^{-1}) as soil application at the time of sowing and combined with either boron or molybdenum with a foliar spray.

Kader and Mona (2011) revealed that application of sulphur to the soil and foliar spray with micronutrients (Zn and B) together had a significant effect on peanut seed yield and its attributes as well as seed quality.

Yasari and Vahedi (2012) observed that the highest seed oil percentage (25.03 %) was obtained by foliar spray of zinc and that the higher seed yield (359.31 kg ha^{-1}) was obtained by foliar spray of manganese and the higher seed protein content (36.12 %) was obtained by foliar spray of boron on the crop and the higher seed protein yield (545.54 kg ha^{-1}) was obtained when manganese was applied to the soil.

Jyothi *et al.* (2013) observed a significant response from soybean to foliar application of N and Zn at pod development and flowering stage. Higher protein and oil contents (43.9 % and 20.9 %) and uptake of zinc and nitrogen by soybean plants were recorded with the foliar application of urea (2 %) at flowering and at early pod development stage.

Salih (2013) revealed that the treatment with iron 1 per cent foliar spray significantly increased nutrient concentration in seed and seed protein content. Iron treatment has a greater effect on the nutrient uptake and protein percentage of seed than the other treatments. That foliar fertilization with micronutrient may have a possible role for increasing cowpea yield.

Pande *et al.* (2014) reported that the protein content of soybean was increased by 3 per cent with the foliar spray of potassium when compared to soil application and control (no potassium application). Palmic acid percentages showed a significant increase in all concentrations, the highest percentage increase (16.9 %) was observed in 380 mg kg^{-1} of potassium. Linoleic acid percentages increased in both foliar treatments, but linolenic acid percentage increased in high soil treatment 380 mg kg^{-1} of K alone, with an increase (12.2 %) over control, and significant decrease (15.8 %) in linoleic acid was recorded in the foliar application of potassium in soybean.

Abdel *et al.* (2014) concluded that foliar spray of micronutrients recorded the highest values of plant height at harvest, number of branches $plant^{-1}$**,** number of pods $plant^{-1}$, 100 seed weight, seed yield $plant^{-1}$, seed yield (kg ha^{-1}), oil content, oil yield, protein content and protein yield compared to control. However, all micronutrient treatments increased all quantitative traits as compared with control treatment.

Kobraee *et al.* (2014) revealed that irrigation regimes and foliar spray of micronutrient had significant effects on oil, protein, seed yield and biological yield of soybean, and the highest oil concentration (19.51 %) in soybean seed was recorded when the foliar application of zinc (0.5 %) separately. Foliar application of zinc and manganese also decreased the adverse effects of drought stress on grain and biological yield of soybean.

Mannan (2014) reported that foliar spray of micronutrient, either singly or in combination significantly increased the growth and yield of the soybean as well as protein content in soybean seed, at the two growth stages as compared to soil fertilization. However, spray of micronutrients (N, NPK, NPKS and NPKMg @ 100 mg l^{-1}) during pod filling stage was better than vegetative growth stage in all characters were studied. The highest amount of protein content (37.33 %) in soybean seed and grain yield (187.20 g

m^{-2}) were recorded under the spraying of NPK with magnesium during pod filling stage in soybean.

2.4 Effect of foliar application of nutrients on nutrient uptake

Muthuvel *et al.* (1977) reported that foliar spray of DAP (2 %) and urea (1 %) at flowering stage, soil nutrient status was increased with the available N, P and K status of soil (131, 6.3 and 134 kg ha^{-1}, respectively) of rainfed black gram compared to no foliar spray.

Mary Schon and Dale Blevins (1990) revealed that foliar application of boron (1.12 kg ha^{-1} and 2.24 kg ha^{-1}) increased in leaf boron concentration for about 60 mg $gram^{-1}$ level that was previously accepted as the upper level of tolerance for soybean.

Boote *et al.* (1997) observed that foliar application of N, P, K, and S increased the N, P and K concentration in soybean leaves (from 3.28 %, 0.24 % and 0.92 % to 3.48 %, 0.29 % and 1.32 %, respectively).

Mazhar Haq and Antonio Mallarino (2000) showed that foliar fertilization (Fe and Zn @ 0.5 g l^{-1}) increased NPK uptake, concentration in the leaves and photosynthesis of soybean.

Nasef *et al.* (2006) observed that the highest seed yield of groundnut and yield components were obtained from plants receiving foliar spraying with 200 ppm boron and inoculated with Rhizobium strains. Also inoculated with biofertilizer (Rhizobium strains) alone or combined with different levels of boron (100 ppm, 200 ppm and 300 ppm) increased significantly the uptake of N, P, K, Fe, Zn and B by stalk and seeds of groundnut in both seasons with corresponding treatments with biofertilizer.

Raman and Venkatarama (2006) studied the effect of foliar nutrients on N, P and K uptake, yield attributes and yield of green gram. The results revealed that foliar spray of DAP (2 %) with NAA 30 ppm and penshipao (0.01 %) at 20 and 45 DAS recorded higher NPK uptake (69.01, 18.19 and 65.71 kg ha^{-1}, respectively) over control (58.66, 12.97 and 53.6 kg ha^{-1}, respectively).

2.5 Effect of foliar application of nutrients on economics

Adkine *et al.* (2011) reported that the higher BC ratio was recorded with the application of RDF with boron (1 kg ha^{-1}) soil application and combination with foliar spray in soybean.

Garud (2012) revealed that application of phosphorus (60 kg P_2O_5 ha^{-1}) and foliar application of BOOST-52 (0: 52: 34 NPK) at 35 and 50 DAS was significantly recorded highest seed yield (2387.7 kg ha^{-1}) with BC ratio of 3.53.

Kumar *et al.* (2013) revealed that foliar spray of DAP (2 %) twice at flowering initiation and pod formation stage of soybean resulted highest net returns ₹ 20,090 with BC ratio of 2.22.

Shashikumar *et al.* (2013) reported that application of RDF as a basal dose and combined with foliar spray of NAA (40 ppm) + chelated micronutrient (0.5 %) + DAP (2 %) given at 35 and 50 DAS recorded significantly higher grain yield, net returns and BC ratio (1298 kg ha^{-1}, ₹ 52,900 ha^{-1} and 3.03 respectively) over the control treatments but it was at par with RDF + foliar spray of DAP (2 %) + chelated micronutrient (0.5%) in blackgram.

III MATERIAL AND METHODS

The experiment entitled “Studies on the foliar application of nutrients on the productivity of soybean [*Glycine max* (L.) Merrill]” was carried out during the *kharif* season of 2016 at Zonal Agricultural Research Station, GKVK, Bengaluru. Details of the materials used and the methods adopted during the course of investigation are described in this chapter.

3.1 Location of the experimental site

The field experiment was conducted at the Zonal Agricultural Research Station, GKVK, Bengaluru during *kharif*, 2016. Gandhi Krishi Vignana Kendra (GKVK) campus of the University of Agricultural Sciences, Bengaluru-65, Karnataka, India, is located about 15 km away from Bengaluru city on the Bengaluru Bellary Road (National Highway No.7). Geographically, the place is located at 13º 05" N latitude and 77º 34" E longitude. The centre is at an altitude of 924 meters above mean sea level.

3.2 Soil of experimental site and previous history

The soil of the experimental site is red sandy clay loam in texture. The soils are deep and possess good drainage. The physical and chemical properties of the soil of the experimental site were analyzed from the composite soil sample collected from 0-15 cm depth are presented in Table 3.1.

3.3 Climatic conditions

The meteorological data pertaining to monthly total rainfall, maximum and minimum temperature, relative humidity, bright sunshine hours, wind speed and evaporation recorded during the cropping period of 2016 is presented in Table 3.2.

3.3.1 Normal climatic conditions

The normal annual rainfall of the station was 920.4 mm. In the year 2016, the major portion of rainfall was received during April to November with two peaks in the months of September (197.4 mm) and October (165.5 mm). The mean maximum air

Table 3.1: Physical and chemical properties of soil in the experimental site (ZARS, Bengaluru)

Particulars	Mean value obtained	Method adopted
I. Physical properties		
1. Particle size analysis		
a. Coarse sand (%)	**35.00**	International pipette method **(Piper, 1966)**
b. Fine sand (%)	**28.70**	
c. Silt (%)	**6.70**	
d. Clay (%)	**29.60**	
e. Textural class	**Red Sandy clay loam**	
II. Chemical analysis		
	Mean value obtained	
1. Soil pH (1:2.5)	**6.59**	Glass electrode pH meter **(Piper, 1966)**
2. Electrical conductivity (dS m^{-1})	**0.31**	Conductivity bridge **(Jackson, 1973)**
3. Organic carbon (%)	**0.35**	Wet oxidation method **(Walkley and Black, 1934)**
4. Available nitrogen (kg N ha^{-1})	**264.50**	Alkaline permanganate method **(Subbiah and Asija, 1956)**
5. Available phosphorus (kg P_2O_5 ha^{-1})	**38.34**	Bray's method **(Jackson, 1973)**
6. Available potassium (kg K_2O ha^{-1})	**110.25**	Flame photometry method **(Jackson, 1973)**

Table 3.2: Meteorological data of the experimental area during 2016 at GKVK, Bengaluru

Year/ Months	Rainfall (mm)			Mean temperature (°C)						Mean Relative Humidity (%)			Mean Sunshine hours (hr day^{-1})			Mean wind speed (km hr^{-1})			Pan evaporation (mm day^{-1})		
				Maximum			Minimum														
2016	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**	**N**	**A**	**D**
January	1.4	2.4	1.0	27.5	27.5	0.0	14.0	14.7	0.7	86.0	90.0	4.0	8.8	7.6	-1.2	6.8	6.5	-0.3	5.1	4.2	-0.9
February	9.0	0.0	-9.0	29.8	31.2	1.4	15.3	16.2	0.9	80.7	85.0	4.3	9.4	9.0	-0.4	6.8	7.1	0.3	6.2	5.2	-1.0
March	16.9	4.2	-12.7	32.6	34.0	1.4	18.0	19.9	1.9	75.3	86.0	10.7	9.3	8.2	-1.1	6.8	6.8	0.0	7.6	6.9	-0.7
April	48.2	1.2	-47.0	33.8	35.8	2.0	20.5	23.1	2.6	79.3	84.0	4.7	8.9	9.1	0.2	6.7	6.6	-0.1	7.7	8.6	0.9
May	100.7	112.6	11.9	33.1	33.1	0.0	20.5	21.4	0.9	81.5	88.0	6.5	8.2	7.8	-0.4	8.1	7.4	-0.7	7.1	6.3	-0.8
June	78.6	141.4	62.8	29.5	28.4	-1.1	19.6	19.9	0.3	85.8	92.0	6.2	8.7	4.7	-1.0	12.8	9.1	-3.7	6.0	3.0	-3.0
July	101.9	268.2	166.3	28.1	27.6	-0.5	19.1	19.3	0.2	88.1	94.0	6.9	4.3	4.1	-0.2	12.2	9.3	-2.9	5.3	3.4	-1.9
August	130.4	27.2	-103.2	27.6	28.1	0.5	18.9	19.5	0.6	89.0	92.0	3.0	4.7	5.7	1.0	10.4	9.2	-1.2	4.8	4.0	-0.8
September	197.4	44.4	-153	28.0	27.8	-0.2	18.8	19.0	0.2	88.9	92.0	3.1	5.7	3.5	-2.2	7.1	7.0	-0.1	5.0	3.4	-1.6
October	165.5	30.2	-135.3	27.8	29.6	1.8	18.2	18.0	-0.2	88.0	85.0	-3.0	6.0	7.9	1.9	5.5	4.6	-0.9	4.7	4.9	0.2
November	58.5	0.0	-58.5	26.7	29.6	2.9	16.5	16.2	-0.3	84.7	82.0	-2.7	6.2	8.5	2.3	6.1	6.2	0.1	4.5	4.6	0.1
December	11.9	63.5	51.6	26.2	27.2	1.0	14.5	14.7	0.2	84.4	85.0	0.6	7.2	6.9	-0.3	6.9	6.4	-0.5	4.5	3.9	-0.6
Total/Mean	920.4	695.3	-225.1	29.2	30.0	0.8	17.8	18.5	0.7	84.3	87.9	3.6	7.0	6.9	-0.1	8.0	7.2	-0.8	5.7	4.9	-0.8

Note: N - Normal meteorological data (mean of 1976 – 2016), A - Actual meteorological data, D - Deviation from the normal (A-N) temperature ranged from 26.2 to 33.8 ºC. Whereas, mean minimum air temperature ranged from 14 to 20.5 ºC. The mean monthly relative humidity ranged from 75.3 per cent in March to 89.1 per cent in August. Mean bright sunshine hours was maximum in February (9.4 hrs) and lowest in the month of July (4.3 hrs) and the mean wind speed was maximum during June (12.8 km hr^{-1}) and the minimum in October (5.5 km hr^{-1}). The open pan evaporation was directly related to maximum and a minimum temperature of the month and followed the same trend as that of maximum evaporation with maximum temperature in a year during March (7.6 mm day^{-1}) and April (7.7 mm day^{-1}).

3.3.2 Actual climatic conditions

The total amount of rainfall received during 2016 (695.3 mm) was less than normal. The crop growth period was from September to December in the year 2016. During the cropping period received less rainfall (166.3 mm) than normal. During the cropping period, the highest amount of rainfall (63.5 mm) received in the month of December but it was lower than the normal in the season.

The mean maximum air temperature was higher in the month of April (35.8 °C) and March (34.0 °C) during 2016. The mean minimum air temperature was more than normal for most of the months in the year. Mean monthly relative humidity ranged from 82 % in November 2016 to 94 per cent in July 2017. The mean bright sunshine hours was highest in November (8.5 hrs) and the lowest in September (3.5 hrs).

The mean wind speed was maximum during September of 2016 (7.0 km hr^{-1}). The lowest wind speed was recorded in October 2016 (4.6 km hr^{-1}). The mean pan evaporation ranged from 3.4 mm day^{-1} in September and 4.9 mm day^{-1} during November 2016.

3.6 Experimental details

The experiment was laid out in Randomized Block Design (RBD) with three replications. The treatments comprised of ten combinations of RDF and foliar spray of micronutrients.

3.6.1 Treatment details

Treatment details

T_1: RDF + Water spray at pod initiation

T_2: RDF + Urea 2 % spray at pod initiation

T_3: RDF + DAP 2 % spray at pod initiation

T_4: RDF + MOP 0.5 % spray at pod initiation

T_5: RDF + 19:19:19(NPK) 2 % spray at pod initiation

T_6: RDF + Molybdenum 0.5 % spray at pod initiation

T_7: RDF + Boron 0.5 % spray at pod initiation

T_8: RDF + Zinc chelated 0.5 % spray at pod initiation

T_9: RDF + Bio-digester liquid 2 % spray at pod initiation

T_{10}: RDF through the organic source (13.44 kg FYM plot^{-1})

(RDF: 25: 60: 25 NPK kg ha^{-1})

3.6.1 Design and layout

The experiment was conducted at the Zonal Agricultural Research Station, GKVK, Bengaluru-65 during *kharif*, 2016. The experiment was laid out in RCBD with three replications.

No. of treatments	:	10
Design	:	Randomized Block Design
Replications	:	3
Gross plot size	:	6.0 m x 3.6 m = 21.66 m^2
Net plot size	:	5.6 m x 2.4 m = 13.44 m^2
Variety	:	MAUS-2
Spacing	:	30 cm x 10 cm
RDF	:	25: 60: 25 NPK kg ha^{-1}
Date of sowing	:	10-08-2016
Date of harvesting	:	24-11-2016

3.7 Crop husbandry

3.7.1 Field preparation

The experimental layout was done when the soil reached to proper tilth condition. The land was ploughed with tractor drawn cultivator and disc harrow was passed to remove weeds, crush the clods and levelled the plot.

3.7.2 Seed treatment and sowing

In order to prevent the crop from seed and soil borne diseases, the seeds were treated with Bavistin @ 3 g kg^{-1} of seeds followed by Rhizobium culture @ 5 g kg^{-1} of seeds. Then treated seeds were dried under shade for 3-4 hours before sowing. The seeds were sown at 60 kg ha^{-1} with the spacing of 30 cm between the rows and 10 cm between the plant or seed manually.

3.7.3 Fertilizer

The recommended dose of fertilizer i.e. 25: 60: 25 kg NPK ha^{-1} through Urea, SSP, and Muriate of Potash (MOP), respectively were applied as basal dose before sowing and mixed properly.

3.7.4 Aftercare

3.7.4.1 Weed management

General weed management practice was adopted at 25 DAS by using pre-emergence herbicide Alachlor @ 1 kg a.i. ha^{-1} followed by one manual hand weeding at 45 DAS.

3.7.4.2 Application of nutrients

All micronutrients were applied as per treatments at an early stage of pod initiation and precaution was taken care of during preparation of micronutrients solution.

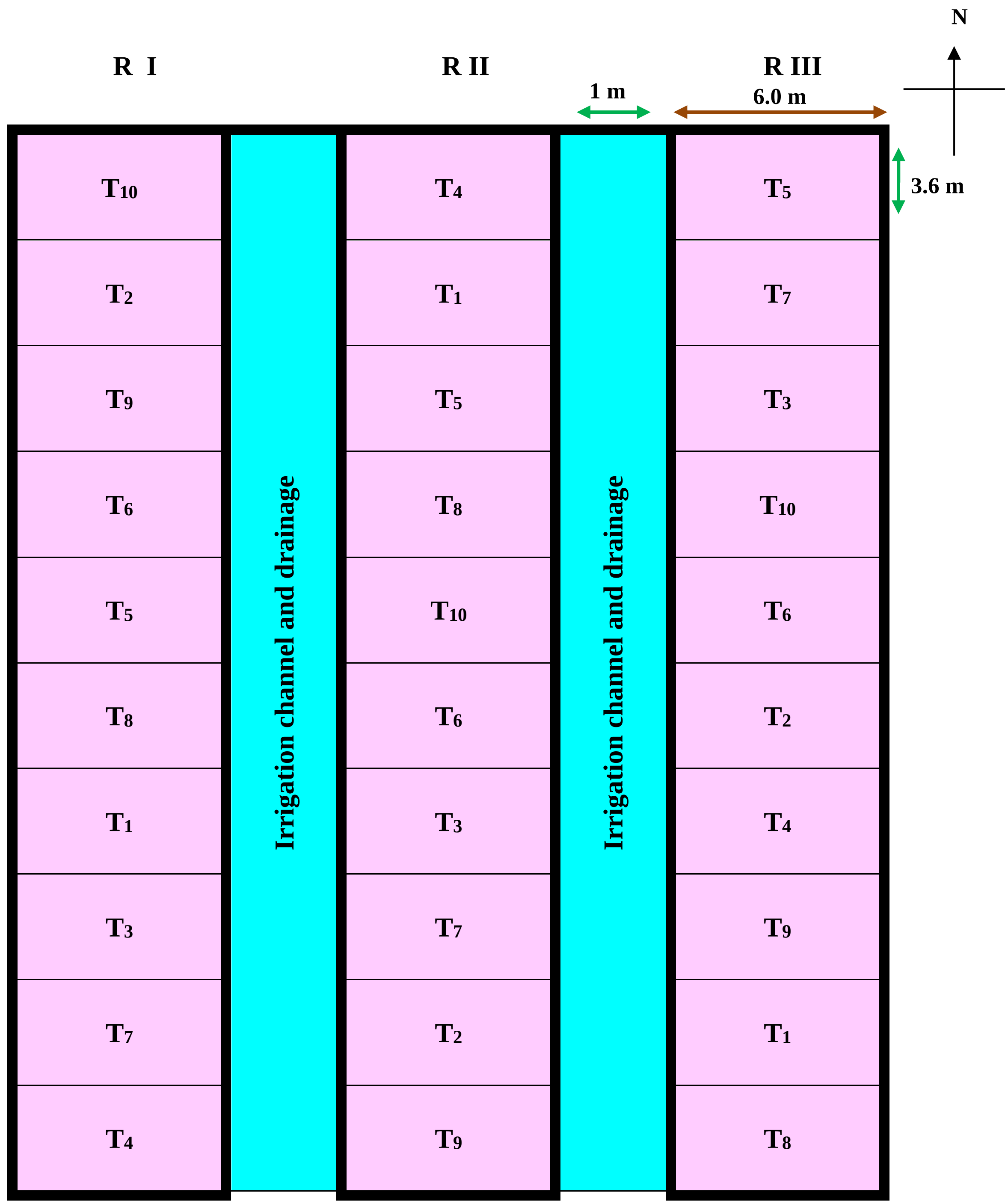

Fig. 3.1: Plan of layout of experimental plot

Legend

Treatment details

T_1: RDF + Water spray at pod initiation

T_2: RDF + Urea 2 % spray at pod initiation

T_3: RDF + DAP 2 % spray at pod initiation

T_4: RDF + MOP 0.5 % spray at pod initiation

T_5: RDF + 19:19:19(NPK) 2 % spray at pod initiation

T_6: RDF + Molybdenum 0.5 % spray at pod initiation

T_7: RDF + Boron 0.5 % spray at pod initiation

T_8: RDF + Zinc chelated 0.5 % spray at pod initiation

T_9: RDF + Bio-digester liquid spray

T_{10}: RDF through the organic source

Plate 1: General view of experimental plot at 60 DAS.

Plate 2: General view of field at 30 DAS

Plate 3: General view of field at 60 DAS

Plate 4: General view of field at 90 DAS

3.7.4.3 Harvesting

Harvesting was done manually from the net plot area when the seed became hard and leaves turned yellow in color. The plants were left in the plot for five days to sundry. The bundle weight plot^{-1} was recorded.

3.7.4.4 Threshing and winnowing

Threshing of the produce of each net plot was done manually by beating with a wooden stick and after manual winnowing seed yield plot^{-1} was recorded. Stalk yield was also recorded after subtracting the seed yield from bundle weight.

3.8 Biometric observations

3.8.1 Growth parameters of soybean recorded at 30, 60 DAS and at harvest

3.8.1.1 Plant height (cm)

The height of five tagged plants in each plot was recorded in centimetre and then the average was worked out and used for statistical analysis. Height was measured in centimetre from the ground surface to the tip of the fully opened leaf.

3.8.1.2 Number of branches plant^{-1}

A number of branches were counted from five tagged plants of each plot. The mean number of branches plant^{-1} was obtained by dividing the summation with five and used for statistical analysis.

3.8.1.3 Number of leaves plant^{-1}

Numbers of leaves plant^{-1} were counted from the five tagged plants in each plot, periodically and an average value was used for statistical analysis.

3.8.1.4 Leaf area (cm^{2} plant^{-1})

Leaf area plant^{-1} was recorded from the five tagged plants in each plot, the leaves were separated and leaf area was recorded by using leaf area meter periodically at 60, 90 DAS and at harvest. The leaf area is expressed in cm^{2} plant^{-1}.

3.8.1.4 Number of nodules plant^{-1}

The numbers of nodules plant^{-1} were recorded at 30 and 60 DAS from five randomly selected plants from each plot. The uprooting of sample plants was performed along with the soil up to the effective root zone. The roots of the plant were washed in a sieve with running water and effective root nodules were separated and counted.

3.8.2 Yield parameters of soybean

3.8.2.1 Number of pods plant^{-1}

To study the influence of different treatments on pod formation in the soybean crop, a total number of pods were recorded from five randomly tagged plants and mean was worked out by dividing the total number of pods by five and used for statistical analysis.

3.8.2.2 Number of seeds pod^{-1}

Randomly selected matured pods of five tagged plants from each plot and their seeds were counted and the average was calculated by dividing the total number of pods of five tagged plants to get the mean number of seeds pod$^{-1.}$

3.8.2.3 Number of seeds plant^{-1}

All matured pods of five tagged plants from each plot were picked up and their seeds were counted and the average was calculated by dividing the total number of seeds of five tagged plants to get the mean number of seeds plant^{-1}.

3.8.2.4 Test weight (g)

Randomly seed samples were taken from each net plot and hundred healthy seeds from the produce of each plot were counted and same was oven dried at a temperature of 60 °C for 24 hours then weight (g) was recorded accurately by using an electronic digital balance.

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

Seed yield of the net plot was noted down after threshing, winnowing and drying then calculated in kg ha^{-1} with appropriate multiplication factor (740.74).

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

The harvested produce from each net plot was tied in bundles separately. Bundle weight was recorded with the help of spring balance and converted into kg ha^{-1}. Stalk yield of the plot was calculated after subtraction of seed yield from bundle weight.

3.8.3 Quality parameters of soybean

3.8.3.1 Oil percentage

Oil was extracted from seeds of soybean with the help of Sacs plus solvent extractor using acetone as a solvent. Sample seeds of each plot were dried in an oven at 80 °C for 4-5 hours. After that, seeds were crushed into powder. One gram powder of crushed seed was taken for oil extraction. The sample was placed in the cellulose thimble. Beaker used in this instrument was weighed. Further, 80 ml of solvent (acetone) was added to the beaker. The cellulose thimble containing sample was dipped into the beaker containing solvent. Later, the sample was placed on the instrument and boiled for about 40-45 minutes at 90 °C. After 40-45 minutes, the temperature of the unit was increased to 150 °C and the stopper knob was opened for proper rinsing. Thereafter, the stopper knob closed and the solvent was emptied, which was collected in the extractor. Beakers were removed and kept in the oven for about 1 hour; these beakers were taken outside, cooled and weighed. The percent of oil present in a sample was calculated with the help of following formula:

$$\text{Oil content (\%)} = \frac{W_2 - W_1}{W} \times 100$$

Where,

W_1 = Initial weight of beaker (g)

W_2 = Final weight of beaker (beaker + oil) (g)

W = Weight of powdered sample (1 g)

3.8.3.2 Protein percentage

Protein content (%) of seeds collected from respective plots or treatments was calculated by multiplying the conversion factor (6.25) with nitrogen content estimated by the prescribed method of seed.

3.9 Chemical analysis:

3.9.1 Chemical analysis of soil before the start of the experiment and after harvest

3.9.1.1 Soil sampling and preparation of the sample

Soil samples were collected in the beginning and after the harvest of individual plots of the experiment by taking a slice of soil to the depth of 20 cm. Soil samples were air dried and sieved through 2 mm sieve and analyzed to estimate soil reaction (pH), organic carbon (OC %) and available soil NPK.

3.9.1.2 Soil pH

The soil pH was determined in 1:2.5 soil water suspension using a digital pH meter with a glass electrode (Jackson, 1973).

3.9.1.3. Electrical conductivity (EC) (dSm^{-1})

Electrical conductivity (EC) of the clear soil water (1:2.5) extract was determined using conductivity bridge.

3.9.1.4 Organic carbon (OC)

The organic carbon was determined by following Walkely Black's wet-oxidation method using $K_2Cr_2O_7$ with H_2SO_4 and back titrated against standard ferrous ammonium sulphate as described by Jackson (1973).

3.9.1.5 Available nitrogen (kg ha^{-1})

The available nitrogen was determined by Micro Kjeldhal distillation of soil sample following alkaline permanganate method as suggested by Jackson (1973). The soil samples were taken during the time of harvest.

3.9.1.6 Available phosphorus (kg ha^{-1})

The available phosphorus was extracted with Bray's No.1 extractant (0.03 N NH4F + 0.025 N HCl). The phosphorus in the extract was determined by stannous chloride reduced molybdophosphoric blue colour method. The intensity of blue color was read at 660 nm using a spectrophotometer (Bray and Kurtz, 1945). The soil samples were taken during the time of harvest.

3.9.1.7 Available potassium (kg ha^{-1})

The available potassium was determined by using flame photometer after extracting the soil with neutral normal ammonium acetate (Jackson, 1973). The soil samples were taken during the time of harvest.

3.9.2 Chemical analysis of plant samples

3.9.2.1 Sample preparation

Soybean leaves and branches were collected and dried, powdered and used for estimating the N, P and K contents.

3.9.2.2 Nitrogen content (kg ha^{-1})

The nitrogen content in the grain and straw samples was estimated by Micro Kjeldhal method (Jackson, 1967) and expressed in percentage on a dry weight basis.

3.9.2.3 Phosphorus content (kg ha^{-1})

The phosphorus in the plant sample which was digested in the di-acid mixture (900 ml conc. HNO_3 + 400 ml of perchloric acid) as described by Piper (1966). The phosphorus content of the di-acid digested grain and straw samples was determined by Vanado molybdo phosphoric yellow colour method (Jackson, 1973) and expressed in percentage on a dry weight basis.

3.9.2.4 Potassium content (kg ha^{-1})

The potassium content in grain and straw samples was determined by flame photometer method as described by Jackson (1973) and expressed in percentage on a dry weight basis.

3.9.3 Nutrient uptake studies

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Dry weight (g)}}{100}$$

3.10 Economic analysis

The cost of various inputs used and the prices of outputs in the prevailing local markets were considered for estimation of the cost of cultivation, gross returns, and net returns hectare^{-1}. The details of which are given in appendix-I.

Net returns were calculated by deducting the cost of cultivation from total gross returns.

Benefit-cost ratio was worked as follows:

$$\text{BC ratio} = \text{Gross returns (₹ ha}^{-1}\text{)} / \text{Cost of cultivation (₹ ha}^{-1}\text{)}$$

3.11 Statistical analysis

The experimental data collected on various growth and yield components of the plant were subjected to Fisher's method of "Analysis of variance" (ANOVA). Whenever F-test was significant for comparison among the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise, against CD values abbreviation NS (Non-Significant) was indicated. All the data were analyzed and the results are presented and discussed at a probability level of 0.05 % and correlation study was done as given by Panse and Sukhatme (1967).

IV RESULTS AND DISCUSSION

A field experiment entitled "Studies on foliar application of nutrients on productivity of soybean [*Glycine max* (L.) Merrill]" was carried out during *kharif* season of 2016 at the Zonal Agricultural Research Station, GKVK, Bengaluru. The data recorded on various aspects of crop growth, yield attributing characters, productivity, quality and economics and other aspects are briefly described. The results are discussed in this chapter along with establishing 'cause' and 'effect' relationship in the light of available literature on the subject, which is postulated by various workers within and outside the country. The sequence of results and discussion is around growth, yield and yield components, quality, available soil nutrient status, nutrient uptake and economics of soybean.

4.1 Growth parameters of Soybean:

The data on growth parameters of soybean *viz.*, plant height (cm), number of branches $plant^{-1}$, number of leaves $plant^{-1}$, leaf area (cm^2 $plant^{-1}$) and number of nodules $plant^{-1}$ as influenced by foliar nutrition are presented in Tables 4.1 to 4.5.

4.1.1 Plant height (cm)

The data on plant height (cm) at 30, 60 DAS and at harvest of soybean as influenced by foliar nutrition is presented in Table 4.1.

30 days after sowing

Plant height was found non-significant due to the application of foliar nutrients at pod initiation stage in soybean. However, higher plant height (20.33 cm) was recorded with the application of RDF + zinc chelated 0.5 % spray followed by RDF + 19:19:19 2 % spray (20.17 cm) and lower plant height (16.00 cm) was recorded in RDF + MOP 2 % spray.

60 days after sowing

Plant height of soybean varied significantly due to the application of foliar nutrients at pod initiation stage. Application of RDF + DAP 2 % spray recorded higher plant height

(40.32 cm) while, lower plant height (34.00 cm) was recorded in the treatment RDF + water spray.

At harvest stage

Plant height did not vary significantly due to the application of foliar nutrients at pod initiation stage in soybean. However, maximum plant height (41.66 cm) was noticed in RDF + DAP 2 % spray followed by RDF + 19:19:19 2 % spray (39.00 cm) and RDF through organic source (39.00 cm) whereas, minimum plant height was noticed in RDF + bio-digester liquid spray (37.10 cm) and RDF + water spray (37.10 cm).

Table 4.1: Plant height (cm) of soybean as influenced by foliar spray of nutrients at pod initiation stage

Treatments	30 DAS	60 DAS	At harvest
T_1: RDF + Water spray	19.33	34.00	37.10
T_2: RDF + Urea 2 % spray	18.67	35.67	38.00
T_3: RDF + DAP 2 % spray	18.93	40.32	41.66
T_4: RDF + MOP 2 % spray	16.00	36.33	38.67
T_5: RDF + 19:19:19(NPK) 2 % spray	20.17	35.00	39.00
T_6: RDF + Molybdenum 2 % spray	19.63	37.23	38.23
T_7: RDF + Boron 0.5 % spray	17.33	36.67	38.33
T_8: RDF + Zinc chelated 0.5 % spray	20.33	34.97	38.70
T_9: RDF + Bio-digester liquid spray	18.67	34.67	37.10
T_{10}: RDF through organic source	17.66	35.33	39.00
SEm±	**1.86**	**0.39**	**2.28**
CD (P=0.05)	**NS**	**1.16**	**NS**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant DAS: Days after sowing

4.1.2 Number of branches plant^{-1}

Number of branches plant^{-1} of soybean as influenced by foliar application of various nutrients at pod initiation stage was measured at 30, 60 DAS and at harvest and data are presented in Table 4.2.

It was observed that the various treatments failed to cause any significant differences in relation to number of branches plant^{-1} over the course of the experiment. However, highest number of branches plant^{-1} (2.20, 4.10 and 4.93, respectively) was recorded in RDF + DAP 2 % spray compared to all other treatments at 30, 60 DAS and at harvest.

Table 4.2: Number of branches plant^{-1} as influenced by foliar spray of nutrients at pod initiation stage

Treatments	30 DAS	60 DAS	At harvest
T$_1$: RDF + Water spray	2.33	3.70	4.51
T$_2$: RDF + Urea 2 % spray	2.10	4.00	5.82
T$_3$: RDF + DAP 2 % spray	2.20	4.10	4.93
T$_4$: RDF + MOP 2 % spray	2.17	4.00	4.20
T$_5$: RDF + 19:19:19(NPK) 2 % spray	2.27	3.40	4.31
T$_6$: RDF + Molybdenum 2 % spray	2.23	3.50	4.49
T$_7$: RDF + Boron 0.5 % spray	2.33	3.70	4.63
T$_8$: RDF + Zinc chelated 0.5 % spray	2.07	3.80	4.48
T$_9$: RDF + Bio-digester liquid spray	2.17	3.70	4.40
T$_{10}$: RDF through organic source	2.29	3.65	4.30
SEm±	**0.28**	**0.015**	**0.82**
CD (P=0.05)	**NS**	**NS**	**NS**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant DAS: Days after sowing

4.1.3 Number of leaves plant^{-1}

Number of leaves plant^{-1} of soybean as influenced by foliar application of various nutrients at pod initiation stage at 30, 60 DAS and at harvest is presented in Table 4.3.

30 days after sowing

Number of leaves plant^{-1} was found to be non-significant due to the application of foliar nutrients at pod initiation stage in soybean. However, higher number of leaves plant^{-1} (9.20) was observed in the application of RDF + Molybdenum 2 % spray, RDF + zinc chelated 0.5 % spray (9.20) and lower number of leaves plant^{-1} (6.30) was recorded in RDF + boron 0.5 % spray.

60 days after sowing

Application of foliar nutrients at pod initiation stage in soybean significantly increased number of leaves plant^{-1}. Significantly maximum number of leaves plant^{-1} (37.73) was observed with the application of RDF + DAP 2 % spray followed by RDF + Molybdenum 2 % spray (34.83) while, minimum number of leaves plant^{-1} was observed with the application of RDF through organic source (29.76).

Table 4.3: Number of leaves plant^{-1} as influenced by foliar spray of nutrients at pod initiation stage

Treatments	30 DAS	60 DAS	At harvest
T_1: RDF + Water spray	9.10	30.17	6.84
T_2: RDF + Urea 2 % spray	8.90	31.77	6.31
T_3: RDF + DAP 2 % spray	8.10	37.73	10.46
T_4: RDF + MOP 2 % spray	7.90	30.73	7.99
T_5: RDF + 19:19:19(NPK) 2 % spray	8.70	31.53	8.43
T_6: RDF + Molybdenum 2 % spray	9.20	34.83	9.96
T_7: RDF + Boron 0.5 % spray	6.30	30.70	5.63
T_8: RDF + Zinc chelated 0.5 % spray	9.20	30.83	7.11
T_9: RDF + Bio-digester liquid spray	6.90	30.20	4.77
T_{10}: RDF through organic source	8.50	29.76	5.60
SEm±	**0.84**	**0.75**	**0.97**
CD (P=0.05)	**NS**	**2.21**	**2.89**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant DAS: Days after sowing

At harvest

Significant variation in the number of branches plant^{-1} of soybean at harvest due to the foliar spray of nutrients at pod initiation stage. Application of RDF + DAP 2 % spray was noticed more number of branches plant^{-1} (10.46) compared to RDF + Molybdenum 2 % spray (9.96) and less number of leaves plant^{-1} (5.60) was noticed with the application of RDF through organic source.

4.1.4 Leaf area plant^{-1} (cm^2)

Leaf area plant^{-1} (cm^2) of soybean as influenced by various foliar application of nutrients at pod initiation stage was recorded at 30, 60 DAS and at harvest and the data is presented in Table 4.4.

30 days after sowing

There was no significant difference observed in leaf area due to foliar application of nutrients. However, maximum leaf area plant^{-1} (350.00 cm^2) was noticed in application of RDF + Urea 2 % spray and minimum leaf area plant^{-1} (322.00 cm^2) was noticed in application of RDF + Molybdenum 2 % spray.

60 days after sowing

A significant difference in leaf area plant^{-1} was observed due to the influence of foliar application of nutrients in soybean. Significantly higher leaf area plant^{-1} (850.63 cm^2) was recorded in RDF + DAP 2 % spray and lower leaf area plant^{-1} (764.23 cm^2) was recorded in application of RDF through organic source.

At harvest

Leaf area plant^{-1} of soybean varied significantly due to the application of foliar nutrients at pod initiation stage. More leaf area plant^{-1} (394.34 cm^2) was observed in application of RDF + DAP 2 % spray and lesser leaf area plant^{-1} (231.56 cm^2) was observed in RDF through organic source.

Table 4.4: Leaf area (cm^2) $plant^{-1}$ as influenced by foliar spray of nutrients at pod initiation stage

Treatments	30 DAS (cm^2)	60 DAS (cm^2)	At harvest (cm^2)
T_1: RDF + Water spray	343.33	799.00	258.06
T_2: RDF + Urea 2 % spray	350.00	807.63	248.14
T_3: RDF + DAP 2 % spray	333.33	850.13	394.34
T_4: RDF + MOP 2 % spray	342.00	777.10	345.89
T_5: RDF + 19:19:19(NPK) 2 % spray	336.33	778.67	325.89
T_6: RDF + Molybdenum 2 % spray	322.00	771.67	348.60
T_7: RDF + Boron 0.5 % spray	326.70	794.03	291.95
T_8: RDF + Zinc chelated 0.5 % spray	329.45	780.33	252.60
T_9: RDF + Bio-digester liquid spray	334.97	770.60	234.74
T_{10}: RDF through organic source	356.31	764.23	231.56
SEm±	**40.46**	**10.70**	**12.09**
CD (P=0.05)	**NS**	**31.79**	**35.93**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant DAS: Days after sowing

4.1.5 Number of nodules $plant^{-1}$

The data recorded on the number of nodules $plant^{-1}$ in soybean at 30 and 60 DAS as influenced by foliar spray of nutrients is given in Table 4.5.

It was observed that there was non-significant difference in the number of nodules $plant^{-1}$ due to the application of foliar nutrients in soybean. However, the maximum number of nodules $plant^{-1}$ (7) was observed on 30 DAS in RDF + bio-digester spray and the minimum number of nodules $plant^{-1}$ (5) was observed in RDF + zinc chelated 0.5 % spray, RDF + boron 0.5 % spray (5) and RDF + Molybdenum 0.5 % spray. Also, the higher number of nodules $plant^{-1}$ (14) was observed on 60 DAS in RDF + zinc chelated 0.5 % spray and the lower number of nodules $plant^{-1}$ (9) was observed in RDF + bio-digester spray and RDF through the organic source.

Table 4.5: Number of nodules plant^{-1} as influenced by foliar spray of nutrients at pod initiation stage

Treatments	30 DAS	60 DAS
T1: RDF + Water spray	6	10
T2: RDF + Urea 2 % spray	6	12
T3: RDF + DAP 2 % spray	6	12
T4: RDF + MOP 2 % spray	6	11
T5: RDF + 19:19:19(NPK) 2 % spray	6	13
T6: RDF + Molybdenum 2 % spray	5	10
T7: RDF + Boron 0.5 % spray	5	11
T8: RDF + Zinc chelated 0.5 % spray	5	14
T9: RDF + Bio-digester liquid spray	7	9
T10: RDF through organic source	6	9
SEm±	**0.09**	**0.19**
CD (P=0.05)	**NS**	**NS**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant DAS: Days after sowing

Discussion on the findings relating to the effect of foliar application of nutrients on growth parameters of soybean

The economic yield of a plant is an outcome of a continuously integrated interactions of various biological events involving biochemical, physiological and morphological changes which takes place during plant development in accordance with the supply of nutrients, light, water, and temperature (Donald, 1962). Foliar application of nutrients obviously results in greater variation in growth pattern leading to different levels of yield. This is ascribed with higher growth and yield components recorded in the present investigation might be due to foliar application of nutrients. The results have been presented in Tables 4.1 to 4.5 and Figures 4.1 to 4.5.

In the present study, RDF + DAP 2 % spray at pod initiation stage significantly recorded higher readings followed by RDF + Urea 2 % spray and lower with RDF through organic sources at 60 DAS. The improvement in growth parameters of soybean with RDF

+ DAP 2 % spray at pod initiation stage maybe ascribed to beneficial effects of DAP 2 % spray on crop growth. Foliar application of nutrients at the time of pod initiation significantly influenced on growth parameters of soybean might be due to the maximum uptake of nutrients through foliage, micronutrients enhance the shoot growth and also formation of leaves through an increase in photosynthetic rate and cell division. Also, the application of DAP as a foliar spray at the rate of 2 % might have supplied both nitrogen and phosphorus and helped in effective absorption, translocation and proper distribution of nutrients into different parts of the plant. These results are in agreement with Nadergoli *et al.* (2011), the highest plant height and other growth parameters were found due to foliar application of nutrients at shooting, flowering and pod formation stages. According to Salwa *et al.* (2011), foliar application of micronutrients was also helpful to absorb more quantity of macronutrients, such as N, P and K. They have a major role in cell division and development of meristematic tissues; plant height, photosynthesis, respiration and acceleration of crop physiology when the plant doesn't absorb necessary nutrients through roots in soybean. Results of the present study are in line with Solaiappan *et al.* (2002) had also noticed that the foliar application of DAP @ of 2 % might have supplied nitrogen and phosphorus at the far end of crop might have helped in effective translocation and proper distribution of nutrients towards different parts resulting increases in the number of leaves plant^{-1}. Similar findings have also been obtained by Popovic *et al.* (2013) in soybean and Thakare *et al.* (2006) in redgram.

4.2 Yield parameters of soybean

The yield and yield attributes of soybean as influenced by the foliar application of nutrients at pod initiation stage *viz.*, number of pods plant^{-1}, number of seeds pod^{-1}, test weight (g) and seed yield plant^{-1} (g) is presented in Table 4.6 and Figure 4.6.

4.2.1 Number of pods plant^{-1}

There was a significant difference observed in the number of pods plant^{-1} due to foliar application of nutrients at pod initiation in soybean. Significantly higher number of pods plant^{-1} (43) was observed in RDF + DAP 2 % spray and significantly lower number of pods plant^{-1} (35) was observed in the application of RDF through the organic source.

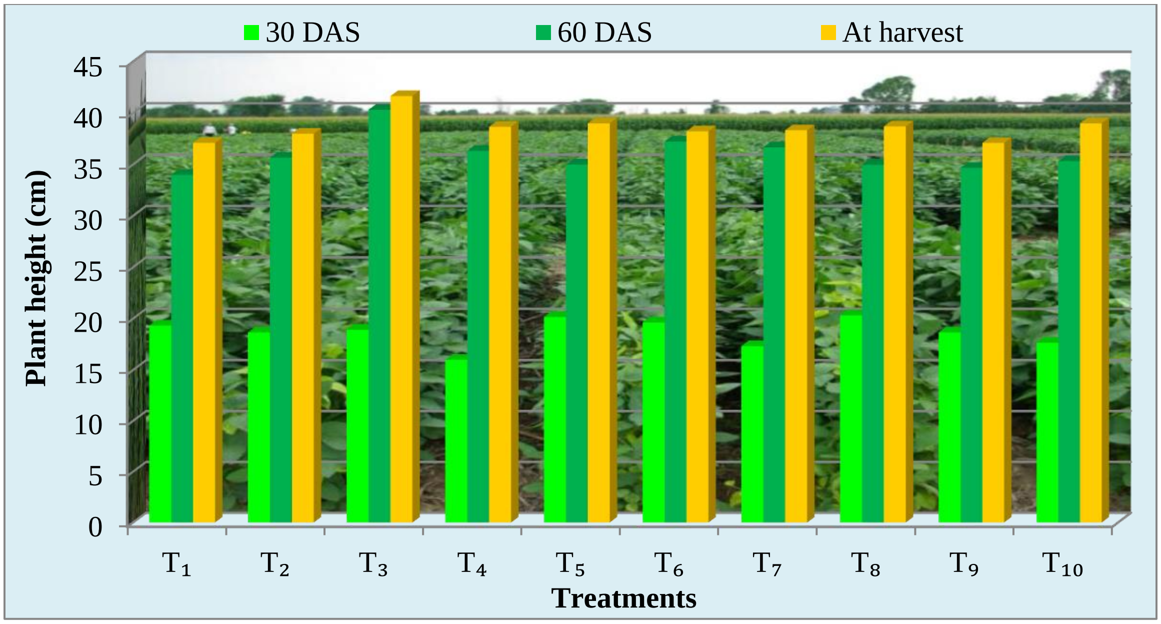

Fig. 4.1: Plant height (cm) of soybean as influenced by foliar spray of nutrients at pod initiation stage

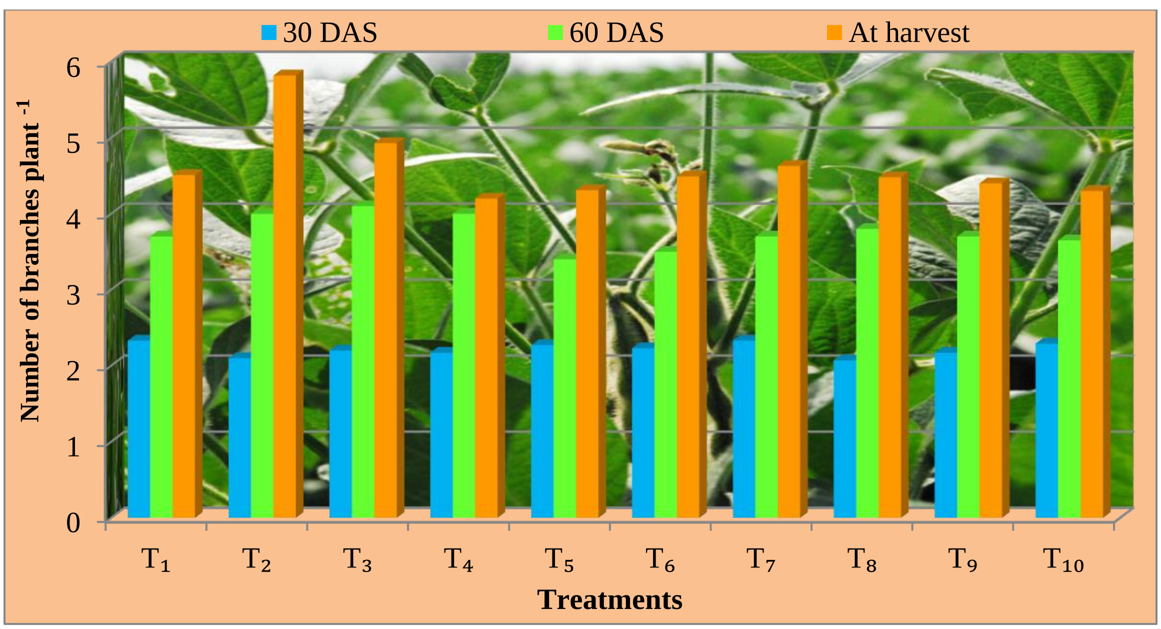

Fig. 4.2: Number of branches plant^{-1} at 30, 60 DAS and at harvest as influenced by foliar spray of nutrients at pod initiation stage

Legend:

T_1: RDF + Water spray at pod initiation
T_2: RDF + Urea 2 % spray at pod initiation
T_3: RDF + DAP 2 % spray at pod initiation
T_4: RDF + MOP 0.5 % spray at pod initiation
T_5: RDF + 19:19:19(NPK) 2 % spray at pod initiation
T_6: RDF + Molybdenum 0.5 % spray at pod initiation
T_7: RDF + Boron 0.5 % spray at pod initiation
T_8: RDF + Zinc chelated 0.5 % spray at pod initiation
T_9: RDF + Bio-digester liquid spray at pod initiation
T_{10}: RDF through the organic source

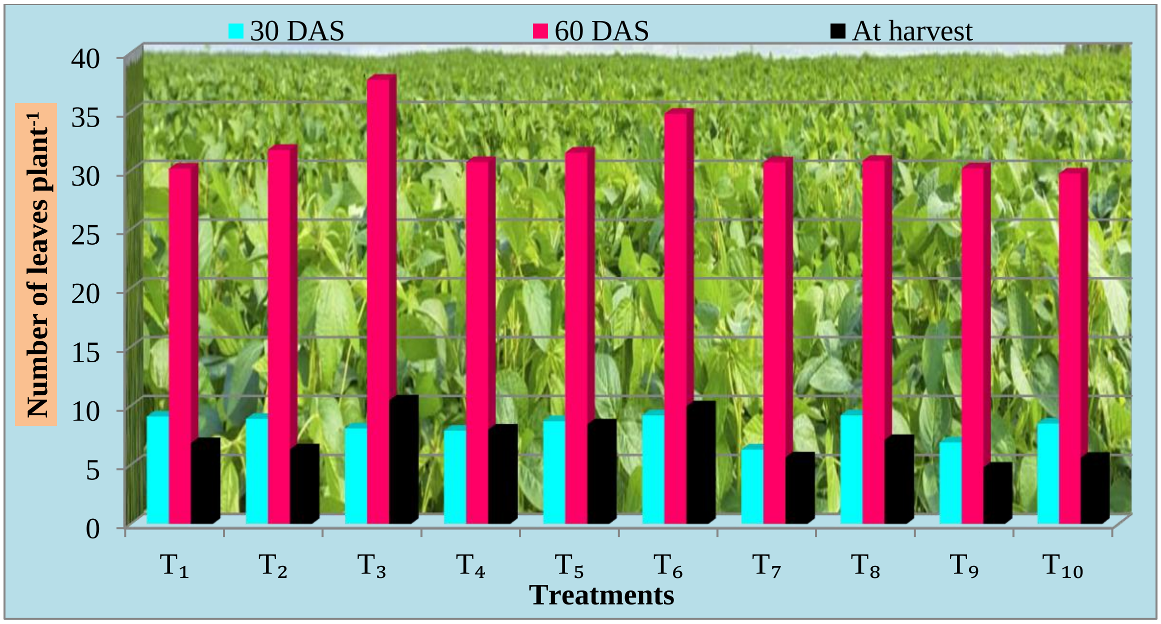

Fig. 4.3: Number of leaves plant^{-1} at 30, 60 DAS and at harvest as influenced by foliar spray of nutrients at pod initiation stage

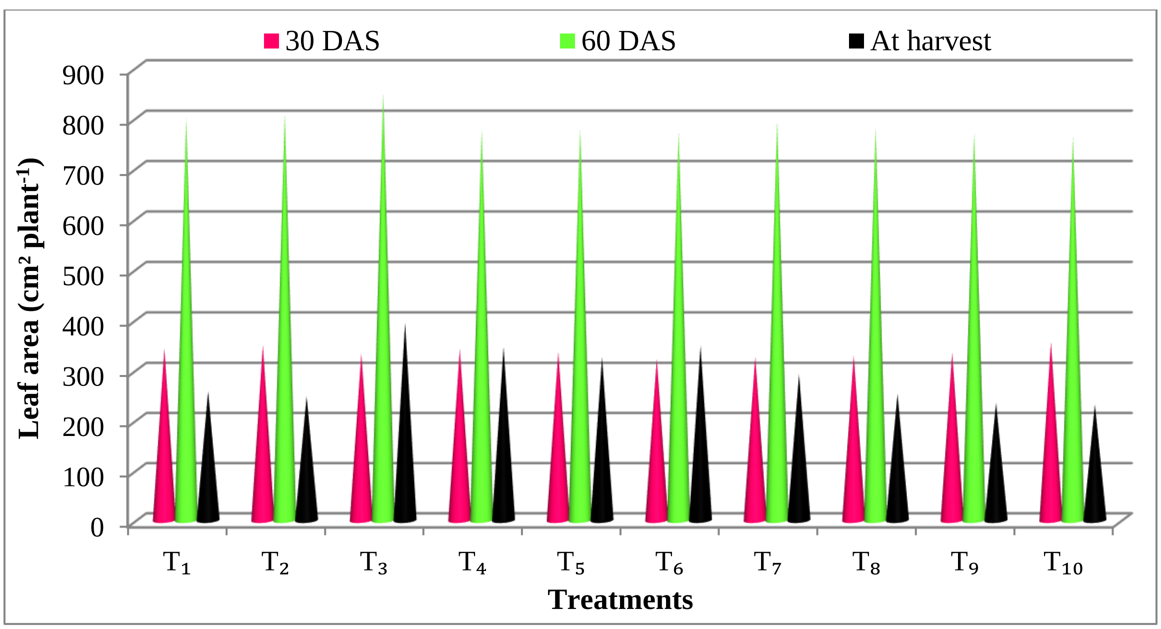

Fig. 4.4: Leaf area (cm^2 plant^{-1}) at 30, 60 DAS and at harvest as influenced by foliar spray of nutrients at pod initiation stage

Legend:

T_1: RDF + Water spray at pod initiation
T_2: RDF + Urea 2 % spray at pod initiation
T_3: RDF + DAP 2 % spray at pod initiation
T_4: RDF + MOP 0.5 % spray at pod initiation
T_5: RDF + 19:19:19(NPK) 2 % spray at pod initiation
T_6: RDF + Molybdenum 0.5 % spray at pod initiation
T_7: RDF + Boron 0.5 % spray at pod initiation
T_8: RDF + Zinc chelated 0.5 % spray at pod initiation
T_9: RDF + Bio-digester liquid spray at pod initiation
T_{10}: RDF through the organic source

4.2.2 Number of seeds pod^{-1}

A significant variation was recorded in the number of seeds pod^{-1} as influenced by the foliar application of nutrients at pod initiation in soybean. A maximum number of seeds pod^{-1} (3.00) was observed with application of RDF + 2 % DAP spray and this treatment was on par with RDF + 2 % Urea spray (2.91) and RDF + 2 % MOP spray (2.86). A minimum number of seeds pod^{-1} was observed with the application of RDF through the organic source (1.78).

4.2.3 Test weight

A significant difference was found in the test weight of soybean due to the effect of foliar application of nutrients at pod initiation. More test weight (11.40 g) was recorded in application of RDF + DAP 2 % spray and lesser (10.00 g) was recorded in the application of RDF through the organic source.

4.2.4 Number of seeds plant^{-1}

Foliar application of nutrients at pod initiation stage of soybean significantly influenced on a number of seeds plant^{-1}. A higher number of seeds plant^{-1} (88.37) was observed in the application of RDF + DAP 2 % spray and it was on par with RDF + Urea 2 % spray (82.37) and lower number of seeds plant^{-1} (52.67) was observed in RDF through the organic source.

4.2.5 Seed yield

Seed yield of soybean varied significantly due to the foliar application of nutrients at pod initiation stage. Significantly higher seed yield (37.72 q ha^{-1}) was obtained with RDF + DAP 2 % spray followed by RDF + Urea 2 % spray (34.31 q ha^{-1}) and lower seed yield (19.27 q ha^{-1}) was obtained with the application of RDF through the organic source.

4.2.6 Stalk yield

Foliar application of nutrients at pod initiation stage of soybean significantly increased the stalk yield. Significantly higher stalk yield (45.59 q ha^{-1}) was recorded with the application of RDF + DAP 2 % spray compared to RDF thorough organic source was recorded lower seed yield (25.77 q ha^{-1}).

Table 4.6: Yield attributing characters of soybean as influenced by foliar spray of nutrients at pod initiation stage

Treatments	Number of pods plant^{-1}	Number of seeds pods^{-1}	Test weight (g)	Seeds plant^{-1} (g)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})
T1: RDF + Water spray	37	1.98	11.01	56.10	2323	2945
T2: RDF + Urea 2 % spray	41	2.91	11.20	82.37	3431	4152
T3: RDF + DAP 2 % spray	43	3.00	11.40	88.37	3772	4559
T4: RDF + MOP 2 % spray	38	2.86	11.00	75.82	3091	3852
T5: RDF + 19:19:19 (NPK) 2 % spray	37	2.76	10.80	65.48	2581	3297
T6: RDF + Molybdenum 2 % spray	40	2.82	11.00	81.57	3325	3995
T7: RDF + Boron 0.5 % spray	38	2.67	11.07	62.53	2601	3153
T8: RDF + Zinc chelated 0.5 % spray	39	2.63	11.10	63.80	2753	3249
T9: RDF + Bio-digester liquid spray	37	2.02	11.05	61.07	2688	3045
T10: RDF through organic source	35	1.78	10.00	52.67	1927	2577
SEm±	**0.60**	**0.17**	**0.04**	**6.84**	**32.53**	**52.37**
CD (P=0.05)	**1.77**	**0.52**	**0.13**	**20.31**	**96.66**	**155.59**

RDF: 25: 60: 25 NPK kg ha^{-1}

Discussion on the findings relating to the effect of foliar application of nutrients on yield and yield parameters of soybean.

Foliar nutrition increased the seed yield of soybean significantly compared to the soil application of nutrients through the organic source during *kharif*, 2016 (Table 4.6 and Fig. 4.6). Higher seed yield (3772 kg ha^{-1}) was recorded with RDF + DAP 2 % spray at pod initiation stage compared to RDF through organic sources recorded lower seed yield (1927 kg ha^{-1}). This was attributed to higher values of number of pods plant^{-1} (43), number

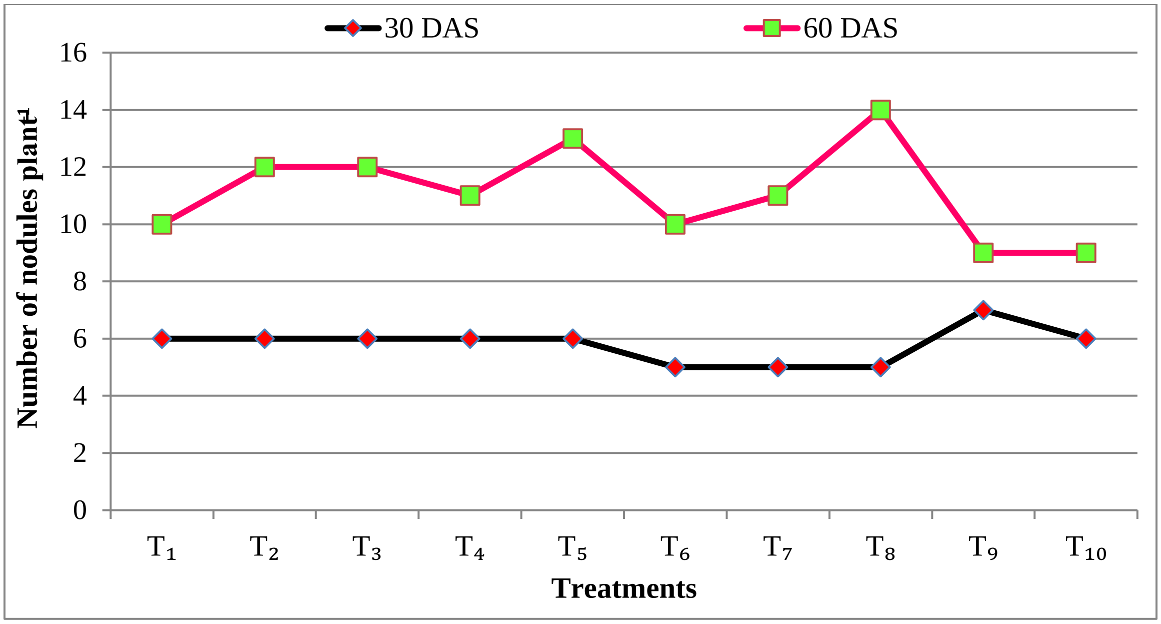

Fig. 4.5: Number of nodules plant^{-1} at 30 and 60 DAS as influenced by foliar spray of nutrients at pod initiation stage

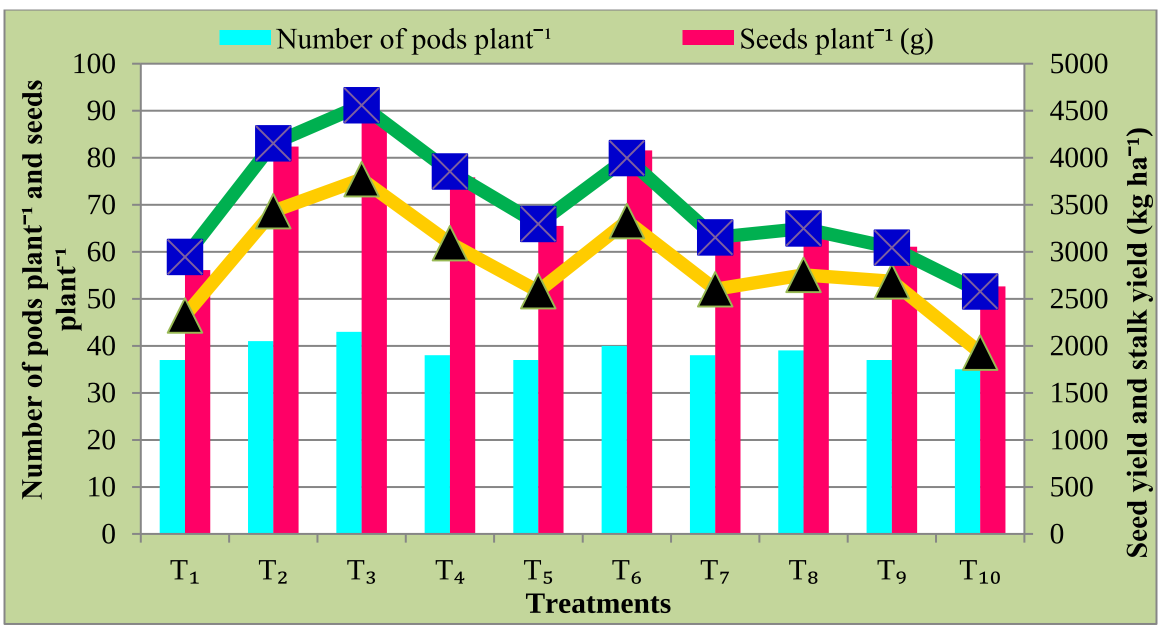

Fig. 4.6: Yield attributing characters of soybean as influenced by foliar spray of nutrients at pod initiation stage

Legend:

T_1: RDF + Water spray at pod initiation
T_2: RDF + Urea 2 % spray at pod initiation
T_3: RDF + DAP 2 % spray at pod initiation
T_4: RDF + MOP 0.5 % spray at pod initiation
T_5: RDF + 19:19:19(NPK) 2 % spray at pod initiation
T_6: RDF + Molybdenum 0.5 % spray at pod initiation
T_7: RDF + Boron 0.5 % spray at pod initiation
T_8: RDF + Zinc chelated 0.5 % spray at pod initiation
T_9: RDF + Bio-digester liquid spray at pod initiation
T_{10}: RDF through the organic source

of seeds pod^{-1} (3.00), test weight (11.40 g) and seed yield plant^{-1} (88.37 g). This might be due to optimum availability of all nutrients at flower initiation and pod formation stages of crop growth might have caused efficient translocation of photosynthates from source to sink. Decreased the flower drop due to prolonged assimilatory activity of leaves might be another possible reason for higher number of pods plant^{-1}. The present study findings are in agreement with Solaiappan *et al.* (2002), who had also reported that the foliar application of nitrogen and phosphorus at the initial stages might have been effectively absorbed and translocated to the pods resulting in more number of pods plant^{-1} in red gram. According to Kumar *et al.* (2013), the application of RDF + spray of DAP @ 2 % spray also increased the seeds plant^{-1}, which was significantly superior to the other treatments in red gram. Further, the present study results are similar to those of Ganapathy *et al*. (2008), reported the foliar sprays of DAP 2 % at flower initiation and pod formation stage might have been helpful to reduced flower drop, which in turn significantly increased in number pods plant^{-1}. Similarly, Nadergoli *et al*. (2011) had also reported that significantly higher number of pods plant^{-1} was produced by foliar application of RDF + DAP 2 % spray at flowering and pod initiation stage increased the number of pods plant^{-1} could be attributed due to significant effect of micronutrients on reproductive organs, such as stamens and pollens. These results are in confirmation with the findings of Abbas *et al*. (1994) in blackgram, Mathan *et al*. (1996) in black gram, Kumar *et al.*, (2013) in red gram and Ghosh and Joseph (2008) in green gram.

4.3 Quality parameter analysis

4.3.1 Oil content (%)

The oil content of soybean as influenced by the application of foliar nutrients at pod initiation stage was estimated and the data is presented in Table 4.7 and Figure 4.7.

A significant difference was observed in the oil content of soybean as influenced by the foliar application of nutrients at pod initiation stage. More oil content of 22.01 % was observed with the application of RDF + DAP 2 % spray compared to all other treatments and lesser oil content of 19.15 % was observed with the application of RDF through the organic source.

4.3.2 Protein content (%)

The application of foliar nutrients at pod initiation stage of soybean significantly influenced on the protein content and the data is presented in Table 4.7 and Figure 4.7.

There was a significant difference in protein content of soybean as influenced by the foliar application of nutrients at pod initiation stage. Application of RDF + DAP 2 % spray significantly recorded highest protein content (40.00 %) and lowest protein content (35.00 %) was recorded with the application of RDF + boron 0.5 % spray.

Table 4.7: Oil content (%) and Protein content (%) of soybean as influenced by foliar spray of nutrients at pod initiation stage

Treatments	Oil (%)	Protein (%)
T_1: RDF + Water spray	19.17	36.30
T_2: RDF + Urea 2 % spray	19.97	38.00
T_3: RDF + DAP 2 % spray	22.01	40.00
T_4: RDF + MOP 2 % spray	21.03	38.60
T_5: RDF + 19:19:19 (NPK) 2 % spray	18.87	38.80
T_6: RDF + Molybdenum 2 % spray	16.67	37.80
T_7: RDF + Boron 0.5 % spray	16.93	37.10
T_8: RDF + Zinc chelated 0.5 % spray	17.93	37.60
T_9: RDF + Bio-digester liquid spray	19.46	35.60
T_{10}: RDF through organic source	19.15	35.00
SEm±	**0.30**	**0.34**
CD (P=0.05)	**0.90**	**1.02**

RDF: 25: 60: 25 NPK kg ha^{-1}

The response of soybean crop to the various foliar application of nutrients at pod initiation stage was recorded and it was observed that there was a significant impact on the oil content (Table 4.7). Higher oil content (22.01 %) was recorded under the application of RDF + DAP 2 % spray as compared to the other treatments and lower oil content (19.15 %) was observed in the application of RDF through the organic source. This might be due to readily availability of nutrients enhanced the activity of enzymes for biosynthesis of oil through foliar application of nutrients. A similar case was observed by Kalpana *et al.* (2003), they found the highest oil content (20.9 %) from the spray of DAP @ 2 % and KCL 1 % due to foliar spray of micronutrients which helped in increasing the availability and uptake of nutrients and in turn led to a higher amount of protein content. According to Sukhija *et al*. (1984), the increase in oil content might be due to the readily available nutrients applied through foliar spray which enhanced the enzyme activity for synthesis of oil and the enzymatic activity was enhanced leading to effectively increased photosynthesis and translocation of assimilates to the seed. The present experimental results and findings are similar to those results of Lalitha *et al*. (2006), who observed a significant increase in oil content (42.33 %) in niger due to a combined foliar spray of K, S, and B along with RDF at 60 DAS. Similar cases have also been reported by Galavi *et al*. (2011) who recorded maximum seed oil content (21.19 - 21.50 %) from foliar application of Zn (3 ml l^{-1}) as compared to control (21.19 %).

The results of the foliar application of nutrients at pod initiation stage in soybean were recorded and it was observed that there was a significant variation with respect to the protein content (Table 4.7 and Fig. 4.7). Among the treatments, application of RDF + DAP 2 % spray recorded maximum protein content (40 %) as compared to the application of RDF through organic sources (35 %).

The increase in protein content might be due to the fact that the nutrients were readily available to the plant and this was responsible for the structure of enzymes involved in amino acids synthesis and ultimately protein synthesis and thereby protein content increased. With the readily available nitrogen applied by foliar spray, it increased the protein synthesis and protein content of soybean. Similar findings were also reported by Kumar *et al.* (2013), who also observed higher protein content with the application of RDF + spray of DAP 2 % at pod initiation. The increase in protein content might be due to the involvement of macro and micronutrients in catalytic activity and breakdown of complex substances into their simple form (glucose, amino acids, and fatty acids etc.) and stimulation of enzymatic activities by micronutrients which led to increasing in photosynthesis. The results were in agreement with the findings of Sathiyamoorthy and

Vivekanandan (1988), who observed that foliar spray of KNO_3, Thiourea and DAP increased the protein yield.

4.4 Chemical analysis

4.4.1 Nutrient content (%) in soybean after harvest

The nutrient content in soybean as influenced by the foliar application of different nutrients at pod initiation was recorded and the data is presented in Tables 4.8 and 4.9 and Figure 4.8.

4.4.1.1 N, P and K content (%) in seed after harvest

The nitrogen content in seed after harvest was significantly influenced by the foliar application of nutrients at pod initiation in soybean. Higher nitrogen content (6.40 %) was observed in the application of RDF + DAP at 2 % spray and lower nitrogen content (5.60 %) was observed in RDF through the organic source.

Phosphorous content in seed after harvest differed significantly due to foliar application of nutrients at pod initiation. More phosphorus content was observed in application of RDF + DAP 2 % spray (0.48 %) and it was found to be on par with RDF + MOP 2 % spray (0.43 %). Lesser phosphorus content (0.30 %) was observed in RDF through organic source.

Potassium content in seed after harvest varied significantly due to foliar application of different nutrients at pod initiation. Significantly higher content was observed in in application of RDF + DAP 2 % spray (1.69 %) and it was observed to be on par with RDF + MOP 2 % spray (1.67 %). Significantly lower content was observed in RDF + water spray (1.41 %).

Table 4.8: N, P and K concentration (%) of soybean seed at harvest as influenced by foliar application of nutrients at pod initiation stage

Treatments	N (%)	P (%)	K (%)
T_1: RDF + Water spray	5.80	0.35	1.41
T_2: RDF + Urea 2 % spray	6.08	0.41	1.66
T_3: RDF + DAP 2 % spray	6.40	0.48	1.69
T_4: RDF + MOP 2 % spray	6.17	0.43	1.67
T_5: RDF + 19:19:19 (NPK) 2 % spray	6.20	0.39	1.61
T_6: RDF + Molybdenum 2 % spray	6.05	0.39	1.56
T_7: RDF + Boron 0.5 % spray	5.94	0.36	1.51
T_8: RDF + Zinc chelated 0.5 % spray	6.01	0.34	1.55
T_9: RDF + Bio-digester liquid spray	5.69	0.32	1.45
T_{10}: RDF through organic source	5.60	0.30	1.42
SEm±	**0.03**	**0.05**	**0.07**
CD (P=0.05)	**0.10**	**0.15**	**0.21**

RDF: 25: 60: 25 NPK kg ha^{-1}

4.4.1.2 N, P and K content (%) in stalk after harvest

The N, P and K content in stalk after harvest as influenced by the foliar application of nutrients at pod initiation on soybean and the data is presented in Table 4.9 and Figure 4.8.

The nitrogen content in straw after harvest was not influenced significantly by foliar application of nutrients at pod initiation. However, maximum nitrogen content (1.35 %) was observed in the application of RDF + DAP 2 % spray and minimum nitrogen content (1.18 %) was observed in the application of RDF through the organic source.

Phosphorous content in straw after harvest was significantly influenced by foliar application of different nutrients at pod initiation. Significantly higher phosphorus content (0.38 %) was observed in RDF + DAP 2 % spray and it was on par with RDF + MOP 2 % spray (0.34 %), RDF + Urea 2 % spray (0.33 %). Significantly lower content (0.23 %) was observed in RDF through organic source.

Table 4.9: N, P and K concentration (%) of soybean stalk at harvest as influenced by foliar application of nutrients at pod initiation stage

Treatments	N (%)	P (%)	K (%)
T_1: RDF + Water spray	1.25	0.22	0.91
T_2: RDF + Urea 2 % spray	1.32	0.33	0.95
T_3: RDF + DAP 2 % spray	1.35	0.38	0.99
T_4: RDF + MOP 2 % spray	1.34	0.34	0.97
T_5: RDF + 19:19:19 (NPK) 2 % spray	1.29	0.31	0.94
T_6: RDF + Molybdenum 2 % spray	1.28	0.28	0.92
T_7: RDF + Boron 0.5 % spray	1.21	0.26	0.89
T_8: RDF + Zinc chelated 0.5 % spray	1.26	0.27	0.90
T_9: RDF + Bio-digester liquid spray	1.20	0.25	0.89
T_{10}: RDF through organic source	1.18	0.23	0.88
SEm±	**0.24**	**0.04**	**0.03**
CD (P=0.05)	**NS**	**0.14**	**0.10**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant

Potassium content in straw after harvest significantly varied as influenced by foliar application of different nutrients at pod initiation. Maximum potassium content (0.99 %) was recorded in RDF + DAP at 2 % spray and it was on par with RDF + MOP 2 % spray (0.97 %). Minimum potassium content was observed in RDF through organic source (0.88 %).

Nitrogen (N), phosphorus (P) and potassium (K) was analyzed after harvest and presented in Tables 10 to 11 and in Figure 9. The findings revealed that significant difference in N, P and K concentration in soybean seeds and stalks was noticed. Higher NPK content in seed and stalk was recorded with RDF + spray of DAP @ 2 % as compared to RDF + Urea 2 % spray and the lower NPK content was found in seed and stalk RDF through organic sources only. This might be due to the beneficial effect of micronutrients applied in foliar form which also help to utilize all macronutrients in balance form. This is similar with the findings of Mittra *et al.* (1987) who reported that application of NPK (Urea, SSP and MOP) through foliar spray with recommended RDF was found to be more beneficial and productive for pulse crops as compared to RDF with split application of fertilizers in soil.

4.5 Nutrient uptake (kg ha^{-1})

The nutrient uptake (kg ha^{-1}) of soybean as influenced by the foliar application of different nutrients at pod initiation in soybean at harvest was recorded and the data are presented in Tables 4.10 to 4.12 and Figure 4.9.

4.5.1 Nitrogen uptake (kg ha^{-1})

The nitrogen uptake (kg ha^{-1}) by soybean as influenced by the foliar application of nutrients at pod initiation was recorded and the data is presented in Table 4.10.

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

Nitrogen uptake by soybean seeds varied significantly due to foliar application of different nutrients at pod initiation in soybean. Significantly higher nitrogen uptake was observed in RDF + DAP 2 % spray (241.40 kg ha^{-1}) and significantly lower nitrogen uptake (107.91 kg ha^{-1}) was observed in RDF through the organic source.

4.5.1.2 Nitrogen uptake by a stalk (kg ha^{-1})

Nitrogen uptake by soybean stalks differed significantly due to foliar application of different nutrients in soybean at pod initiation. Highest uptake was recorded in RDF + DAP at 2 % spray (61.54 kg ha^{-1}) and lower uptake (30.40 kg ha^{-1}) was observed in RDF through the organic source.

4.5.1.3 Total nitrogen uptake (kg ha^{-1})

There was a significant difference in the total nitrogen uptake by soybean due to foliar application of nutrients at pod initiation stage. Maximum nitrogen uptake (302.95 kg ha^{-1}) was observed in RDF + DAP 2 % spray and minimum lower uptake was observed in RDF through the organic source (138.47 kg ha^{-1}).

The significant increase in nitrogen uptake may be due to the synergistic effect of nitrogen and phosphorus. A higher level of phosphorus must have enhanced the root growth, which helped in better absorption of nitrogen through symbiotic nitrogen fixation process as reported by Veerabhadrappa (2003). The increasing trend of nitrogen uptake up to maturity was a consequence of the progressive increase in the corresponding dry matter production. Similar results were also reported by Reddy (1979) in groundnut.

Table 4.10: Effect of foliar spray of nutrients on uptake of nitrogen by soybean at pod initiation stage

Treatments	N in seed (kg ha^{-1})	N in stalk (kg ha^{-1})	Total N (kg ha^{-1})
T_1: RDF + Water spray	134.73	38.06	172.79
T_2: RDF + Urea 2 % spray	208.60	54.80	263.41
T_3: RDF + DAP 2 % spray	241.40	61.54	302.95
T_4: RDF + MOP 2 % spray	190.71	51.61	242.33
T_5: RDF + 19:19:19 (NPK) 2 % spray	160.02	42.53	202.55
T_6: RDF + Molybdenum 2 % spray	201.16	51.10	252.29
T_7: RDF + Boron 0.5 % spray	159.90	40.57	200.47
T_8: RDF + Zinc chelated 0.5 % spray	165.45	43.45	208.91
T_9: RDF + Bio-digester liquid spray	128.93	35.22	164.15
T_{10}: RDF through organic source	107.91	30.40	138.32
SEm±	**4.57**	**1.45**	**3.47**
CD (P=0.05)	**13.71**	**4.30**	**10.43**

RDF: 25: 60: 25 NPK kg ha^{-1}

4.5.2 Phosphorus uptake (kg ha^{-1})

The phosphorus uptake (kg ha^{-1}) by soybean as influenced by the foliar application of nutrients at pod initiation was recorded was recorded and the data is presented in Table 4.11.

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

Phosphorus uptake by soybean seeds varied significantly due to foliar application of different nutrients on soybean at pod initiation. Significantly higher uptake (18.10 kg ha^{-1}) was observed in RDF + DAP 2 % spray and it was on par with RDF + Urea 2 % spray (14.06 kg ha^{-1}). Significantly lower uptake (5.70 kg ha^{-1}) was observed in RDF through the organic source.

4.5.2.2 Phosphorus uptake by a stalk (kg ha^{-1})

Phosphorus uptake by soybean stalks differed significantly by the influence of foliar application of nutrients at pod initiation in soybean. Maximum uptake (17.32 kg ha^{-1}) was observed in RDF + DAP 2 % spray and minimum uptake (5.92 kg ha^{-1}) was observed in RDF through the organic source.

Table 4.11: Effect of foliar spray of nutrients on uptake of phosphorus by soybean at pod initiation stage.

Treatments	P in seed (kg ha^{-1})	P in stalk (kg ha^{-1})	Total P (kg ha^{-1})
T_1: RDF + Water spray	8.13	6.69	14.82
T_2: RDF + Urea 2 % spray	14.06	13.70	27.76
T_3: RDF + DAP 2 % spray	18.10	17.32	35.42
T_4: RDF + MOP 2 % spray	13.29	13.09	26.38
T_5: RDF + 19:19:19 (NPK) 2 % spray	10.06	10.22	20.28
T_6: RDF + Molybdenum 2 % spray	11.97	11.18	23.15
T_7: RDF + Boron 0.5 % spray	9.69	8.71	18.40
T_8: RDF + Zinc chelated 0.5 % spray	9.36	9.31	18.67
T_9: RDF + Bio-digester liquid spray	7.25	7.33	14.58
T_{10}: RDF through organic source	5.70	5.92	11.70
SEm±	**3.01**	**0.55**	**4.01**
CD (P=0.05)	**9.05**	**1.64**	**12.07**

RDF: 25: 60: 25 NPK kg ha^{-1}

4.5.2.3 Total Phosphorus uptake (kg ha^{-1})

There was a significant variation in the phosphorus uptake due to foliar application of nutrients in soybean at pod initiation. More uptake was observed in RDF + DAP at 2 % spray pod initiation stage (35.42 kg ha^{-1}) and on par with RDF + Urea 2 % spray (27.76 kg ha^{-1}) and RDF + MOP 2 % spray (26.38 kg ha^{-1}). Significantly lower uptake (11.70 kg ha^{-1}) was observed in RDF through the organic source.

The increased phosphorus uptake may be due to the increased dry matter production and the synergistic effect between nitrogen and phosphorus. The greater mobilization of phosphorus in presence of nitrogen was reported by Hocking and Pinkerton (1993) as they found that especially in the case of phosphorus and potassium, applied phosphorus and potassium will be absorbed within 20-25 days after application so there will be less phosphorus in soils.

4.5.3 Potassium uptake (kg ha^{-1})

The potassium uptake (kg ha^{-1}) by soybean as influenced by the foliar application of nutrients at pod initiation was recorded was recorded and the data is presented in Table 4.12.

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

Potassium uptake by soybean seeds varied significantly due to foliar application of different nutrients at pod initiation. Significantly higher uptake (63.75 kg ha^{-1}) was observed in RDF + DAP 2 % spray and significantly lower uptake (27.36 kg ha^{-1}) was observed in RDF through the organic source.

4.5.3.2 Potassium uptake by the stalk (kg ha^{-1})

Potassium uptake by soybean stalks varied significantly due to foliar application of different nutrients on soybean at harvest (Table 14). Significantly higher uptake was observed in DAP at 2 % spray at pod initiation stage (45.13 kg ha^{-1}) and on par with Urea at 2 % spray at pod initiation stage (39.44 kg ha^{-1}) and MOP at 2 % spray at pod initiation stage (37.36 kg ha^{-1}). Significantly lower uptake was observed in RDF through the organic source (22.67 kg ha^{-1}).

4.5.3.3 Total potassium uptake (kg ha^{-1})

Potassium uptake varied significantly due to foliar application of different nutrients on soybean at harvest (Table 14). Significantly higher potassium uptake (108.88 kg ha^{-1}) was observed in DAP at 2 % spray and it was on par with RDF + Urea at 2 % spray (96.39 kg ha^{-1}). Significantly lower potassium uptake was observed in RDF through the organic source (50.04 kg ha^{-1}).

Table 4.12: Effect of foliar spray of nutrients on uptake of potassium by soybean at pod initiation stage

Treatments	K in seed (kg ha^{-1})	K in stalk (kg ha^{-1})	Total K (kg ha^{-1})
T1: RDF + Water spray	32.75	27.70	60.46
T2: RDF + Urea 2 % spray	56.95	39.44	96.39
T3: RDF + DAP 2 % spray	63.75	45.13	108.88
T4: RDF + MOP 2 % spray	51.61	37.36	88.98
T5: RDF + 19:19:19 (NPK) 2 % spray	41.55	30.99	72.54
T6: RDF + Molybdenum 2 % spray	51.87	36.75	88.62
T7: RDF + Boron 0.5 % spray	40.64	29.84	70.49
T8: RDF + Zinc chelated 0.5 % spray	42.67	31.04	73.71
T9: RDF + Bio-digester liquid spray	32.85	26.12	58.97
T10: RDF through organic source	27.36	22.67	50.04
SEm±	**1.01**	**0.37**	**4.25**
CD (P=0.05)	**3.05**	**1.08**	**12.55**

RDF: 25: 60: 25 NPK kg ha^{-1}

This higher uptake might be attributed due to significantly higher dry matter accumulation as a result of the application of other deficient nutrients such as N, P, S and B. The results confirm that micronutrients application enhanced the potassium uptake. The enhanced mobilization of potassium was reported by Hocking and Pinkerton (1993) as they found that especially in the case of phosphorus and potassium, applied phosphorus and potassium will be absorbed within 20-25 days after application so there will be less potassium in soils.

4.6.2 Soil nutrient status after harvest

The available NPK nutrients in the soil as influenced by the foliar application of nutrients in soybean was recorded and the data are presented in Tables 4.13 to 4.15.

4.6.2.1 Available nitrogen

Among the different foliar applications of nutrients at pod initiation in soybean, there was no significant difference observed. However, higher available nitrogen was observed in RDF through the organic source (273.81 kg ha^{-1}) and lower available nitrogen (250.19 kg ha^{-1}) was observed in RDF + DAP 2 % spray at pod initiation stage. The maximum buildup of nitrogen might be due to through the high activity of root nodules which help the atmospheric nitrogen fixation which turn increases the nutrient status of the soil.

Table 4.13: Available nitrogen in soil before and after experiment as influenced by foliar spray of nutrient at pod initiation stage

Treatments	Available N	
	Initial (kg ha^{-1})	**Final (kg ha^{-1})**
T_1: RDF + Water spray	264.50	261.45
T_2: RDF + Urea 2 % spray	264.50	255.13
T_3: RDF + DAP 2 % spray	264.50	250.19
T_4: RDF + MOP 2 % spray	264.50	258.13
T_5: RDF + 19:19:19 (NPK) 2 % spray	264.50	265.02
T_6: RDF + Molybdenum 2 % spray	264.50	272.35
T_7: RDF + Boron 0.5 % spray	264.50	266.13
T_8: RDF + Zinc chelated 0.5 % spray	264.50	269.28
T_9: RDF + Bio-digester liquid spray	264.50	270.31
T_{10}: RDF through organic source	264.50	273.81
SEm±	**-**	**10.43**
CD (P=0.05)	**-**	**NS**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant

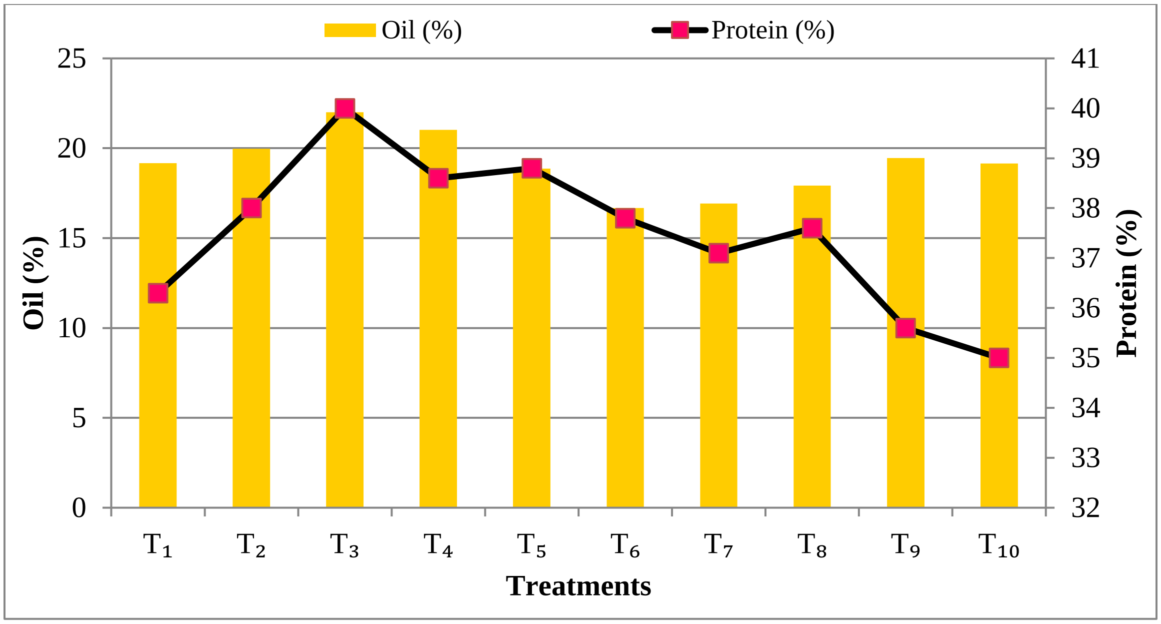

Fig. 4.7: Oil and protein content (%) as influenced by foliar spray of nutrients at pod initiation stage

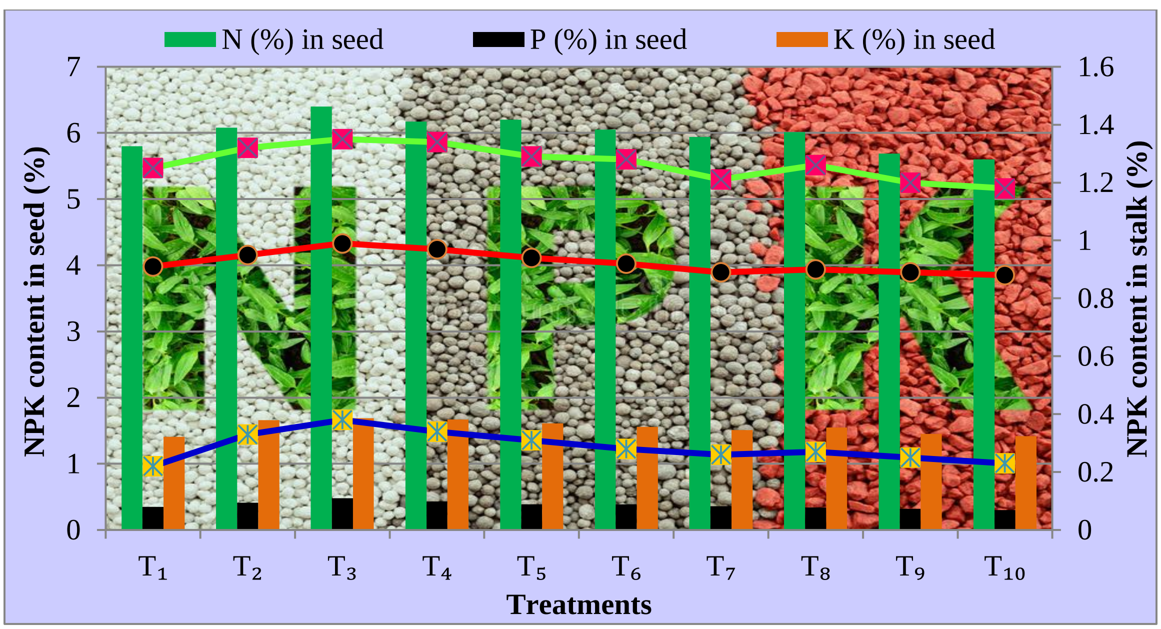

Fig. 4.8: N, P and K concentration (%) of soybean seed and stalk at harvest as influenced by foliar spray of nutrients at pod initiation stage

Legend:

T1: RDF + Water spray at pod initiation
T2: RDF + Urea 2 % spray at pod initiation
T3: RDF + DAP 2 % spray at pod initiation
T4: RDF + MOP 0.5 % spray at pod initiation
T5: RDF + 19:19:19(NPK) 2 % spray at pod initiation
T6: RDF + Molybdenum 0.5 % spray at pod initiation
T7: RDF + Boron 0.5 % spray at pod initiation
T8: RDF + Zinc chelated 0.5 % spray at pod initiation
T9: RDF + Bio-digester liquid spray at pod initiation
T10: RDF through the organic source

4.6.2.2 Available phosphorus

There was no significant difference on available phosphorus status of soil due to foliar applications of nutrients at pod initiation in soybean, but, more available phosphorus (49.30 kg ha^{-1}) was observed in RDF through the organic source and lesser available phosphorus (35.25 kg ha^{-1}) was observed in RDF + DAP 2 % spray. It might be due to fact that phosphorus fixation in to the soil and also shading of leaves helpful to increasing the phosphorus status in the soil.

Table 4.14: Available phosphorus in soil before and after experiment as influenced by foliar spray of nutrients at pod initiation stage.

Treatments	Available P	
	Initial (kg ha^{-1})	Final (kg ha^{-1})
T_1: RDF + Water spray	38.34	39.27
T_2: RDF + Urea 2 % spray	38.34	36.29
T_3: RDF + DAP 2 % spray	38.34	35.25
T_4: RDF + MOP 2 % spray	38.34	38.99
T_5: RDF + 19:19:19 (NPK) 2 % spray	38.34	41.53
T_6: RDF + Molybdenum 2 % spray	38.34	45.24
T_7: RDF + Boron 0.5 % spray	38.34	42.48
T_8: RDF + Zinc chelated 0.5 % spray	38.34	45.32
T_9: RDF + Bio-digester liquid spray	38.34	47.15
T_{10}: RDF through organic source	38.34	49.30
SEm±	**-**	**12.07**
CD (P=0.05)	**-**	**NS**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant

4.6.2.3 Available potassium

The non-significant difference was observed in the available potassium status of soil due to foliar application of nutrients at pod initiation in soybean, whereas, higher available potassium (117.12 kg ha^{-1}) was observed in RDF through the organic source and lower available potassium (86.91 kg ha^{-1}) was observed in RDF + DAP 2 % spray. It may be due to fact that some quantity of Potash fixed in to the soil which are balance to the nutrient level in the soil which are not absorb by the plant and also shading of leaves and senescence of root nodule may help to increase the potash level in the soil.

Table 4.15: Available potassium in soil before and after experiment as influenced by foliar spray of nutrient at pod initiation stage.

Treatments	Available K	
	Initial (kg ha^{-1})	**Final (kg ha^{-1})**
T_1: RDF + Water spray	110.25	99.88
T_2: RDF + Urea 2 % spray	110.25	90.81
T_3: RDF + DAP 2 % spray	110.25	86.91
T_4: RDF + MOP 2 % spray	110.25	94.61
T_5: RDF + 19:19:19 (NPK) 2 % spray	110.25	104.32
T_6: RDF + Molybdenum 2 % spray	110.25	113.13
T_7: RDF + Boron 0.5 % spray	110.25	108.33
T_8: RDF + Zinc chelated 0.5 % spray	110.25	112.14
T_9: RDF + Bio-digester liquid spray	110.25	114.51
T_{10}: RDF through organic source	110.25	117.12
SEm±	**-**	**12.55**
CD (P=0.05)	**-**	**NS**

RDF: 25: 60: 25 NPK kg ha^{-1} NS: Non-significant

4.8 Economics of soybean

To examine the economic feasibility and viability of the different treatments under-investigated during the field experiment, economics of soybean production in terms of gross return, net return and benefit cost ratio were calculated for different treatments of foliar application of nutrients at pod initiation in soybean and the outcome is presented in Table 4.16 and Figure 4.10.

The data revealed that the maximum gross return (₹ 75440 ha^{-1}), net return (₹ 55808 ha^{-1}), and benefit cost ratio (2.84) was recorded under application of RDF + DAP 2 % spray.

The maximum cost of cultivation (₹ 34382 ha^{-1}) was recorded with the application of RDF + Molybdenum 0.5 % spray, whereas, minimum gross return (₹ 38540 ha^{-1}), net return (₹ 19358 ha^{-1}), and benefit cost ratio (1.09) was obtained with treatment of RDF through organic source only.

To scrutinize the economic feasibility and the performance of the different foliar spray of nutrients under investigation, economics of soybean production in terms of gross return, net return and benefit cost ratio was calculated for the different foliar spray of nutrients in soybean (Table 4.16 and Fig. 4.10)

Table 4.16: Economics of soybean as affected by foliar application of nutrients at pod initiation stage

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C
T_1: RDF + Water spray	19382	46460	27078	1.39
T_2: RDF + Urea 2 % spray	19452	68620	49168	2.52
T_3: RDF + DAP 2 % spray	19632	75440	55808	2.84
T_4: RDF + MOP 2 % spray	19427	61820	42393	2.18
T_5: RDF + 19:19:19 (NPK) 2 % spray	21632	51620	29988	1.38
T_6: RDF + Molybdenum 2 % spray	34382	66500	32118	0.93
T_7: RDF + Boron 0.5 % spray	20922	52020	31098	1.48
T_8: RDF + Zinc chelated 0.5 % spray	21227	55050	33833	1.59
T_9: RDF + Bio-digester liquid spray	19382	53760	34378	1.77
T_{10}: RDF through organic source	19182	38540	19358	1.09

RDF: 25: 60: 25 NPK kg ha^{-1}

The data revealed that the maximum gross return (₹ 75440 ha^{-1}), net return (₹ 55808 ha^{-1}), and benefit cost ratio (2.84) was recorded under application of RDF + spray of DAP @ 2 % in soybean. The increase in gross and net return is due to higher seed yield. Less input cost and higher economical yield might be resultant in increase the BC ratio. The maximum cost of cultivation (₹ 34382 ha^{-1}) recorded under application of RDF + spray of Molybdenum @ 0.5 % of soybean among all the different treatments whereas, minimum gross return (₹ 66500 ha^{-1}), net return (₹ 32118 ha^{-1}), and benefit: cost ratio (0.93) was obtained under treatment of RDF + spray of Molybdenum @ 0.5 % in soybean due to appear on burning on leaves over the control (RDF only). It was also reported by Kumar *et al*., (2011) as they observed that spray of DAP @ 2 % twice at flower initiation and pod formation stages of crop growth recorded higher gross returns (₹ 36,500) and net returns (₹ 20,090) followed by foliar spray of local variety at flower initiation and pod formation stages of crop growth with gross returns of ₹ 33,125 and net returns of ₹ 15,675. Water spray recorded the least gross returns (₹ 46460) and net returns (₹ 27078). A similar result of improvement in the grain yield and net income with high B:C ratios due to foliar application of DAP @ 2 % has been reported by

Chandrasekhar and Bangarusamy (2003). Yakadri and Ramesh (2002) also reported that foliar applications of DAP @ 2 % in black gram recorded the highest BC ratio of 3.78 compared to control is on the basis of the present investigation.

Practical application of the results

The findings of the present studies are concluded as follows:

1. On the basis of present investigation, it can be concluded that the application of recommended dose of fertilizer along with foliar spray of DAP @ 2 % registered significantly highest value of plant height $plant^{-1}$, number of leaves $plant^{-1}$, leaf area $plant^{-1}$, number of pods $plant^{-1}$, number of seeds pod^{-1}, number of seeds $plant^{-1}$, seed yield and stalk yield.

2. Foliar spraying of DAP @ 2 % was also positive and registered significantly higher net return of (₹ 75440) with BC ratio of 2.84.

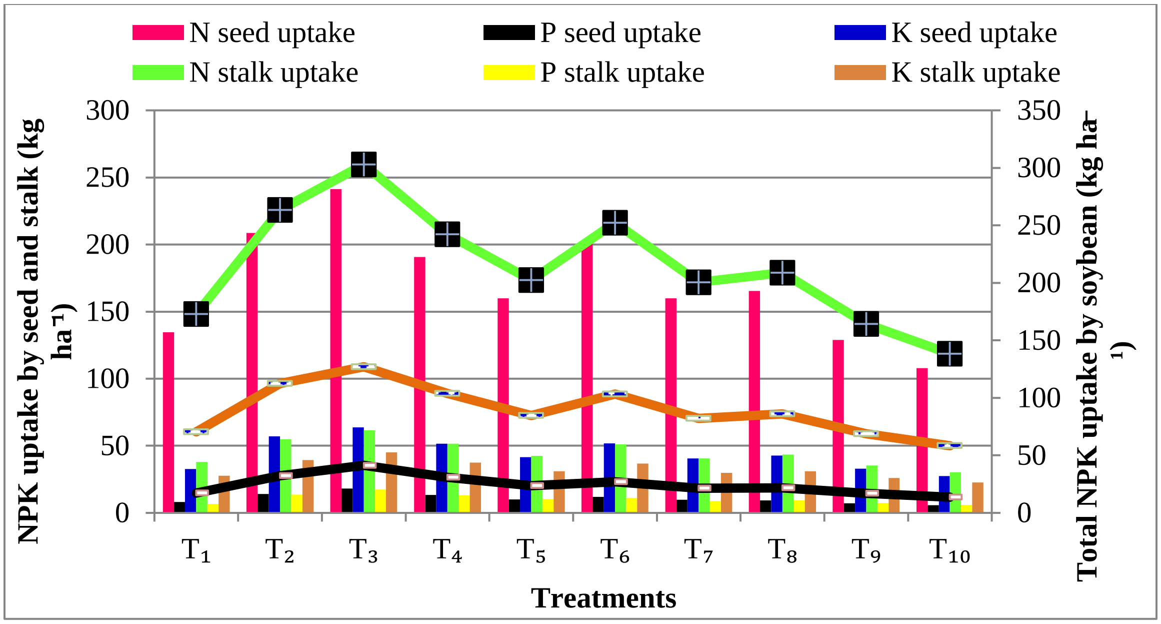

Fig. 4.9: Nutrient uptake (kg ha^{-1}) by soybean crop as influenced by foliar spray of nutrients at pod initiation stage

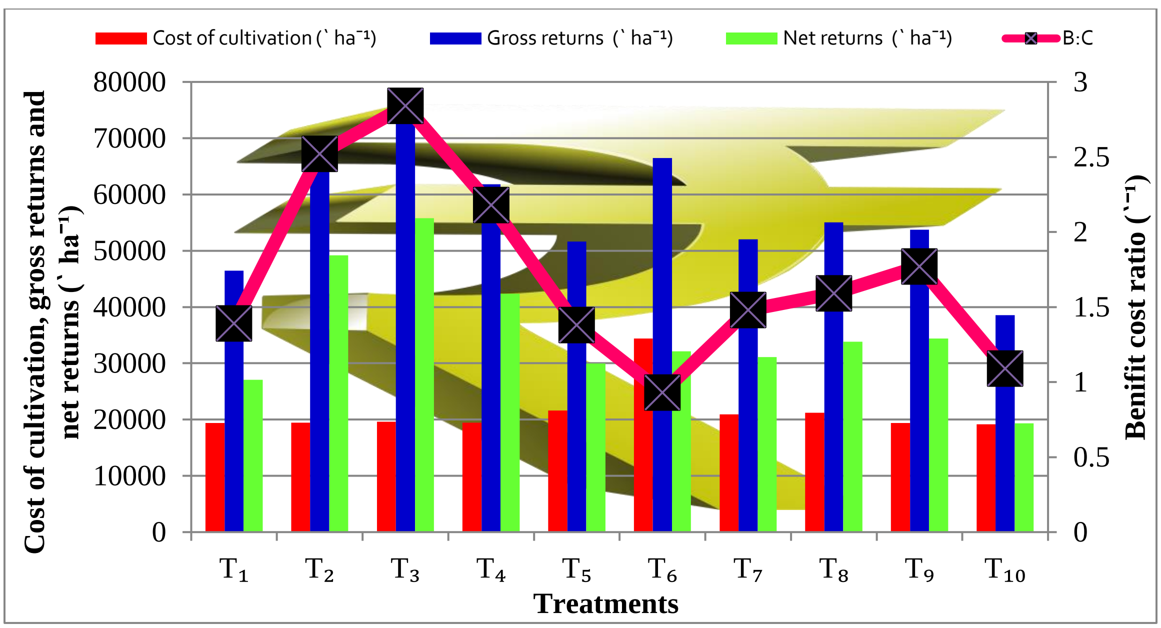

Fig. 4.10: Economics of soybean due to different treatments of nutrients as influenced by foliar spray of nutrients at pod initiation stage

Legend:

T_1: RDF + Water spray at pod initiation
T_2: RDF + Urea 2 % spray at pod initiation
T_3: RDF + DAP 2 % spray at pod initiation
T_4: RDF + MOP 0.5 % spray at pod initiation
T_5: RDF + 19:19:19(NPK) 2 % spray at pod initiation
T_6: RDF + Molybdenum 0.5 % spray at pod initiation
T_7: RDF + Boron 0.5 % spray at pod initiation
T_8: RDF + Zinc chelated 0.5 % spray at pod initiation
T_9: RDF + Bio-digester liquid spray at pod initiation
T_{10}: RDF through the organic source

Suggestions for the future research work

In the light of the findings and experience gained during the course of the investigation, it is felt that the following points should be given due consideration in future studies:

1) The results of the present investigation belong to only one year of experimentation. Therefore, to conclude the result further refinement is required.

2) The physiological parameter needs to be quantified to draw a specific role of micronutrients.

V SUMMARY

The experimental findings and their interpretation, as presented in the preceding chapter, have been summarized in this chapter. The present experiment entitled "Studies of foliar application of nutrients on the productivity of soybean [*Glycine max* (L.) Merrill]" was carried out during the *kharif* season of 2016 at Zonal Agricultural Research Station, GKVK, Bengaluru-65, with the objective to find out the effect of foliar nutrition on productivity and profitability of soybean.

The experiment was laid out in a randomized block design (RBD) with three replications. The treatment comprised nutrient combination of foliar spray of micronutrients + RDF as application of RDF + water spray at pod initiation, application of RDF + spray of Urea @ 2 % spray at pod initiation, application of RDF + spray of DAP @ 2 % at pod initiation, application of RDF + spray of MOP @ 0.5 % at pod initiation, application of RDF + spray of NPK (19:19:19) 2 % at pod initiation, application of RDF + spray of Molybdenum @ 0.5 % at pod initiation, application of RDF + spray of Boron @ 0.5 % at pod initiation, application of RDF spray of Zinc Chelated @ 0.5 % at pod initiation, RDF + bio-digester liquid and RDF through organic source only.

Growth parameters like plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1}, leaf area (cm^2) plant^{-1}, number of nodules plant^{-1} were recorded.

Yield parameters like number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1}, test weight (g), seed yield (kg ha^{-1}) and stalk yield (kg ha^{-1}) were recorded and statistically analyzed.

The computation and statistical analysis were done for NPK content in stalk, protein and oil content in seed after harvest of the crop as well as economics were also worked out.

The results of the investigation are highlighted below:

The application of RDF + spray of DAP @ 2 % at pod initiation (T_3) recorded significantly higher plant height at harvest (40.32 cm) over other combination of fertilizer applied.

The number of branches plant^{-1} was not significantly influenced due to various combinations of micronutrients applied.

The maximum number of leaves plant^{-1} was significantly higher at 60 DAS (37.73) and harvest (10.46) from the plot where fertilizer was in recommended dose + spray of DAP @ 2 % at pod initiation (T_3).

The leaf area was significantly higher under the application of RDF + spray of DAP @ 2 % at pod initiation (T_3) at 60 DAS (850 cm^2) and at harvest (394.34 cm^2) and the minimum number of leaves plant^{-1} recorded under the application of RDF through organic source only.

A number of root nodules were not found significant due to the application of different combinations of micronutrients.

Significantly maximum number of pods plant^{-1} (43) was recorded the plot where fertilizer was applied in recommended dose + spray of DAP @ 2 % (T_3) and RDF + Urea 2 % at pod initiation (T_2), the number of seeds pod^{-1} (3.00) and seeds plant^{-1} (88.37) was also significantly highest in the application of RDF + spray of DAP @ 2 % spray (T_3).

The significantly highest Seed yield (3772 kg ha^{-1}) and stalk yield (4559 kg ha^{-1}) of soybean were recorded by application of RDF + spray of DAP @ 2 % (T_3) and the yield was higher over the plot that is the application of RDF through organic source alone.

N, P, and K concentration in seed samples (6.40 %, 0.48 %, and 1.69 % respectively) were significantly affected and the highest value of these nutrients was recorded with the application of DAP @ 2 % spray.

N, P, and K concentration in stalk samples (1.35 %, 0.38 %, and 0.99 % respectively) were significantly affected and the highest value of these nutrients was recorded with the application of DAP @ 2 % spray.

The highest oil (22.01 %) and protein content (40.41 %) were recorded under the application of RDF + spray of DAP @ 2 % spray (T_3).

The findings revealed that the highest build up of available soil nitrogen was recorded under the application of RDF through the organic source (273.81 kg ha^{-1}). The lowest build up was observed under the application of DAP 2 % spray (250.19 kg ha^{-1}).

Results indicated that in all the treatments, the soil available Phosphorus status at harvest was higher than the initial status (38.34 kg ha^{-1}). The findings revealed that the highest build up was recorded under the application of RDF through the organic source (49.30 kg ha^{-1}) and lowest was observed in DAP 2 % spray (35.25 kg ha^{-1}).

The maximum available potassium build up was recorded under the application of RDF through the organic source (117.12 kg ha^{-1}) and the lowest was recorded under the application of DAP 2 % spray (86.91 kg ha^{-1}).

The maximum gross return (₹ 75440 ha^{-1}), net return (₹ 55808 ha^{-1}), and benefit cost ratio (2.84) was recorded under application of RDF + Spray of DAP @ 2 % in soybean.

The maximum cost of cultivation (₹ 34382 ha^{-1}) recorded under application of RDF + spray of Molybdenum @ 0.5 % of soybean among the different treatments. Minimum gross return (₹ 38540 ha^{-1}), net return (₹ 19358 ha^{-1}), and benefit cost ratio (1.09) was obtained under the treatment of RDF through organic source only.

VI REFERENCES

ABBAS, M., SINGH, M. P., NIGAM, K. P. AND KANDALKAR, V. S., 1994, Effect of phosphorus, plant density and plant type on yield attributing characters of soybean (*Glycine max*). *Indian J. Agron.,* **39**: 249-255.

ABDEL, E., LATIF, M. A. AND HAGGAN, E., 2014, Effect of micronutrients foliar application on yield and quality traits of soybean cultivars. *Int. J. Agr. Crop Sci.*, **7**(11): 908-914.

ADKINE, P. M., MANKAR, D. D., KHANDAIT, V. M., BHANDARE, V. L. AND NAWLAKHE, S. M., 2011, Effect of boron, molybdenum and potassium nitrate on growth, yield and economics of soybean. *J. Soils Crops*, **21(**1): 116- 123.

ANADHAKRISHNAVENI, S., PALCHAMY, A. AND MAHENDRAN, S., 2004, Effect of foliar spray of nutrients on growth and yield of green gram (*Phaseolus radiatus*). *Legume Res.,* **27**(2): 149-150.

ANONYMOUS, 2015, Directorate of Economics and Statistics, Department of Agriculture and Cooperation. Report of the working group on agriculture statistics. **1**: 5-6.

ANONYMOUS, 2015.WWW. Indiastat.Com.

BABAEIAN, M., ESMAEILIAN, Y., TAVASSOLI, A., ASGHARZADE, A. AND SADEGHI, M., 2011, The effects of water stress, manure and chemical fertilizer on grain yield and grain nutrient content in barley. *Sci. Res. Essays*, **6**(17): 3697-3701.

BEHROUZI, F. G., GERMCHI, S. AND YARNIA, M., 2012, Effect of complete micro-nutrient fertilizer application on soybean yield and yield components. *Am. J. Agril. Biol. Sci.,* **7(**4): 412-416.

BOOTE, K., J., GALLAGHER. R. N., ROBERTSON, W. K., HINSON, K. AND HAMMOND, L.C., 1997, Effect of foliar fertilization on photosynthesis, leaf nutrition and yield of soybeans. *Agron. J.* **70**(5): 787-791.

BOZORGI, H. A., AZARPOUR, E. AND MORADI, M., 2011, Effects of bio, mineral nitrogen fertilization and foliar zinc spraying on yield and yield components of faba bean. *World Appl. Sci. J.,* **13**(6): 1409-1414.

BRAY, R. H. AND KURTZ, L. T., 1945, Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.*, **59**: 39-45.

CHANDRASHEKHAR, C. N. and BANGARUSAMY, U., 2003, Maximising the yield of mung bean by foliar application of growth regulating chemicals and nutrients. *Madras Agric. J.,* **90**(1-3): 142-145.

CHOUDHARY, P., JHAJHARIA, A. AND KUMAR, R., 2014, Influence of sulphur and zinc fertilization on yield, yield components and quality traits of Soybean (*Glycine Max* L.). *Bioscan,* **9**(1): 137-142.

COSTA, D. S., BARBOSA, R. M., OLIVEIRA, J. S. AND EUSTAQUIO, M., 2014, Foliar application of calcium and molybdenum in common bean plants: yield and seed physiological potential. *Agril. Sci*., **5**: 1037-1045.

DONALD, C. M., 1962, Competition among crops and pasture plants. *Adv. Agron*., **15**: 1-114.

GALAVI, M., MOUSAVI, S. R. AND REZAEI, M., 2011. Zinc importance for crop production. *Int. J. Agron. Plant Prod.,* **4**(1): 64-68.

GANAPATHY, M., BARADHAN, G. AND RAMESH, N., 2008, Effect of foliar nutrition on reproductive efficiency and grain yield of rice fallow pulses. *Legume Res.,* **31**: 142-144.

GARUD, H. S., AWASARMAL, V. B., PAWAR, S. U. AND BHUSAWAR, P. V., 2012, Yield economics and quality of soybean as influenced by foliar and soil application of phosphatic fertilizer. *Natl. Acad. Agril. Sci.*, 2011.

GHASEMIAN, V., GHALAVAND, A., ZADEH, A. S. AND PIRZAD, A., 2010, The effect of iron, zinc, and manganese on quality and quantity of soybean seed. *J. Phytol.*, **2**(11): 73-79.

GHOSH, M. K. AND JOSEPH, S. A., 2008, Influence of biofertilizers, foliar application of DAP and sulphur sources on yield and yield attributes of summer green gram (*Vigna Radiata* L. Wilczek). *Legume Res*., **31** (3): 232 – 233.

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. *Comm. Soil Sci. Plant Anal.*, **38**: 1137–1154.

GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical procedures for agricultural research. 2nd edition, John Wiley, and Sons, New York.

GOWTHAMI, P. AND RAO, G. R., 2014, Influence of foliar application potassium, boron and zinc on growth and yield of soybean. *Int. J. Food, Agri. Vet. Sci.* **4** (3): 81-86.

HARKAL, S. R., KALE, B. D. AND KARAD, A. S., 1989, Response of sunflower to levels of nitrogen and sulphur on verticals. *J. Maharashtra Agric.*, **18**(2): 321-322.

HEIDARIAN, A. R., KORD, H., MOSTAFAVI, K., LAK, A. P. AND MASHHADI, F. A., 2011, Investigating Fe and Zn foliar application on yield and its components of soybean (*Glycine max* (L) Merr.) at different growth stages. *J. Agril. Biotech. Sustain. Devt.*, **3**(9):189-197.

HOCKING, P. J. AND PINKERTON, A., 1993, Phosphorus nutrition of linseed (*Linum usitatiimum* L.) as affected by nitrogen supply: effects on vegetative development and yield components. *Field crops Res.*, **32**(1-2): 101-114.

JACKSON, M. L., 1973, Soil chemical analysis, Prentice Hall of India, Pvt. Ltd., New Delhi.

JAYABAL, A., REVATHY, M. AND SAXENA, M. G., 1999, Effect of foliar nutrition on nutrient uptake pattern in soybean. *Andhra Agric. J.,* **46**: 243-244.

JYOTHI, C. N., RAVICHANDRA, K. AND BABU, S. K., 2013, Effect of foliar supplementation of Nitrogen and Zinc on soybean (*Glycine max*. L.) yield, quality and nutrient uptake. *Indian J. Dryland Agric. Res. Dev*., **28**(2): 46-48.

KADER, A. E. AND MONA, G., 2011, Effect of sulphur application and foliar spraying with zinc and boron on yield, yield components and quality of peanut (*Arachis hypogaea* L.). *Res. J. Agril. Biol. Sci.* **9**(4): 127-135.

KALPANA, R., SUBBIAN, P. AND SELVI, R. V., 2003, Effect of irrigation layouts and foliar nutrition on grain yield and quality of soybean. *Tropical Agrl. Res.*, **1**: 20-26.

KINACI, E. AND GULMEZOGLU, N., 2007, Grain yield and yield components of triticale upon application of different foliar fertilizers *Interciencia,* **32**(9): 624-628.

KOBRAEE, S. AND SHAMSI, K., 2013, Impact of micronutrients foliar application on soybean yield and its components under water deficit condition. *J. Biodiver. Environ. Sci*., **3**(2): 39-45.

KOBRAEE, S., NOORMOHAMADI, G., HEIDARISHARIFABAD, H., DARVISHKAJORI, F. AND DELKHOSH, B., 2011, Influence of micronutrient fertilizer on soybean nutrient composition. *J. Sci. Tech.,* **4**(7): 127-136

KOBRAEE, S., SHAMSI, K. AND VAGHAR, M. S., 2014, Effect of irrigation and micronutrient foliar application on quality and quantity parameters of soybean. *Current Biotica.* **7**(4): 275-282.

KRISHNAVENI, S., ANANDHA, P. A. AND MAHENDRAN, S., 2004, Effect of foliar spray of nutrients on growth and yield of green gram (*Phaseolus radiatus*). *Legume Res.*, **27(**2): 149-150.

KUMAR, C. V., VAIYAPURI, K., AMANULLAH, M. M. AND GOPALASWAMY, G., 2011, Influence of foliar spray of nutrients on yield and economics of soybean (*Glycine max* L. Merill). *J. Biol. Sci.*, **13**(6) 563-565.

KUMAR, S., BASAVARAJAPPA, R., SALAKINKOP, S. R., HEBBAR, M., BASAVARAJAPPA, M. P. AND PATIL, H. Y., 2013, Influence of foliar nutrition on the performance of black gram (*Vigna mungo* L.), *Econ. Dry Land Ecosys. Legume Res.* **36**(5): 345-356.

LALITHA, B. H., YELADHALLI, N. A. AND RAVI, M. V., 2006, Effect of foliar application of potassium sulphate and boric acid on yield, nutrient uptake and yield of niger (*Guizotia abyssinica* L.). *Karnataka J. Agric. Sci.*, **21**(2): 282-283.

MANDIC, V., SIMIC, A., KRNJAJA, V., BIJELIC, Z., TOMIC, A., STANOJKOVIC, D. AND MUSLIC, R., 2015, Effect of foliar fertilization on soybean grain yield. *Biotech. Animal Husb.*, **31**(1): 133-143.

MANIVANNAN, V., THANUNATHAN, K., MAYAVARAMBAN, V. AND RAMANATHAN, N., 2002, Effect of foliar application of N, P, K and chelated micronutrients (microsol) on growth and yield of rice-fallow urd bean. *Legume Res.*, **25**(4): 270-272.

MANNAN, M. A., 2014, Foliar and soil fertilization effect on seed yield and protein content of soybean*.* *Bangladesh Agron. J.*, **17**(1): 67-72.

MARY SCHON, K. AND DAVE BLEVINS, G., 1990, Foliar boron applications increases the number of branches and pods on branches of field-grown soybeans. *J. Plant Physiol.*, **92**(3): 602-607.

MATHAN, K. K., HONORA FRANCIS, J. AND RAMANATHAN, B. P., 1996, Response of black gram (*Phaseolus mungo*) to fertilization and Rhizobium inoculation. *Indian J. Agron.* **41**(1): 74-77.

MAZHAR HAQ, U. AND ANTONIO MALLARINO, P., 2000, Investigating Fe and Zn foliar application on yield and its components of soybean (*Glycine max* L. Merr.) at different growth stages. *J. Agril. Biotech. Sust. Dev.*, **3**(9): 189-197.

MITTRA, G. N., SAHU, S. K., AND PATNI, S. C., 1996, Effect of zinc application on the uptake of nutrients by rice an inceptisol. *J. Ind. Soc. Sci.,* **44**: 795-806.

MOOSAVI, A. A. AND RONAGHI, A., 2011, Influence of foliar and soil applications of iron and manganese on soybean dry matter yield and iron-manganese relationship in a calcareous soil. *Au. J. Soil Sci.* **5**(12): 1550-1556.

MOSTAFAVI, K., 2012, Grain yield and yield components of soybean upon application of different micronutrient foliar fertilizers at different growth stages. *Inter. J. Agr. Res. Review*, **2**(4): 389-394.

MUTHUVEL, P., SIVASAMY, R. AND SUBRAMANIAN, V., 1977, Mitigating the adverse effects of drought in rainfed black gram. *Madras Agric. J.*, **72**(1): 22-24.

NADERGOLI, M. S., YARNIA, M. AND KHOEI, F. R., 2011, Effect of zinc and manganese and their application method on yield and yield components of common bean (*Phaseolus vulgaris* L.) *J. Scif. Res.,* **8**(5): 859-865.

NARIMANI, H., RAHIMI M. M., AHMADIKHAH A. AND VAEZI, B., 2010, Study on the effects of foliar spray of micronutrient on yield and yield components of durum wheat. *Arch. Appl. Sci. Res.,* **2**(6): 168-176.

NASEF, M. A., NADIA, BADRAN, M., AMAL AND ABD EL-HAMIDE, F., 2006, Response of peanut to a foliar spray of boron and/or rhizobium inoculation. *J. Appl. Sci. Res.,* **2**(12): 1330-1337.

NASIRI, Y., ZEHTAB-SALMASI, S., NASRULLAHZADEH, S., NAJAFI, N., GHASSEMI-GOLEZANI, K., 2010, Effects of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). *J. Medl. Plants Res.*, **4**(17): 1733- 1737.

ODELEYE, F. O., ODELEYE, M. O. AND ANIMASHAUN, M. O., 2007, Effects of nutrient foliar spray on soybean growth and yield (*Glycine max* L.). *Bot. Hort. Agrobot.,* **35**(2): 35-56.

OPLINGER, E. S., HOEFT, R. G., JOHNSONY, J. W. AND TRACY, P. W., 1993, Boron fertilization of soybeans: Foliar fertilization of soybeans and cotton, potash and phosphate a regional summary, **12**: 7-16.

OSMAN, A. S., ABIDO, Y. M., ALLAM, Y. AND SALAH, M. M., 2000, Response of soybean to phosphorus and zinc fertilization under irrigation regime. *Annals. Agril. Sci.,* **45(**1): 229-238.

PANDE, M., MUDLAGIRI, B. AND BELLALOUI, G. N., 2014, Effect of foliar and soil application of potassium fertilizer on soybean seed protein, oil, fatty acids, and minerals. *Am. J. Plant Sci.,* **5**: 541-548.

PANSE, V.G. AND SUKHATME, P.V., 1967, Statistical methods of Agricultural workers, ICAR publication. New Delhi, pp: 381.

PIPER, C. S., 1966, Soil and plant analysis. Interscience, New York. 368 p.

POPOVIC, V., MILADINOVIC, J., GLAMOCLIJA, D., IKANOVIC, J., DEKIC, V., DORDEVIC, S., MICKOVSKI, V. AND NOVIC, S., 2013, Effect of foliar nutrition on morphological characteristics and soybean yield in the organic cropping system. IV. *Inter. Symp. Agrosym*., **10:** 713-725.

PRADEEP M. D. S. AND ELAMATHI, S., 2007, Effect of foliar application of DAP and micronutrients and NAA in mungbean. *Leg. Res.*, **30**: 305–307.

RAMAN, R. AND VENKATARAMA, K., 2006, Effect of the foliar application on N, P and K uptake, yield and yield attributes of green gram (*Vigna radiata). Crop Res.*, **32**(1): 21-23.

RAO, S. N., NAIDU, T. C. M. AND RANI, Y. A., 2015, Effect of foliar nutrition on water potential, photosynthetic rate, dry matter production and yield of mung bean under receding soil moisture condition. *Inter. J. applied Boil. Sci. Pharma. Tech.,* **6**(2): 259-267.

REDDY, D. V. R., GHANEKAR, A. M., IIZUKA, N., AMIN, P. W. AND GIBBONS, R. W., 1979. Bud necrosis of groundnut (*Arachis hypogeae*) in India caused by tomato spotted wilt virus. *Ann. Appl. Biol*., **93**: 173-179.

REZAEI, R., ZARGHAMY, R. AND OVEYSEE, M., 2013, Evaluation the effect of Fe foliar application and changes sink and sources on yield and yield components of soybean (*Glycine max* L.), *Tech. J. Engg. Applied Sci***.,** **3**(16): 1825-1828.

SADEGHI, S. M. AND NOORHOSSEINI S. A., 2014, Evaluation of foliar application effects of Zn and Fe on yield and its components of lentil (*Lens Culinaris,* Medik), *Indian J. Fund. Applied Life Sci*. **223**: 100-110**.**

SALIH, H. O., 2013, Effect of foliar fertilization of Fe, B and Zn on nutrient concentration and seed protein of cowpea (*Vigna unguiculata*). *J. Agri. Vet. Sci*., **6**(3): 42-46.

SALWA, A. I. E., TAHA, M. B., ABDALLA, M. A. M., 2011, Amendment of soil fertility and augmentation of the quantity and quality of soybean crop by using phosphorus and micronutrients. *Int. J. Acad. Res.,* **3**(2): 3-5.

SATHIYAMOORTHY, P. AND VIVEKANANDAN, M., 1988, Cumulative effects of pre-sowing seed treatment and foliar application of salts in improving biomass and grain yield of soybean in moderate saline/alkaline soil. *J. Agron. Crop Sci*., **161**(2): 107-113.

SHASHIKUMAR, BASAVARAJAPPA, R., SALAKINKOP, S. R., HEBBAR, M., BASAVARAJAPPA, M. P. AND PATIL, H. Y., 2013, Influence of foliar nutrition on performance of blackgram (*Vigna mungo* L.), nutrient uptake and economics under dryland ecosystems. *Legume Res.*, **36**(5): 422 - 428.

SOLAIAPPAN, U., PAULPANDI, V. K. AND CHELLAIAH, N., 2002, Effect of graded levels of phosphorus and foliar fertilization on short duration red gram in rainfed vertisol. *Madras Agric. J.*, **87**: 451-454.

SRIVASTAVA, G. P. AND SRIVASTAVA, V. C., 1994. Effect of irrigation and foliar spray of nutrients on growth and seed yield of gram (*Cicer arietinum*). *Indian J. Agril. Sci.*, **64**(4): 20-31.

SUKHIJA, P. S., DHILLON, L. S., FARISCHA, N. S. AND MUNSHI, S. N., 1984, Effect of phosphorus application on the biochemical quality of groundnut. *J. Res. Punjab Agric. Univ*, **21**: 243- 250.

THAKARE, K. G., CHORE, C. N., DEOTALE, R. D., KAMBLE, P. S., PAWAR, S. B. AND LENDE, S. R., 2006, Influence of nutrients and hormones on biochemical and yield and yield contributing parameters of soybean. *J. Soils Crops,* **16**(1): 210-216.

VEERABHADRAPPA, B. H., 2003, Effect of foliar nutrition (N, P, K, Ca and S) on growth and yield of groundnut. M. Sc (Agri) Thesis, *Univ. Agric. Sci.,* Dharwad, Karnataka (India).

WALKEY, A. AND BLACK, I. A., 1934, An examination of the method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci*., **37**(1): 29-38.

YAKADRI, M. AND RAMESH, T., 2002, Effect of soil application of potassium and DAP spray in blackgram (*Vigna mungo* L.). *Madras Agric. J.,* **89**: 147-149.

YASARI, E. AND VAHEDI, A., 2012, Micronutrients impact on soybean (*Glycine max* M.) qualitative and quantitative traits. *Inter. J. Bio.*, **4**(2): 15-25.

ZAYED, A., SALEM, M. AND SHARKAWY, M., 2011, Effect of different micronutrient treatments on rice (*Oryza sativa* L.) growth and yield under saline soil conditions. *World J. Agric. Sci.*, **7**(2): 179-184.

APPENDIX

A. Fixed cost of soybean cultivation

Sl. No.	Particular	Requirement	Price	Total cost (₹ ha^{-1})
1.	**Land preparation**			
	• Ploughing	Tractor 2h ₹ ha^{-1}.	₹ 500 ha^{-1}	1000
	• Harrowing	Tractor 2h ₹ ha^{-1}.	₹ 500 ha^{-1}	1000
	• Planking	Tractor 1h ₹ ha^{-1}.	₹ 500 ha^{-1}	500
2.	**Seed Treatment**			
	• Seed rate	60 kg ha^{-1}.	₹ 32 kg^{-1}	1920
	• Rhizobium culture	12 kg ha^{-1}.	₹ 15 200 g^{-1}	900
3.	**Sowing operation**	15 man days	₹ 150 day^{-1}	2250
4.	**Fertilizer**			
	• N (Urea)	65 kg ha^{-1}	₹ 7 kg^{-1}	455
	• P_2O_5 (SSP)	375 kg ha^{-1}	₹ 6.5 kg^{-1}	2437
	• K_2O (MOP)	50 kg ha^{-1}	₹ 18 kg^{-1}	900
5.	**Fertilizer application**	4 man days	₹ 200 day	800
6.	**Weeding**			
	• Herbicide	Alachlor 1l ha^{-1}	₹ 120 l^{-1}	120
	• Application cost	2 man days	₹ 200 day^{-1}	400
	• Hand weeding	10 man days	₹ 150 day^{-1}	1500
7.	**Harvesting(manual)**	15 man days	₹ 200 day^{-1}	3000
8.	**Threshing & winnowing**	10 man days	₹ 200 day^{-1}	2000

B. Variable cost of soybean cultivation

Particulars	Input	Price	Total cost (₹ ha^{-1})
T_1: RDF + Water spray at pod initiation	Labour cost for 1 day, 500 l water ha^{-1}	200	200
T_2: RDF + Urea 2% spray at pod initiation urea	Labour cost + 500 l water + Urea 10 kg^{-1} ha^{-1}	₹ 7 kg^{-1} (Urea)	270
T_3: RDF + DAP 2% spray at pod initiation	Labour cost + 500 l water + DAP 10kg-1 ha^{-1}	₹ 25 kg^{-1} (DAP)	450
T_4: RDF + MOP 0.5% at pod initiation	Labour cost + 500 l water + MOP 2.5 kg-1 ha^{-1}	₹ 18 kg^{-1}	245
T_5: RDF + 19:19:19 (NPK) 2% at pod initiation	Labour cost + 500 l water + N.P.K.(Nitrophoska) 10 kg^{-1} ha^{-1}	₹ 225 kg^{-1}	2450
T_6: RDF + Molybdenum 0.5% at pod initiation	Labour cost + 500 l water + Molybdenum 2.5kg^{-1} ha^{-1}	₹ 600 (100 g^{-1})	15200
T_7: RDF + Boron 0.5% at pod initiation	Labour cost + 500 l water + Boron 2.5 kg^{-1} ha^{-1}	₹ 308 (500 g^{-1})	1740
T_8: RDF + Zinc chillated 0.5% at pod initiation	Labour cost + 500 l water+ Zinc Chillated 2.5 ha^{-1}	₹ 369 (500 g^{-1})	2045
T_9: RDF + Bio-digester liquid spray at pod initiation	Labour cost + 500 l water	-	200
T_{10}: RDF through organic source	-	-	-