

**EFFECT OF FOLIAR APPLICATION OF WATER
SOLUBLE FERTILIZER ON GROWTH, YIELD AND
QUALITY OF SOYBEAN [*Glycine max* (L.) Merrill]**

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**DEPARTMENT OF AGRONOMY
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BENGALURU**

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*Affectionately
Dedicated to
Afghanistan*

**DEPARTMENT OF AGRONOMY
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CERTIFICATE


This is to certify that the thesis entitled “Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]” submitted by Mr. **SHAH KHALID PALB 5336** for the award of degree of **MASTER OF SCIENCE (Agriculture)** in **AGRONOMY** to the University of Agricultural Science, Bengaluru, is a record of research work done by him during the period of his study in this University, under my guidance and supervision. This thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
March, 2018



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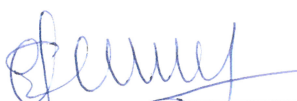
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Bengaluru

(**SHAH KHALID**)

**EFFECT OF FOLIAR APPLICATION OF WATER SOLUBLE
FERTILIZER ON GROWTH, YIELD AND QUALITY OF SOYBEAN**
[*Glycine max* (L.) Merrill]

ABSTRACT

Field experiment was conducted to study the effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill] at Zonal Agricultural Research Station, UAS, GKVK, Bengaluru during summer-2017. The experiment soils are red sandy loam with neutral pH and medium in available nitrogen, phosphorous and potassium. The experiment was laid out in RCBD with seven treatments replicated thrice and treatments application of recommended dose of fertilizer (30:80:38 kg N: P₂O₅: K₂O ha⁻¹+ 6.5 t FYM ha⁻¹), RDF (50% N as basal and 50 % N as top dressing), RDF + foliar application of WSF @ 2 % at 8-12 leaf stage, RDF + foliar application of WSF @ 2 % at flowering stage, RDF + foliar application of WSF @ 2 % at pod filling stage, RDF + foliar application of WSF @ 2 % at flowering and pod filling stage, recommended dose of nitrogen through FYM only. The RDF + foliar application of WSF @ 2 % at flowering and pod filling stage resulted significantly higher pods per plant (86.18), seed weight per plant (17.55 g), 100 seed weight (14.53 g) and finally higher seed yield (2283kg ha⁻¹). Higher net returns (₹ 50526 ha⁻¹) and benefit cost (2.71) was also recorded with RDF + foliar application of WSF @ 2 % at flowering and pod filling stage.

March, 2018

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**ಸೋಯಾಬಿನ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟದ ಮೇಲೆ ನೀರಿನಲ್ಲಿ ಕರಗುವ
ರಸಗೊಬ್ಬರ ಸಿಂಪರಣೆಯ ಪರಿಣಾಮ**

ಶಕಾಲೀದ್

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ನೀರಿನಲ್ಲಿ ಕರಗುವ ರಸಗೊಬ್ಬರ ಸಿಂಪರಣೆಯ ಪರಿಣಾಮವನ್ನು ಸೋಯಾಬಿನ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟದ ಬಗ್ಗೆ ಅಭ್ಯಾಸಿಸಲು 2017 ರಲ್ಲಿ ಗಾಂಧಿ ಕೃಷಿ ವಿಜ್ಞಾನ ಕೇಂದ್ರ, ವಲಯ ಕೃಷಿ ಸಂಶೋಧನಾ ಕೇಂದ್ರದಲ್ಲಿ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ತೆಗೆದುಕೊಳ್ಳಲಾಯಿತು. ಪ್ರಯೋಗದ ತಾಕು ಕೆಂಪು ಮಿಶ್ರಿತ ಮರಳು ಮಣ್ಣಿನಿಂದ ಕೂಡಿದ್ದು ರಸಸಾರವು ತಟಸ್ಥವಾಗಿದೆ ಮತ್ತು ಸಾವಯವ ಇಂಗಾಲ (0.43 %) ಕಡಿಮೆ ಹಾಗೂ ಲಭ್ಯ ಸಾರಜನಕ, ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಷ್ ಅಂಶವು ಮಧ್ಯಮ ಪ್ರಮಾಣದಲ್ಲಿದೆ. ಏಳು ಉಪಚಾರ ಸಂಯೋಜನೆಗಳನ್ನು ಮೂರು ಬಾರಿ ಪುನಾರಾವರ್ತನೆಗೊಂಡ ಅಪವರ್ತನೀಯ ಯಾದೃಚ್ಛಿಕ್ ಪೂರ್ಣಬ್ಲಾಕ್ ವಿನ್ಯಾಸ (ಆರ್‌ಸಿಬಿಡಿ) ದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಉಪಚಾರಗಳೆಂದರೆ ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ (30:80:38 ಕಿ.ಗ್ರಾಂ ಸಾರಜನಕ:ರಂಜಕ:ಪೊಟ್ಯಾಷ್ + 6.5 ಟನ್ ತಿಪ್ಪೆಗೊಬ್ಬರ/ಹೆ.), ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ (ಶೇ. 50 ಸಾರಜನಕ, ಬಿತ್ತನೆ ಸಮಯದಲ್ಲಿ ಮತ್ತು ಶೇ. 50 ಮೇಲು ಗೊಬ್ಬರವಾಗಿ ಕೊಡುವುದು), ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ + ಶೇ 2 ನೀರಿನಲ್ಲಿ ಕರಗುವ ರಸಗೊಬ್ಬರ ಸಿಂಪರಣೆ 8-10 ಎಲೆಯ ಹಂತದಲ್ಲಿ, ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ + ಶೇ. 2 ನೀರಿನಲ್ಲಿ ಕರಗುವ ರಸಗೊಬ್ಬರ ಹೂ ಬಿಡುವ ಹಂತದಲ್ಲಿ ಸಿಂಪರಣೆ, ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ + ಶೇ. 2 ನೀರಿನಲ್ಲಿ ಕರಗುವ ರಸಗೊಬ್ಬರ ಕಾಯಿ ಕಟ್ಟುವ ಹಂತದಲ್ಲಿ ಮತ್ತು ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ + ಶೇ. 2 ನೀರಿನಲ್ಲಿ ಕರಗುವ ರಸಗೊಬ್ಬರ ಸಿಂಪರಣೆ ಹೂ ಬಿಡುವ ಹಂತ ಹಾಗೂ ಕಾಯಿ ಕಟ್ಟುವ ಹಂತದಲ್ಲಿ ಕೊಡುವುದು ಮತ್ತು ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ಸಾರಜನಕವನ್ನು ಕೊಟ್ಟಿಗೊಬ್ಬರದ ಮೂಲಕ ಕೊಡುವುದು. ಎಲ್ಲಾ ಉಪಚಾರಗಳಲ್ಲಿ ಸಿಫಾರಸ್ಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರ + ಶೇ. 2 ನೀರಿನಲ್ಲಿ ಕರಗುವ ರಸಗೊಬ್ಬರ ಹೂ ಬಿಡುವ ಹಂತ ಹಾಗೂ ಕಾಯಿ ಕಟ್ಟುವ ಹಂತದಲ್ಲಿ ಸಿಂಪರಣೆ ಉಪಚಾರವು ಉತ್ಪಾದನಾ ಸಾಮರ್ಥ್ಯ ಸೂಚಕಗಳಾದ, ಕಾಯಿಗಳ ಸಂಖ್ಯೆ (86.16 ಕಾಯಿಗಳು/ಗಿಡಕ್ಕೆ) ಕಾಯಿಗಳ ತೂಕ (17.55 ಗ್ರಾಂ /ಗಿಡಕ್ಕೆ), 100 ಕಾಳಿನ ತೂಕ (14.53 ಗ್ರಾಂ.) ಓಟ್ಟು ಕಾಳಿನ ತೂಕ (3654.26 ಕಿ. ಗ್ರಾಂ/ಹೆ.) ಮತ್ತು ಹೆಚ್ಚಿನ ಒಟ್ಟು ಲಾಭ ರೂ. 50526 ಪ್ರತಿ ಹೆ. ಹಾಗೂ ಹೆಚ್ಚಿನ ಆದಾಯ:ವೆಚ್ಚದ ಅನುಪಾತ (2.71) ವನ್ನು ಕೊಟ್ಟಿದೆ.

ಮಾರ್ಚ್, 2018

ಬೇಸಾಯ ಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃ.ವಿ.ವಿ., ಗಾ.ಕೃ.ವಿ.ಕೇ., ಬೆಂಗಳೂರು

ಡಾ|| ಬಿ. ಎಸ್. ಲಲಿತ
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]

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INTRODUCTION

✓ Soybean (*Glycine max* (L.) Merrill) is a dual purpose crop which contains 40 percent protein and 20 percent oil. Soybean being legume crop fixes atmospheric nitrogen through symbiotic way. There by improves fertility status of soil.

✓ It is miracle bean having many advantages as food, feed, fodder crop, green manure crop and numerous industrial importance.

✓ In India, it is grown over an area of 9.60 m ha with production of 9.70 m t and productivity of 983 kg ha⁻¹.

✓ The major soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat. In Karnataka, soybean occupies in an area of 0.15 m ha with production of 0.09 m t and productivity of 675 kg ha⁻¹. Belgaum, Dharwad, Bidar, Bagalkot and Haveri are the major soybean growing districts of Karnataka.

✓ Soil application of nutrients often results in lower efficiency of concerned nutrients due to several changes and losses due to leaching and volatilization.

✓ Foliar spray is the fastest way to boost the plant growth because the nutrients are directly available to the plants.

✓ Almost all pulses flower drop determine the yield and yield attributing characters. Retention of flowers by the plant gives higher yield. According to several studies revealed that retention of flower is possible through foliar spray of growth regulators and macro nutrients during flower initiation to pod development stages along with soil application. Very little information is available regarding the effect of foliar application of water soluble NPK (19:19:10) fertilizer on growth, yield and quality of soybean.

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 (KBS-23)

Season : summer (2017)

Treatments : 7

Replication : 3

Design : RCBD

Net plot size : 4.4 x 3.4 m

Location : ZARS, UAS, GKVK, Bengaluru

Treatment details:

T₁- Recommended fertilizer dose

T₂- RDF (50 % N as basal and 50 % N as top dressing)

T₃- RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄- RDF + foliar application of WSF @ 2 % at flowering stage

T₅-RDF + foliar application of WSF @ 2 % at pod filling stage

T₆- RDF + foliar application of WSF @ 2 % at flowering and pod filling stage

T₇- Recommended dose of nitrogen through FYM only

RDF: 30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹

WSF: 19:19:19

RESULTS

Table 1 : Number of pods, seed weight, seed yield, net return and B:C ratio as influenced by foliar application of water soluble fertilizer.

Treatments	Pods Plant ⁻¹	Seed wt (g Plant ⁻¹)	Seed yield (kg ha ⁻¹)	Net income (ha ⁻¹)	B:C ratio
T ₁	63.9	14.8	1533	27585	2.0
T ₂	64.2	13.0	1518	27073	2.0
T ₃	64.6	14.6	1637	29553	2.0
T ₄	69.1	13.3	1782	34662	2.2
T ₅	71.3	15.0	2006	42487	2.5
T ₆	86.1	17.5	2283	50526	2.7
T ₇	57.8	12.4	1296	15823	1.5
S.Em.±	3.8	0.9	44.74		
C.D at 5%	11.9	2.8	137.87		

✓ Among the treatments, RDF + foliar application of WSF at 2 % at flowering + pod filling stage recorded significantly higher (86.18) pods Plant⁻¹ were recorded and lowest (57.87) pods plant⁻¹ were obtained with recommended dose of nitrogen applied through FYM only.

✓ Significantly higher seed weight plant⁻¹(17.55 g) was recorded with application of RDF + foliar application of WSF at 2 % at flowering + pod filling stage. The lowest seed weight plant⁻¹(12.42 g) was recorded with application of recommended dose of nitrogen through FYM only.

✓ Among the treatments significantly higher seed yield recorded with RDF + foliar application of WSF at 2 % at flowering + pod filling stage (2283.89 kg ha⁻¹) over all other treatments. The significantly lower seed yield was recorded with application of recommended dose of nitrogen through FYM only (1296.30 kg ha⁻¹).

✓ RDF + foliar application of WSF at 2 % at flowering + pod filling stage given higher net returns (Rs.50526 ha⁻¹) with B:C ratio (2.71) compared to all other treatments and lower net returns and B:C ratio was recorded with recommended dose of nitrogen through FYM only.

Discussion

➤ The increased yield was with application of RDF + foliar application of WSF at 2 % at flowering + pod filling stage significantly increased plant height, number of branches, number of leaves and total dry weight than single spray either at flowering and pod filling stage. The higher growth parameters helped to put forth significantly higher yield attributing characters like number of pods plant⁻¹, higher seed weight Plant⁻¹ and 100 grain weight were finally led to increased soybean yield. The increased yield attributes with RDF + foliar application of WSF at 2 % at flowering + pod filling stage.

➤ Foliar spray twice during flowering and pod filling stage might be due to enhanced photosynthetic activity and higher uptake of nutrients and thereby increased plant dry matter production in the pod setting phase which might have improved the pod development and number of pods plant⁻¹. Similarly, Kalarani and Moosa Sheriff (1994) found increased number of pods with the foliar application of 1.5% urea and 0.5% DAP in green gram and Patel and Patel (1994) in soybean crop.

➤ Higher net return and B:C ratio were recorded in treatment with application of RDF +foliar application of WSF at 2 % at flowering + pod filling stage over all other treatments. Lower net return and B:C ratio were observed with recommended dose of nitrogen through FYM only. Similarly, Vinoth kumar *et al.* (2013) reported that the foliar spray of 2 % DAP also recorded significantly higher net return and B:C ratio.

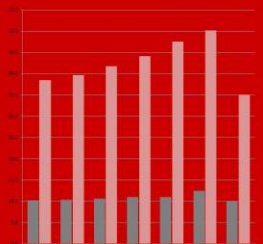


Fig. 1: Plant height and number of branches observed at harvest.



Plate.1 General view of the experimental crop at 60 DAS

SUMMARY

▪ Significantly higher number of pods Plant⁻¹, seed weight Plant⁻¹ and 100 seed weight was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage, and lowest was recorded with recommended nitrogen through FYM only.

▪ Higher net returns and B:C ratio were recorded in treatment with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage.

REFERENCES

- KALARANI, M. K. AND MOOSA SHARIFF, M., 1994, Increasing yield of green gram due to delaying leaf senescence by the foliar fertilization of NPK & B. *Madras Agric. J.*, **81** (3): 171-172.
- PATEL, T. R. AND PATEL, Z. G., 1994, Effect of foliar fertilization of nitrogen and phosphorus on growth and yield of summer soybean. *Indian J. Agron.*, **39** (4): 578-580.
- VINOTHKUMAR, C., VAIYAPURI, M., MAHAMED AMANULLAH AND GOPALSWAMY, 2013, Influence of foliar spray of nutrients on yield and economics of soybean (*Glycine max* L. Merrill). *J. Bio Sci.*, **13** (6): 563-565.

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ABBREVIATIONS USED IN THESIS

DAS	Days after sowing
S.Em±	Standard error mean
C.D	Critical difference
B:C ratio	Benefit cost ratio
NS	Non significant
S	Significant
N	Nitrogen
P	Phosphorus
K	Potassium
g plant ⁻¹	Gram per plant
kg ha ⁻¹	Kilogram per hectare
t ha ⁻¹	Ton per hectare
cm	Centimeter
mm	Millimeter
m ⁻¹	Per meter
Cm ² plant ⁻¹	Square centimeter per plant
DMY	Dry matter yield
dSm ⁻¹	Desi Simons per meter
P=0.05	At 5 per cent probability
%	Per cent
ZARS	Zonal Agriculture Research Station

I INTRODUCTION

Soybean is recognized as golden bean because of its high nutritional value and economic importance. Soybean [*Glycine max* (L.) Merrill] is one of the most important oilseed crop in the world, also wonder crop of the twentieth century and the cheapest source of vegetable oil as well as protein. It contains about 40 per cent protein with well balanced essential amino acids, 20 per cent oil rich with polyunsaturated fatty acids, 6-7 per cent minerals, 5-6 per cent crude fiber and 17-19 per cent carbohydrates. The protein quality of soybean is equivalent to that of meat, milk and egg. It is generally grown as rainy season crop under rainfed situation.

The crop also helps in improving the fertility status of soil through symbiotic nitrogen fixation. Thus, it is miracle bean having many advantages and the crop in fact has made revolution in the agricultural economy with its immense potential utility as food, feed, numerous industrial products and export commodity in addition to improving soil fertility. Soybean is known to grow in different agro climatic conditions and its unmatched nutritional value, which make it one of the commercial crops in many countries including India.

Soybean is a major oil seed crop of world growing in an area of 111.27 m ha and production of 276.4 m t with average productivity of 2484 kg ha⁻¹. In the world, it is cultivated mainly in USA, China, Brazil, Argentina and India. In India, it is grown over an area of 9.60 m ha with production of 9.70 m t and productivity of 983 kg ha⁻¹. The major soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat. In Karnataka, soybean occupies in an area of 0.15 m ha with production of 0.09 m t and productivity of 675 kg ha⁻¹ (Anonymous, 2016). Belgaum, Dharwad, Bidar, Bagalkot and Haveri are the major soybean growing districts of Karnataka.

Nitrogen is one of the most recognized plant nutrient required in abundant help to put forth more vegetative growth, reproductive parts and also integral part of protein molecule. It plays an important role in synthesis of the plant constituents through the

action of different enzymes. Phosphorus requirement is high in young cells, such as shoot and root tips, where metabolism is high and cell division occurs rapidly. Root development, flower initiation, seed and fruit development is aided by phosphorus and it has been shown to reduce disease incidence in some plants and found to improve the quality of certain crops. Potassium is an important macro-nutrient and the most abundant cation in higher plants and essential for enzyme activation.

Soil application of nutrients often results in lower efficiency of applied nutrients due to losses by leaching and volatilization. Problematic soils, lack of adequate moisture, water logged condition etc., will also affect the availability of nutrients.

Foliar fertilization is gaining more importance in recent years due to availability of soluble fertilizers and is of great significance in rainfed areas under changing climatic conditions. Many research reports indicated positive effect in enhancing crop yield and quality of oilseed/pulse crops. Foliar application of nutrients constitutes one of the important milestones in the progress of agricultural production.

Foliar spray of nutrients is the fastest way to boost up crop growth because, nutrients are available to plants in critical stages and the nutrients will reach the site of food synthesis directly leading to no wastage and quick supply of food, thereby reduce the requirement of fertilizers. Foliar application resulted in efficient absorption and usage which is economical in respect to other methods of fertilization. It is also known that active nodulation of soybean or any pulse crop stops 45-50 days after sowing and at that time for legume plants if supply nutrients through foliar spray found to be beneficial effects on enhancing growth, increasing seed yield and quality parameters. Specific in soybean leaf senescence starts much before completion of pod maturity and which breaks source sink relationship finally lead to unfilled pods and pods with shriveled seeds are major drawbacks in soybean which can be managed through foliar application of nutrients. Nutrient spray at later stages has been found to delay leaf senescence and improved yield.

Foliar application of nutrients for increasing and exploiting genetic potential of the crop is considered as an efficient and economic method of supplementing the nutrient requirement. Application of inorganic nutrient spray will also enhance the nutrient availability, quick absorption and in turn increases the productivity. Nutrients applied through foliage play a pivotal role in increasing the seed yield in pulses and oilseeds (Chandrasekhar and Bangaruswamy, 2003). The use of alternative fertilizer application strategies to achieve maximum yield and enhance nutrient use efficiency has been proposed for decades. This may be corrected through some combination of starter and booster dose of foliar fertilizer application, fertilizer rate adjustment of both macro and micronutrients.

Application of nutrients through foliar along with soil application has several advantages in supplementing the nutritional requirements of crops. Recently new specialty fertilizers have been introduced exclusively for feeding and fertilization. These fertilizers have different ratios of NPK which are highly water soluble and so amenable for foliar nutrition. In almost all pulses, the extent of flower drop determine the yield, yield attributing characters and retention of flowers by the plant gives higher yield. According to several studies conducted in different crops by different scientists over the world revealed that retention of flowers are possible through foliar spray of growth regulators and macro nutrients during flower initiation to pod development stages along with soil application. Very little information is available regarding the **Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]**. Keeping above things in view the present study was undertaken with following objectives.

Objectives:

1. To study the effect of foliar application of water soluble fertilizer on growth and yield of soybean.
2. To study the effect of foliar application of water soluble fertilizer on quality and nutrient uptake of soybean.
3. To workout the economics of foliar application of water soluble fertilizer of soybean.

II REVIEW OF LITERATURE

The literature pertaining to **Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]** is presented in this chapter.

2.1 Effect of foliar application of water soluble fertilizer on growth parameters of soybean

Rajendran (1991) observed that DAP at 50 kg per hectare as basal dose followed by foliar spray of urea and 2 per cent DAP increased significantly leaf area index (LAI) and dry matter production during both *khari* and *summer* seasons. The yield attributes were also significantly higher when urea or DAP foliar spray was given in mung bean.

Increased leaf area index (LAI) and crop growth rate (CGR) were reported in groundnut with post flowering foliar spray of potassium nitrate 0.5 per cent (Patra *et al.*, 1995).

Sarkar *et al.* (1999) revealed that foliar application of 0.5 per cent KNO_3 + 0.203 per cent $\text{Ca}(\text{NO}_3)_2$ resulted in higher plant height (48.6 cm), dry matter production (14.60 g plant⁻¹) and crop growth rate (0.285 g plant⁻¹ day⁻¹) of groundnut.

Combined application of soil and foliar spray recorded significantly higher plant height (37.3 cm), number of leaves per plant (46.2) and plant dry matter (2.4 g per plant) when compared to other treatments (Hugar and Kurdikeri, 2000) in soybean.

Foliar applications of DAP 2% and KCl 1% along with benzyladenine at the rate of 25 ppm has significantly increased the plant height in soybean (Ramesh and Thirumurugan, 2001).

Prakasa Rao (2002) opined that sesame plants treated with KCl (10 m M) and NAA (20 ppm) produced 16.7 and 21.4 per cent increase in total dry matter and 8.3 per cent increase in LAI as compared to control plants. In Urdbean Manivannan *et al.* (2002) revealed that combined application of rhizobium seed treatment + foliar application of N,

P, K + chelated micronutrients (microsol) at 15, 30 and 45 DAS recorded markedly higher leaf area index, dry matter production and crop growth rate compared to control (no application).

Shinde and Bhilare (2003) revealed that foliar application of 2 per cent DAP at 65 DAS through foliar spray recorded higher plant height (55.72 cm), number of branches (29.15 plant⁻¹) and dry matter (33.15 g plant⁻¹) compared to control in chick pea.

Krishnaveni (2004) revealed that the significantly higher growth parameters of plant height, leaf area index, biological yield, number of branches per plant and yield attributes *viz.*, number of pods per plant, pod length, number of grains per pod with the foliar spray of DAP 2 per cent + KCl 1 per cent + ZnSO₄ 0.5 per cent sprayed at 15, 30 and 45 days after sowing followed by two sprays of DAP 2 per cent + KCl 1 per cent + ZnSO₄ 0.5 per cent given at 30 and 45 DAS in green gram.

The plant nutrients through foliar spray have got many advantages apart from increase in yield of any crop. The foliar supply ensures rapid and efficient absorption of the plant at right time, less product is needed and independent of soil physical, chemical and moisture level. The midterm supplementary foliar fertilization during crop growth can improve the mineral status of plants and increase the crop yield (Elayaraja and Angayarkanni, 2005).

In mung bean increased number and weight of leaves per plant, leaf area, number and weight of pods per plant when 2 per cent potassium nitrate was applied by foliar spray along with 300 ppm zinc-EDTA and 50 ppm magnesium sulphate under water stressed conditions (Thalooth *et al.*, 2006).

Amany (2007) studied the effect of foliar application of one per cent urea on growth of chick pea. The results revealed that one per cent urea spray at pod filling resulted in higher plant height, number of branches, total dry weight, pods per plant, seeds per plant, 100 seed weight (36 g) and harvest index (0.45).

Pradeep and Elamathi (2007) reported that foliar application of DAP, micronutrients and NAA recorded significantly higher plant height (3.4 %) and dry matter production (20.1 %) when compared to control (no foliar application).

Foliar application of nutrients through spray at appropriate stages of growth becomes important for their utilization and better performance of the crop (Ananda Krishnaveni *et al.*, 2008).

Foliar application of nutrient and growth regulator at pre flowering and flowering stage resulted in reduced percentage of flower drop in green gram (Ganapathy *et al.*, 2008). Foliar application of NAA at 40 ppm during pre flowering stage in black gram resulted in increased plant height, number of branches and higher leaf area index (Jeya kumar *et al.*, 2008).

Malay and Bhowmick (2008) conducted two-year field trial to assess the effect of basal as well as foliar application of nutrients on growth and yield of lentil and observed that foliar spray of either urea or 2 per cent diammonium phosphate (DAP) solution twice at pre flowering and 10 days after first in lentil increased the plant height of 33.79 cm and 32.60 cm respectively over control (30.86 cm).

Senthil Kumar *et al.* (2008) observed significant increase in growth parameters like plant height (47.5 cm), dry matter production (2576 kg ha⁻¹) and leaf area index (3.74) of black gram by foliar application of 2 per cent DAP at flowering and pod development stage as compared to no spray (37.1cm, 1712 kg ha⁻¹, and 2.76, respectively).

Subhamoy *et al.* (2010) reported that foliar application of DAP and urea at the rate of 2 per cent in green gram has significantly increased plant height (64.5cm) steadily up to 60 DAS and leaf area index (5.0) than basal application of fertilizers and sprayed with distilled water.

Mondal *et al.* (2011) studied that foliar application of nitrogen alone or combination of nitrogen and micronutrients recorded higher leaf area (497 cm⁻²), specific

leaf weight (10.72 mg cm^{-2}), chlorophyll content and total dry matter per plant (10.2 g) over no foliar application of nutrients in different genotypes of mung bean. In chick pea Venkatesh and Basu (2011) reported that foliar application of urea at 2 per cent concentration during 60, 75 and 90 DAS recorded higher number of branches plant⁻¹ (5.9) which was on par with one or two sprays of urea and least number of branches (4.0) was recorded in control with water spray.

Gupta *et al.* (2011) stated that foliar application of 2 per cent urea at flowering and 10 days after flowering along with biofertilizers (Rhizobium+ PSB+PGPR) resulted in higher dry weight due to enhanced biological nitrogen fixation and continuous supply of nitrogen through basal dose during initial stage and through foliar spray at later stages of crop growth in chick pea.

Hafiz and El-Bramawy (2012) revealed that increasing potassium concentration as foliar spraying up to 2 per cent induced significant increments in plant height, fruiting zone length, number of branches plant⁻¹ in sesame crop.

Vekaria *et al.* (2013) reported that spraying of potassium nitrate @ 0.4 per cent recorded significantly higher crop growth rate (CGR), pod growth rate (PGR) and partitioning percentage in green gram.

Kumar *et al.* (2013) revealed that foliar spray of 2 percent DAP twice at flower initiation and pod formation stage of crop growth resulted significantly higher number of pods plant⁻¹ (62), number of seeds pods⁻¹, seed index and higher grain yield (1460 kg ha^{-1}) and yield was on par with the result obtained from application of 2 per cent urea phosphate and TNAU pulse wonder spray in soybean crop. Foliar application of potassium nitrate at 2 per cent + boric acid at 50 ppm + zinc sulphate at 1 per cent during 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 per plant, test weight and seed yield followed by potassium nitrate at 2 per cent + boric acid at 50 ppm at 30 and 60 DAS. boric acid at 50 ppm + zinc sulphate at 1 per cent during 30 and 60 DAS and

potassium nitrate at 2 per cent + zinc sulphate at 1 per cent during 30 and 60 DAS whereas lower values were recorded in control in soybean (Gowthami and Rao, 2014).

Garud *et al.* (2015) concluded from the field study in soybean that application of phosphorus ($60\text{kg P}_2\text{O}_5\text{ha}^{-1}$) and foliar application of BOOST-52 (0:52:34) at 35 and 50 DAS increased significantly higher plant height, leaf area index, biological yield, number of branches per plant and yield attributes *viz.*, number of pods per plant, pod length, and number of grains per pod with foliar spray in soybean over the control.

Foliar spray of KNO_3 one per cent has recorded higher plant height, leaf area, shoot dry weight and photosynthetic rate by maintaining higher chlorophyll content and high leaf water potential in mung bean over others (Rao *et al.*, 2015).

2.2 Effect of foliar application of water soluble fertilizer on yield and yield attributing parameters of soybean

Ramon Garcia and John Hanway (1976) observed significant yield increase was obtained from two to four sprayings on different soybean cultivars at different experimental sites between developmental stages R5 and R7. The optimum proportion of NPKS in the solution was 10:1:3:0.5. The optimum rate of total nutrient application was about $80 + 8 + 24 + 4 \text{ kg ha}^{-1}$ of NPKS respectively. Yield increase was due to increase in number of harvestable seeds and seed size. The results indicated that foliar fertilization during the seed filling period increased the soybean yield.

Nabih *et al.* (1982) observed that application of nitrogen at pod filling stage either to the soil or to the foliage increased the fruit set and weight of pods in soybean.

Foliar spraying of DAP at 2 per cent significantly increased the grain yield (955 kg ha^{-1}) and 100 grain weight (7.3 g) of black gram over no spray and it was on par with urea at one per cent spray (Muthuvel *et al.*, 1985).

Sathiyamoorthy and Vivekanandan (1988) observed that foliar spray helped moderately in increasing growth of plant with KNO_3 (2 %), thiourea (2.9 %) and DAP (2.5 %) treatment over the control. Seed yield increased significantly from 56 to 70 per

cent in all treatments except NaCl spray, which was attributed due to increased number of pods (41 to 63 %) per plant in soybean.

Rajendran (1991) reported that DAP at 50 kg ha⁻¹ as basal dose followed by spray of 2 per cent urea and DAP twice gave significantly higher yield of mung bean when urea or DAP foliar spray was given either with or without basal application of fertilizers. However, there was no significant yield difference were observed between urea and DAP spray on equal nitrogen basis.

Rao and Gangakishan (1993) noticed that application of 20 kg N ha⁻¹ in two equal splits as basal and at 25 DAS recorded significantly higher dry pod yield of groundnut (1678 kg ha⁻¹) over control (854 kg ha⁻¹). However, it was on par with the application of 20 kg N ha⁻¹ in two equal splits as basal soil incorporation and foliar spray at 25 DAS (1528 kg ha⁻¹).

Srivastava and Srivastava (1994) reported that foliar application of 2% urea at 50 per cent flowering stage gave the significantly higher seed yield of chickpea (1.7 t ha⁻¹) and also the significantly higher plant height, no of branches plant⁻¹, seeds pod⁻¹ and NPK uptake and water use efficiency compared with other treatment combinations in chickpea.

Patra *et al.* (1995) reported that pods per plant and 100 kernal weight increased in groundnut with post flowering foliar spray of potassium nitrate at 0.5 per cent.

Foliar application of macro and micro nutrients at critical stage of crop results in efficient absorption and translocation of nutrients to developing pods and produce more number of pods and filled pods in soybean (Jayabal *et al.*, 1999).

Mazhar Haq and Antonio (2000) reported that foliar fertilization of multivariate analysis across sites showed that 27 per cent of the variation in yield response was explained by a combination of N, P and K availability, vegetative growth and rainfall. Positive yield responses tend to occur when soil or weather conditions reduced plant growth and nutrient availability in soybean. Field experiment in soybean on foliar application reported that spraying nutrients during early pod filling stage was

significantly better than spraying at the early flowering growth stage. The highest seed yield of soybean was obtained by spraying NPK and NPK + Mg at pod filling stage (Abou El-Nour, 2002).

Osman *et al.* (2000) reported that three levels of phosphorus fertilizer (20, 40 and 60 kg P₂O₅ha⁻¹), foliar application of Zn (0.4 g l⁻¹ with spray solution of 300 l ha⁻¹ and untreated) and irrigation intervals (15 days during the whole growing season, 15 and 21 days during vegetative growth and flowering stages respectively and 21 and 15 days during vegetative and flowering growth stages respectively). Irrigation at 15 day interval throughout the growing season resulted higher yield of soybean. Application of Zn fertilizer did not significantly affect the seed yield but yield increased with increased phosphorus level in soybean.

Foliar spray of potassium nitrate 0.5 per cent at 50 per cent flowering stage showed maximum values of pods per plant, length of pod, seeds per pod and 100 seed weight in groundnut (Sarkar and Malik, 2001).

Application of potassium 25 kg ha⁻¹ in combination with 2 per cent DAP at pre flowering + pod developing stage recorded higher seed yield (13.80 q ha⁻¹) and 1000-seed weight (33.80 g) over no spray (8.25 q ha⁻¹ and 27.2 respectively) in blackgram (Yakadri and Thatikunta, 2002). Chandrasekhar and Bangarusamy (2003) observed that foliar application of 2 per cent DAP + 100 ppm salicylic acid + 1 per cent KCl + NAA (40 ppm) significantly increased the number of pods per plant (19.45) and seed yield (1443 kg ha⁻¹) and above treatments were on par with DAP 2 per cent (13.2 and 1162 kg ha⁻¹ of pods per plant and seed yield respectively) in green gram.

Combined application of nutrients (DAP, KCl and boron) and growth hormone (NAA) on grain yield of soybean. Foliar spraying of 2 per cent DAP, 1 per cent KCl, 0.2 per cent boron and 40 mg NAA given comparable results as that of foliar spraying of 2 per cent DAP, 1 per cent KCl and 0.2 per cent boron during both season. The combined application of DAP, KCl, boron and NAA registered significantly higher protein content

while the higher amount of oil content was recorded from foliar spray of DAP and KCl with or without boron in soybean (Kalpana *et al.*, 2003).

Nelson *et al.* (2004) observed that soybean grain yield increased from 727 to 834 kg ha⁻¹ when K was applied through foliar spray at 36 kg ha⁻¹ at growth and flowering (R₁-R₂) stage, pod development (R₃-R₄), seed development (R₅-R₆) and plant maturity (R₇-R₈). Foliar applied K at the R₃-R₄ stage of development increased grain yield but not as much as at (R₁-R₂). DAP 2 per cent foliar spray produced significantly higher yield (748 kg ha⁻¹) over commercial micronutrient mixtures except urea (Barik and Rout 1990).

Lalitha *et al.* (2006) studied the effect of foliar application of K₂SO₄ and boric acid on yield, nutrient uptake and quality of niger and observed significant improvement in seeds per capitulum, 1000 seed weight with foliar application of K₂SO₄ and boric acid along with RDF either at 50 DAS or 60 DAS.

Nasef *et al.* (2006) observed that the highest seed yield of groundnut and yield components were obtained from plants receiving foliar spray with 200 ppm boron and inoculated with *rhizobium*.

Field studies on fababean reported that application of nitrogen 40 kg ha⁻¹ along with 50-100 ppm boron given more number of pods per plant, number of seeds per pod, seed yield per plant, haulm and seed yield ha⁻¹ (Mahmoud *et al.*, 2006). Experiment conducted in soybean by Thakare *et al.* (2006) reported that soil application of half dose of RDF and foliar application of 2 per cent DAP or urea at 50 ppm IAA or NAA significantly increased leaf chlorophyll and nitrogen, seed protein, oil content and yield contributing parameters *viz.*, number and dry weight of pods per plant, 100 seed weight and seed yield ha⁻¹. The combined application of IAA with DAP or urea, NAA with DAP or urea, IAA or NAA individually and 6% cow urine with DAP or urea along with basal application of half RDF also improved all these parameters as well as yield of soybean over the RDF.

Thalooth *et al.* (2006) revealed that foliar application of potassium nitrate 2 per cent surpassed the other treatments of magnesium sulphate 50 ppm and zinc-EDTA 300

ppm in increasing the number and weight of pods per plant, number of seeds per pod, seed dry weight per plant, seed index and seed yield in mung bean grown under water stress condition.

Dixit and Elemathi (2007) observed that foliar application with DAP 2 per cent + 40 ppm NAA + 0.2 per cent boron + 0.05 per cent molybdenum at 30 DAS on greengram increased the seeds (25.86) pod⁻¹, 1000 seed weight (30.33), grain yield (10.16 q ha⁻¹) and haulm yield (30.33 q ha⁻¹) over no spray. In another study Pradeep and Elamathi (2007) reported that significant increase in number of pods per plant, 1000 seed weight, seed and haulm yield was observed in green gram with foliar application of boron 0.2 per cent along with DAP 2 per cent, NAA 40 ppm and Mo 0.5 per cent at 30 days after sowing.

In greengram Ghosh and Joseph (2008) reported that inoculation of *rhizobium* + PSB and sulphur 30 kg ha⁻¹ through gypsum and 2 per cent foliar application of DAP recorded significantly higher number of pods plant⁻¹, fertility coefficient, number of seeds pod⁻¹, seed yield, haulm over yield and test weight in green gram.

Manonmani and Srimathi (2009) concluded that spraying with 2 per cent DAP followed by urea one per cent recorded higher 100 seed weight (5.6 and 5.5 g), seed yield (1240 and 1040 kg ha⁻¹). Further, the seed germination per cent (92 and 88%, respectively) in black gram.

Nasiri *et al.* (2010) reported that soil application of nitrogen at 300 kg/ha and potassium at 20 kg/ha along with foliar application of zinc 6 kg ha⁻¹ in *Phaseolous vulgaris* significantly increased number of pods per plant, number of pods per meter square, number of seeds per pod, 100 seed weight, fresh pod yield, seed yield, biological yield and harvest index.

Significant increased yield, fruit dimensions, fruit volume, fruit weight, flesh to fruit ratio and decreased seed to fruit ratio were observed in soybean with foliar application of potassium nitrate at 4 per cent (Hegazi *et al.*, 2011).

Kuttimani and Velayutham (2011) reported that foliar application of 2 % DAP + 100 ppm salicylic acid + 0.05 % sodium molybdate twice at vegetative and flowering stage of crop growth recorded better yield parameters and economics. However, all the yield attributing parameters recorded under 2 per cent urea + 100 ppm salicylic acid + 0.05 per cent sodium molybdate twice were on par with 2 per cent DAP + 100 ppm salicylic acid + 0.05 per cent sodium molybdate twice in green gram.

Garud (2012) revealed that phosphorus level $P_3(60 \text{ kg } P_2O_5 \text{ ha}^{-1})$ and foliar application of BOOST-52 (0:52:34) at 35 and 50 DAS was significantly higher productive, profitable and better for quality parameters *i.e.*, plant height, leaf area index, biological yield, number of branches plant^{-1} and yield attributes viz., number of pods per plant, pod length, number of grains per pod Foliar spray of BOOST-52 (0:52:34) at 35 and 50 DAS recorded significantly highest seed yield (2387 kg ha^{-1}) with B: C Ratio of 3.53 Over all other treatments of foliar application in soybean.

Beg *et al.* (2013) showed that maximum increase in diameter of flower, number of pods per plant, length of pod, number of seeds per pod, 1000 grain weight and grain yield in urdbean with foliar spray of potassium along with half dose of fertilizer. Jyothi *et al.* (2013) observed significant response for foliar application of N and Zn at two different stages (pod development and flowering stage). An incremental response of 50, 27.2 and 56.9 % was noticed in 100 seed weight, number of pods plant^{-1} and grain yield respectively with foliar application of urea 2 per cent at flowering and at early pod development stages over control.

Jyothi *et al.* (2013) reported that foliar spray of 2 per cent urea at pod development and flowering stage significantly increased yield, yield attributes, quality parameters and nutrient uptake of soybean. An increment of 50, 27.2 and 56.9 % was recorded in 100 seed weight, number of pods/plant and grain yield respectively. Significantly highest with 2 per cent urea as foliar application at flowering and at early pod development stage compared to control.

Vinothkumar *et al.* (2013) revealed that foliar spray of 2 % DAP twice at flower initiation and pod formation stages of crop growth resulted in significantly higher number of pods per plant (62.50), number of seeds per pod, seed index and higher grain yield (1460 kg ha⁻¹) and it was on par with 2 per cent urea phosphate and TNAU pulse wonder spray.

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

Kumar *et al.* (2013) revealed that foliar spray of DAP at 2 per cent twice at flower initiation and pod formation stage of crop growth resulted significantly higher number of pods plant⁻¹ (62) number of seeds pod⁻¹, seed index and higher grain yield (1460 kg ha⁻¹) and yield was on par with the result obtained from application of 2% urea phosphate and TNAU pulse wonder spray in soybean crop.

Foliar application of potassium nitrate 2 per cent + 50 ppm boric acid + 1 per cent zinc sulphate at 30 and 60 DAS was found to be superior in increasing number of pods per plant, test weight and seed yield followed by potassium nitrate 2 per cent + 50 ppm boric acid at 30 and 60 DAS, 50 ppm boric acid + 1 per cent zinc sulphate at 30 and 60 DAS and 2 per cent potassium nitrate + 1 per cent zinc sulphate at 30 and 60 DAS where as lower values were recorded in control in soybean (Gowthami and Rao, 2014). Mannan (2014) conducted field experiment on effect of foliar spray of N, NPK, NPKS and NPKMg on soybean growth, yield and protein content. The results indicated that foliar spray either single or in combination enhanced the growth, yield and protein content in soybean seed at the two growth stages compared to soil fertilization. However spraying nutrients during pod filling stage was better than vegetative stage in all characters studied.

Rao *et al.* (2015) reported that one per cent KNO_3 given higher seed yield under receding soil moisture condition compared to other foliar sprays. Under irrigated conditions urea 2 per cent recorded significantly higher yield over the control. Among all treatments, control (no spray) under un irrigated conditions recorded lower yield due to moisture stress and nutrient deficiency in mung bean.

2.3 Effect of foliar application of water soluble fertilizer on quality parameters of soybean

Sathiyamoorthy and Vivekanandan (1988) observed that foliar spray of KNO_3 , thio urea and DAP increased the protein yield without affecting the oil content in soybean in moderate saline or alkaline soil. DAP at 2 per cent foliar spray produced significantly higher yield (748g ha^{-1}) over commercial micronutrient mixtures except urea. One spray at 20 DAS after sowing was best to maximize the yield. Two sprayings *viz.*, at 20 and 80 DAS recorded the higher protein content of grain (23.04%) over a single spray at 20 or 30 days after sowing Barik and Rout (1990).

Mohammad and Khan (1997) observed foliar spray of 30 kg N ha^{-1} on mustard grown with 60 kg N and 30 kg P ha^{-1} ($\text{BN}_{60}\text{P}_{30} + \text{FN}_{30}$) proved optimum for almost all growth and yield attributing parameters resulted in increase in seed and oil yield of mustard 11.18 per cent and 12.13 per cent respectively over the control.

The foliar applied DAP either alone or in combination with KCl, boron and growth hormone (NAA) resulted significantly higher protein content while the higher amount of oil content was recorded from foliar applied DAP and KCl with or without boron in soybean (Kalpana, 2003).

Hegazi *et al.* (2011) reported that increased leaf N, P and K content and fresh oil content in olive due to foliar spray of potassium nitrate @ 4 per cent. Hafiz and El-Bramawy (2012) revealed that increased potassium concentration at foliar spraying of 2 per cent induced significant increment in seed oil per cent and seed oil yields ha^{-1} in sesamum.

Jyothi *et al.* (2013) reported that foliar spray of 2 per cent urea at pod development and flowering stage significantly increased quality parameters of soybean. Significantly higher protein (43.9 %) and oil content (20.9 %) of soybean were recorded with soil application of NPK fertilizer along with foliar spray than NPK application alone in soybean. Kumar (2013) reported that the foliar application of soluble starter NPK 2 per cent + 2 per cent sulphur spray at 45 DAS and soluble booster NPK 2 per cent + boron spray 0.15 per cent at 65 DAS resulted in significantly higher oil content, oil yield, protein content in 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 micronutrient during pod filling stage was better than vegetative growth stage in all characters were studied. The highest amount of protein content in soybean seed and grain yield were recorded under the spraying of NPKMg during pod filling stage in soybean. Experiment conducted by Nasri *et al.* (2010) revealed that soil application of nitrogen 300 kg ha⁻¹ and potassium 120 kg ha⁻¹ along with foliar application of zinc 6 kg ha⁻¹ in *Phaseolous vulgaris* significantly increased Zn⁻ concentration in pods, nitrate concentration in pods, carbohydrate per cent, carbohydrate yield, protein yield and chloropyll of leaf.

Pande (2014) reported that significantly higher seed protein content increased to extent of 3.0 % in soybean with the foliar spray of K combined with soil application of K rate of 190 mg/kg and K rate of 380 mg kg⁻¹ compared with over the control (no K application). Palmic acid percentages showed significant increase in all concentrations, the highest per cent increase of 16.9 per cent was observed at 380 mg kg⁻¹ of K. Linoleic acid per cent increased in both foliar treatments, but linolenic acid percentage increase was more with soil application at 380 mg kg⁻¹ of K alone (12.2 per cent) in comparison to control and significant decrease (15.8%) in linoleic acid was recorded in foliar application of K in soybean.

2.4 Effect of foliar application of water soluble fertilizer on nutrient uptake and soil available nutrients status after soybean

Boote *et al.* (1977) observed foliar application of N, P, K, and S increased the N, P and K concentration of total canopy leaves from 3.28, 0.24, and 0.92 per cent to 3.48, 0.29, and 1.32 per cent respectively in soybean. Foliar fertilization significantly increased upper leaf Pg (gross leaf photosynthesis) only at two late sample dates when seed growth was nearly complete and most leaves had already started senescence and dropped. Maximum Pg was predicted at 4.6 to 6.0 per cent leaf N. Leaf Pg and per cent P were also positively correlated. The relationship of Pg to leaf N during N removal from leaves can potentially be used to model photosynthetic decline during seed filling stage.

Muthuvel *et al.* (1985) reported that, foliar spray of 2 per cent DAP and 1 per cent urea 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. Singh and Kamath (1989) found that foliar application of 1.5 kg P₂O₅ in two sprays significantly increased the P uptake (20.5 mg plot⁻¹) and dry matter (7.71 gm plot⁻¹) of Mustard.

Elayaraja and Angayarkanni (2005) concluded that, foliar application of 2 per cent DAP at 20, 30 and 45 DAS resulted in higher NPK uptake in both seed (43.03, 46.22 and 6.85 kg ha⁻¹, respectively) and haulm (5.39, 8.18 and 15.01 kg ha⁻¹, respectively) of black gram.

Nelson *et al.* (2005) reported that foliar application of potassium sulphate @ 36 kg ha⁻¹ on soybean leaves acts as an excellent method of supplementary fertilization when edaphic climatic condition do not favor the satisfactory uptake of potassium from soil thus resulting in increased yield. Nasef *et al.* (2006) observed foliar spraying with 200 ppm boron and inoculated with rhizobium increased significantly the uptake of N, P, K, Fe, Mn, Zn and B by straw and seeds of groundnut in both seasons as compared without biofertilizer.

Raman and Venkataramana (2006) studied the effect of foliar nutrients on NPK uptake, yield attributes and yield of green gram in inceptisol. The results revealed that foliar spray of 2 per cent DAP with 30 ppm NAA recorded higher NPK (69.01, 18.19 and 65.71 kg ha⁻¹, respectively) uptake over control (58.66, 12.97 and 53.68 kg ha⁻¹, respectively).

Jyothi *et al.* (2013) reported that foliar spray of 2% urea at pod development and flowering stage significantly increased uptake of Zn, N by soybean and also soil application of NPK fertilizer was found to be more beneficial to improve the productivity of soybean than NPK application alone in soybean. Kumar (2013) reported that the foliar application of soluble starter NPK @ 2 per cent + sulphur spray 2 per cent at 45 DAS and soluble booster NPK 2 per cent + boron spray 0.15 per cent at 65 DAS resulted in significantly higher oil content, oil yield, protein content.

Significantly higher phosphorus and potassium uptake (88.32, 10.72 and 35.09 kg ha⁻¹ respectively) and available N and P₂O₅ content of soil (278.13 kg ha⁻¹ and 28.55 kg ha⁻¹ respectively) was noticed in RDF + foliar spray of 40 ppm NAA + 0.5 % chelated micronutrient + 2% DAP. Which was at par with RDF + foliar spray of 2 per cent DAPS + 0.5 % chelated micronutrient of black gram (Rezaei *et al.*, 2013).

2.5 Effect of foliar application of water soluble fertilizer on economic of soybean

The highest cost benefit ratio (3.47) was registered with foliar spray of DAP 2 per cent which signifies that foliar spray with DAP is the cheapest agronomic practice in achieving good grain yield with minimum production cost in green gram (Chandrasekhar and Bangarusamy, 2003).

Experiment conducted on sandy loam soil to study the effect of foliar spray of DAP and growth regulators on yield and economics of green gram. Foliar spray of 2% DAP and NAA 40 ppm twice at 25 and 35 days after sowing resulted in higher benefit cost ratio (2.58) in green gram (Behera *et al.*, 2007).

Garud (2012) revealed that phosphorus level $60 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ and foliar application of BOOST-52 (0:52:34) at 35 and 50 DAS was significantly recorded highest seed yield ($2387.7 \text{ kg ha}^{-1}$) with B:C ratio of 3.53 over all other treatments of foliar application in soybean.

Kumar *et al.* (2013) revealed that foliar spray of 2 % of DAP twice at flowering initiation and pod formation stage of crop growth resulted in significantly higher net return of Rs 20,090 with B:C Ratio of 2.22 in soybean.

Vinothkumar *et al.* (2013) revealed that foliar spray of 2 per cent DAP twice at flower initiation and pod formation stages of crop growth resulted in significantly higher grain yield (1460 kg ha^{-1}) and it was on par with 2 per cent urea phosphate and TNAU pulse wonder spray. The foliar spray of 2 per cent DAP also recorded significantly higher net returns of Rs. 20,090 with B:C ratio of 2.22.

Foliar spray of 2 per cent DAP recorded significantly higher net return of Rs. 20,090 with B:C ratio of 2.22 in soybean. Foliar application of 2 per cent potassium nitrate at + boric acid at 50 ppm + 1 per cent zinc sulphate 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 per plant, test weight and seed yield followed by potassium nitrate at 2 per cent + boric acid at 50 ppm at 30 and 60 DAS , boric acid at 50 ppm + 1 per cent zinc sulphate at 30 and 60 DAS and 2 per cent potassium nitrate + 1 per cent zinc sulphate at 30 and 60 DAS whereas lower values were recorded in control in soybean (Gowthami and Rao, 2014).

III MATERIAL AND METHODS

The field experiment was carried out to study the **Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]** during summer season of 2017. The material used and the techniques adopted during the course of investigation are described in this chapter.

3.1 Experimental site

The experiment was conducted at Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bengaluru is situated at 13° 05' North latitude and 77° 34' East longitude at an altitude of 924 m above mean sea level which comes under Eastern Dry Zone (ACZ-V) of Karnataka.

3.2 Soil of the experimental site

The soil of the experimental site was red sandy clay loam. Composite soil samples were taken at random from upper 30 cm layers and were analyzed for physic-chemical properties. The values obtained along with the methods followed are given in Table 3.1. The soil reaction was neutral (6.56), medium in available nitrogen (175.61 kg ha⁻¹), available phosphorus (43.56 kg ha⁻¹) and available potassium (273.24 kg ha⁻¹).

3.3 Normal Climatic conditions of the experimental site

The normal (1972-2012) and actual weather data (January-July 2017) viz., maximum and minimum temperature, relative humidity, rainfall and duration of sunshine hours prevailed during the period of investigation are presented in Table 3.2 & Fig. 3.1.

3.3.1 Actual climatic conditions of the experimental site

The total normal rainfall for crop growth period (January-2017 to June-2017) was 356.80 mm. The actual rainfall received in the month of May was 246.6 mm as against the normal rainfall of 50.97 mm. The normal monthly maximum temperature varied between 35.1°C in the month of April and 27.3 °C in the month of January. The monthly minimum temperature varied from 21.9 °C during April to 14.5 °C during January.

Table 3.1: Physical and chemical properties of soil of the experimental site at ZARS, GKVK, UAS, Bengaluru

Particulars	Methods followed	Values
A. Physical properties		
Mechanical analysis (oven dry weight basis)		
Coarse sand (%)	International pipette method (Piper, 1966)	33.20
Fine sand (%)		36.36
Silt (%)		7.26
Clay (%)		23.18
Texture class	Sandy clay loam	
B. Chemical properties		
pH	Buckman's zerometric pH meter (Piper, 1966)	6.56
EC (dSm ⁻¹)	Conductometry (Jackson, 1967)	0.14
Organic carbon (%)	Walkey and Black wet oxidation method (Subbiah and Asija, 1956)	0.43
Available N (kg ha ⁻¹)	Alkaline permanganate method (Subbiah and Asija, 1956)	175.61
Available P ₂ O ₅ (kg ha ⁻¹)	Olsen's method (Jackson, 1967)	43.56
Available K ₂ O (kg ha ⁻¹)	Neutral normal ammonium acetate method (Jackson, 1967)	273.24

Table 3.2: Normal (1972-2012) and Actual (January-July 2017) monthly weather data at ZARS, GKVK, UAS, Bengaluru

Month	Rainfall (mm)			Relative humidity (%)			Mean daily air temperature (⁰ C)						Mean daily Sunshine hours		
							Maximum			Minimum					
	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D
January	1.3	0.0	-1.3	43.0	39.5	-3.5	27.4	27.3	-0.1	13.9	14.5	0.6	9.0	8.2	-0.8
February	9.6	0.0	-9.6	37.0	33.0	-2.0	29.9	30.6	0.7	15.3	14.9	-0.4	9.6	10.1	0.3
March	17.4	9.8	-7.6	33.0	39.00	6.00	32.6	33.0	0.4	17.8	19.5	1.7	9.4	8.9	0.5
April	46.2	1.6	-45.6	34.0	36.0	2.0	33.7	35.1	1.4	20.4	21.9	1.5	8.9	8.4	-0.5
May	100.4	246.6	146.2	40.0	42.0	2.0	33.0	32.7	-0.3	20.5	20.7	0.2	8.4	7.6	-0.8
June	77.3	65.4	-12.1	52.0	54.0	2.0	29.6	28.6	-1.0	19.5	20.1	0.6	6.0	5.2	-0.8
July	104.3	33.4	-70.1	56.00	56.0	00	28.2	28.8	0.2	19.0	19.8	0.8	4.4	5	0.6

N : Normal, A : Actual, D: Deviation.

The highest maximum relative humidity was recorded during June and July month was 89 %. The daily bright Sunshine hours varies between 10.1 hours during February and 5.2 hours in the month of June.

3.4 Cropping history of experimental site

Before the experiment, baby corn (*Zea mays* L.) crop was grown for experimental purpose during *kharif* 2016 and later plot was kept fallow till sowing of soybean.

3.5 Experimental detail

The plan and layout of the experiment and treatments are shown in Fig. 3.2

3.5.1 Treatment details

T₁- Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹+ FYM 6.5 t ha⁻¹)

T₂- RDF (50 % N as basal and 50 % N as top dressing)

T₃- RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄- RDF + foliar application of WSF @ 2 % at flowering stage

T₅-RDF + foliar application of WSF @ 2 % at pod filling stage

T₆- RDF + foliar application of WSF @ 2 % at flowering and pod filling stage

T₇- Recommended dose of nitrogen through FYM only

Note: In treatment two (T₂), the nitrogen in RDF was applied in two splits, 50 per cent as basal at the time of sowing and other 50 per cent as top dress at 30 DAS.

WSF: Water soluble fertilizer

Crop : Soybean

Cultivar : KBS-23

Design : RCBD

Number of treatments : 07

Number of replications : 03

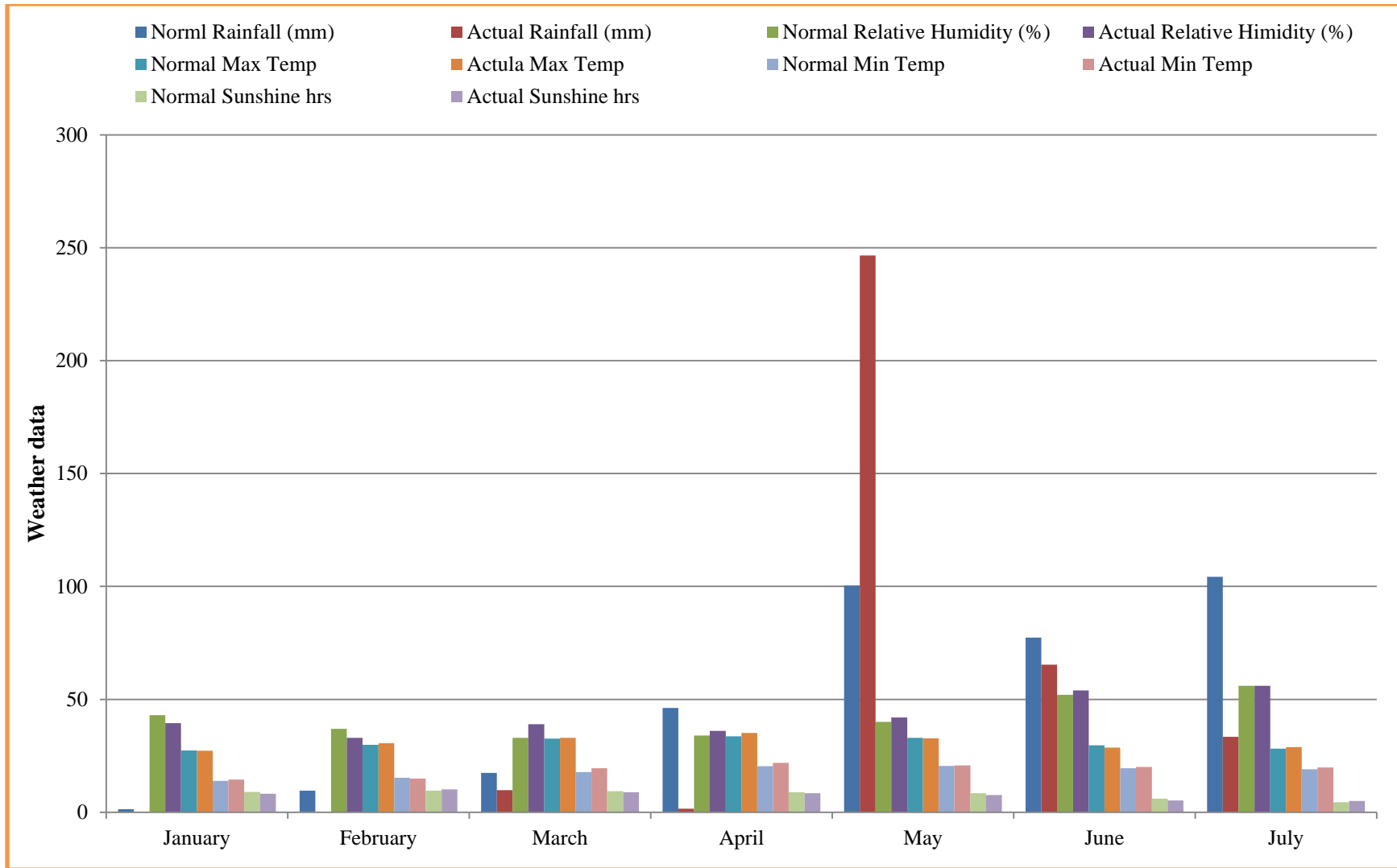


Fig. 3.1: Mean monthly weather data during 2017 at ZARS, GKVK, Bengaluru

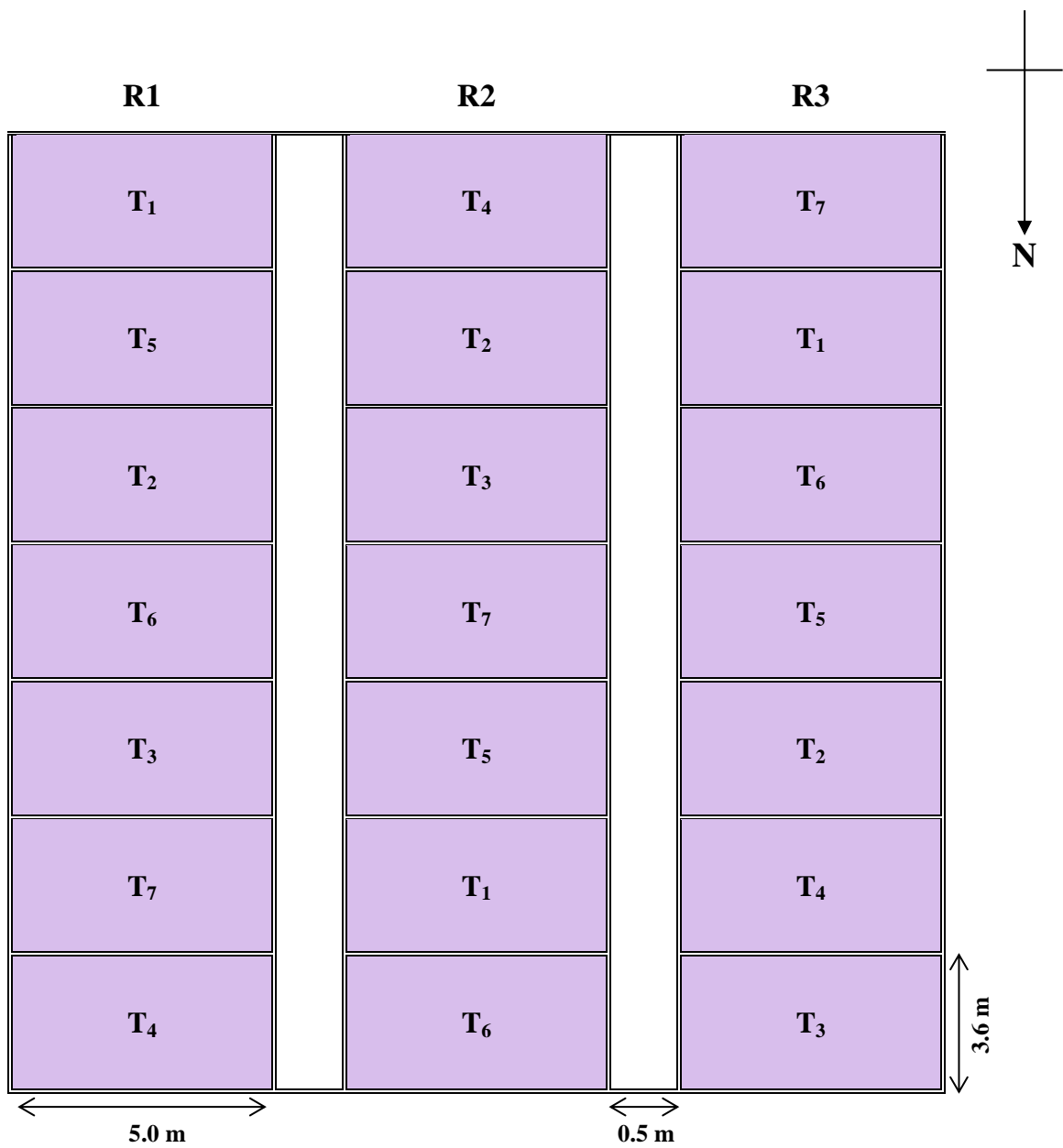


Fig. 3.2: Plan of layout of experiment and treatments.

Plot size	Gross plot	: 5.0 x 3.6 m
	Net plot	: 4.4 x 3.4 m
Season		: Summer 2017
Spacing		: 30 X 10 cm
Recommended Dose of Fertilizer		: 30:80:38 kg N: P ₂ O ₅ : K ₂ O ha ⁻¹ + FYM 6.5 t ha ⁻¹
Seed rate		: 62.5 kg ha ⁻¹
Date of sowing		: 09.02.2017
Date of harvesting		: 12.05.2017
Location		: ZARS, GKVK, Bengaluru

3.6. Varietal Description

3.6.1 Soybean variety KBS-23

KBS-23 variety parentage is JS-335 x KHSb-2 and hybridization breeding method was used to develop the variety and breeding method used to develop the variety was hybridization, pedigree method. The variety was released for *kharif* but can grow in *summer* also in both rainfed and irrigated conditions. The variety was released for agro climatic zones of 5 and 6 in Karnataka. Duration of the variety is 86-90 days with yield potential of 5-6 q ha⁻¹ and resistant to leaf minor and being a short duration suitable for multiple cropping systems.

3.7 Crop husbandry

3.7.1 Land preparation

Primary tillage was done by disc plough followed by passing cultivator twice, harrowed and leveled to get required seed bed. After the seed bed was prepared, the plots were laid out according to the plan of layout manually.

3.7.2 Application of fertilizers

After bringing the soil to a fine tilth, recommended dose of FYM was applied to each plot and incorporated well in soil one week prior to sowing. Chemical fertilizers were applied as per package of practice. Urea, single super phosphate and muriate of potash were applied to supply nitrogen, phosphorus and potassium, respectively, as per the treatment. The chemical fertilizers were applied in furrows and mixed properly at the time of sowing. The water soluble NPK (19:19:19) was sprayed as per the treatments and the quantity of spray solution used was 500 litres per hectare.

3.7.3 Sowing

The seeds were dibbled manually in the pre irrigated plots. After sowing of seeds they were covered with a layer of fine soil firmly and field was given light irrigation immediately after sowing.

3.7.4 Irrigation and inter cultivation

First irrigation was given immediately after sowing for uniform germination. Subsequent irrigations were given as per the crop requirement based on the soil moisture content. All plots were kept weed free by pre-emergent spray of alachlor at the rate of 1kg*a.i.* per hectare and one hand weeding at 30 days after sowing. The earthing up was done at 45 days after sowing in all the plots.

3.7.5 Plant protection measures

During the experimental period, early stage of the crop growth there was incidence of sucking pests and was controlled by spraying of chlorpyrifos at 2 ml per litre with spray solution of 500 litres per ha.

3.7.6 Harvesting

Harvesting was done manually from net plot area when the seed became hard and leaves turned yellow in colour. The plants were left in plot for five days to sun dry and thereafter bundles were made and the bundle weight plot⁻¹ was recorded.



Plate 1: General view of soybean crop at 15 DAS



Plate 2: General view of soybean crop at 30 DAS

3.7.7 Threshing

Threshing of produce from each net plot was done manually by beating with wooden stick and after manual winnowing seed yield plot⁻¹ was recorded. Stover yield was also recorded after subtracting the seed yield from bundle weight.

3.8 Details about collection of experimental data

3.8.1 Observations on growth parameters

Five plants were randomly selected from the net plot and were marked with tags to collect the information on different growth components. Later five plants were selected at random and uprooted for destructive sampling at 15, 30 and 45 days after sowing and at harvest. The various growth parameters such as plant height, number of leaves per plant, leaf area per plant, leaf area index, leaf area duration, dry matter production and days taken for 50 per cent flowering were recorded at different growth stages of soybean.

3.8.2 Growth components

3.8.2.1 Plant height

The plant height (cm) recorded from randomly selected and labeled five plants. Plant height was taken from the base of the plant to the tip of the upper most leaf at 30, 60 DAS and at harvest. The mean plant height was worked out and expressed in centimeter.

3.8.2.2 Number of leaves

Total number of fully opened green leaves of five plants were counted at 30, 60 DAS and at harvest and their average was taken as the number of leaves per plant.

3.8.2.3 Number of branches

Numbers of branches were counted from the five tagged plants and their average was taken as the number of branches plant⁻¹ at 30, 60 DAS and at harvest.

3.8.2.4 Leaf area

Leaf area per plant was recorded from the five tagged plants in each plot, there mean length and width was recorded with the help of scale and calculated the leaf area periodically at 30, 60 DAS and at harvest by using the following formula and leaf area is expressed in cm^2 .

$$\text{Leaf area} = L \times B \times F \times N$$

Where,

L = Maximum length of leaves

B = Maximum breadth of leaves

F = Correction factor (0.70)

N = Number of leaves

3.8.2.5 Leaf area index (LAI)

It is defined as an assimilatory surface per unit area of land (Sestak *et al.*, 1971). Leaf area index (LAI) was worked out at 30, 60 days after sowing and at harvest by dividing the leaf area per plant divided by land area occupied by the plant.

$$\text{LAI} = \frac{\text{Leaf area per plant}(\text{cm}^2)}{\text{Land area per plant}(\text{cm}^2)}$$

3.8.2.6 Leaf area duration (LAD)

Leaf area duration is the integration of leaf area index over a growth period (Watson, 1952). Leaf area duration (LAD) for various growth periods were worked out from the following formula (Powar *et al.*, 1967) and expressed in days.

$$\text{LAD} = \frac{L_2 + L_1}{2} \times (t_2 - t_1)$$

Where,

L_1 = LAI at time t_1

L_2 = LAI at time t_2

$t_2 - t_1$ = Time interval between crop growth period in days



Plate 3: General view of soybean crop at 45 DAS



Plate 4: General view of soybean crop at 60 DAS



Plate 5: General view of soybean crop at 75 DAS



Plate 6: General view of soybean crop at harvest

3.8.2.7 Chlorophyll content (SPAD meter reading)

Chlorophyll content (SPAD meter reading) was recorded from the five tagged plants in each treatment periodically at 30 and 60 DAS and average value used for statistical analysis.

3.8.2.9 Number of nodules plant⁻¹

The numbers of nodules (plant⁻¹) were recorded at 60 DAS from five randomly selected plants from each plot. The uprooting of sample was performed with the help of core cutting equipment along with the soil up to effective root zone. The roots of the plant were washed in sieve with running water and effective root nodules were separated and counted and expressed as number of nodules plant⁻¹.

3.8.2.10 Dry weight of nodules

The dry weight of nodules was recorded at 60 DAS. The counted nodules were dried at 60⁰C for 48 hours in hot air oven there after dry weight of nodules was recorded by using an electronic digital balance and average dry weight of nodules were expressed as g plant⁻¹.

3.8.2.11 Dry matter production and accumulation

Dry weight per plant was recorded at 30, 60 DAS and at harvest from five randomly selected plants in each plot. Samples were dried at 65⁰C to attain constant weight and average dry weight was calculated and expressed in g plant⁻¹.

3.8.3 Observations on yield parameters

3.8.3.1 Day taken for 50 per cent flowering

Days taken for 50 per cent flowering was recorded from each treatment and later expressed as days taken for 50 per cent flowering.

3.8.3.2 Number of pods

Number of pods were recorded from five randomly selected and tagged plants and mean was worked out by dividing the total number of pods by five and expressed as number of pods plant⁻¹.

3.8.3.3 100 seed weight

Seed samples were taken from each treatment from net plot and hundred healthy seeds were picked randomly and counted later oven dried for 60°C for 24 hours then weight (g) was recorded accurately by using an electronic digital balance.

3.8.3.4 Weight of seeds

Weight of seed was recorded from five randomly tagged plants and mean was worked out by dividing the total weight of seeds by five and used for statistical analysis. The seeds were oven dried at temperature of 60°C for 24 hours and then weight was recorded accurately by using an electronic digital balance and expressed in g plant⁻¹.

3.8.3.5 Seed yield

Seed from net plot from each treatment was sun dried and later threshing was done by beating with stick then cleaned and weight was recorded. Seed weight per net plot from each treatment was converted into seed yield per hectare and expressed as kg ha⁻¹.

3.8.3.6 Haulm yield

Haulm yield was recorded after completing sun drying of the haulm for each net plot treatment wise and from this haulm yield per hectare was worked and expressed in kg ha⁻¹.

3.8.3.7 Harvest Index

The harvest index (HI) was determined by using the formula given by Donald (1976).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Where,

Economic yield = Seed yield

Biological yield = Seed yield + haulm yield

3.8.4 Observation on quality parameters

Plant samples from each treatment were collected at harvest and oven dried, powdered and used for analysis of quality parameters.

3.8.4.1 Protein content

The nitrogen content of the whole plant was estimated by modified Kjeldhal method given by Piper (1966) and expressed in percentage. The protein content of seed was worked out by multiplying the nitrogen percentage with factor 6.25. The protein yield was calculated by multiplying protein content with seed yield and expressed in quintals per hectare.

3.9 Nutrient uptake by crop

3.9.1 Digestion of plant samples

One gram plant sample was collected from each treatment and was digested with nitric acid and perchloric acid (9:4). The filtered digested sample was filtered and made up to 50 ml volume with 6 N HCl and was used for the analysis of all mineral elements.

3.9.2 Nitrogen uptake (kg ha⁻¹)

Nitrogen content was estimated by modified micro kjeldhal's method as outlined by Jackson (1967) and expressed in percentage. Nitrogen uptake (kg ha⁻¹) by crop was calculated for each treatment separately using the following formula.

$$\text{Nitrogen uptake (kg ha}^{-1}\text{)} = \frac{\text{Nitrogen concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1}\text{)}$$

3.9.3 Phosphorus uptake (kg ha⁻¹)

Phosphorus content in the digested plant sample was estimated by vanadomolybdate phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 660 nm wave length as outlined by Jackson (1967). It was calculated using the following formula.

$$\text{Phosphorus uptake (kg P}_2\text{O}_5 \text{ ha}^{-1}) = \frac{\text{Phosphorus concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1})$$

3.9.4 Potassium uptake (kg ha⁻¹)

Potassium in the plant samples digested was estimated by atomizing the diluted acid extract in a flame photometer as described by Jackson (1967). It is calculated using the following formula.

$$\text{Potassium uptake (kg K}_2\text{O ha}^{-1}) = \frac{\text{Potassium concentration (\%)}}{100} \times \text{Dry matter (kg ha}^{-1})$$

3.9.5 Chemical analysis of soil

Representative soil samples from the experimental plots were collected from the top 30 cm depth before sowing of the crop. Similarly, surface soil samples from 0 to 30 cm depth were also collected from each experimental plot after harvest of crop.

Soil samples collected were air dried in shade, powdered with wooden mallet and passed through 2 mm sieve and analyzed for organic carbon content (%), pH, EC (dSm⁻¹), available nitrogen, phosphorus and potassium content of the soil.

3.9.6 Available nitrogen

Available nitrogen was determined by alkaline permanganate method as outlined by Subbiah and Asija (1956) and expressed in kg N ha⁻¹.

3.9.7 Available phosphorus

Available phosphorus was determined by Olsen's method as outlined by Jackson (1967) and expressed in kg P₂O₅ ha⁻¹.

3.9.8 Available potassium

Available potassium was determined by Neutral normal ammonium acetate solution using flame photometer as outlined by Jackson (1967) and expressed in kg K₂O ha⁻¹.

3.10 Economics

The economics of soybean crop production pertaining to each of the treatment has been worked out in terms of cost of cultivation. Gross return (Rs. ha⁻¹) was obtained by converting the harvest into monetary terms at the prevailing market rate during the course of investigation for every treatment. Net return (Rs. ha⁻¹) was obtained by deducting cost of cultivation from gross return. The additional return over control and benefit: cost ratio was calculated with the help of following formula:

$$\text{Net return (Rs. ha}^{-1}\text{)} = \text{Gross return (Rs. ha}^{-1}\text{)} - \text{Cost of cultivation (Rs. ha}^{-1}\text{)}$$

3.11 Statistical analysis

The data obtained on various characters under study were analyzed statistically by using the method of analysis of variance for randomized complete block design. For significant treatment effect standard error of mean (S.Em±) and critical difference were calculated at 5 per cent level of significant, when 'F' value was significant (Gomez and Gomez, 1984).

IV EXPERIMENTAL RESULTS

The results of the experiment conducted during summer 2017 on **Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]** is presented in this chapter.

4.1 Effect of foliar application of water soluble NPK (19:19:19) fertilizer on growth parameters of soybean.

Data on plant height, number of branches, number of leaves, leaf area, leaf index, leaf area duration, Chlorophyll content (SPAD meter reading), number of nodules per plant and total dry matter accumulation at different stages of crop growth as influenced by foliar application of water soluble fertilizer is presented in Table 4.1 to 4.8.

4.1.1 Plant height

As per the results indicated in Table-4.1, the plant height differed due to foliar application of water soluble fertilizer at different stages of crop growth. At 30 DAS, the plant height found non significant between treatments. Significantly higher plant height at 60 DAS and at harvest (46.53 and 50.20 cm respectively) was recorded with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next application of RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher plant height (42.43 and 47.60 cm at 60 DAS and harvest respectively) which was on par with RDF + foliar application of WSF @ 2 % at flowering stage at all the stages of crop growth.

The significantly lower height of plant was observed in recommended dose of nitrogen through FYM only at 60 DAS and harvest (33.23 and 35.13 cm respectively) of the crop.

4.1.2 Number of branches

The results presented in the Table-4.2, indicated that the number of branches at grand growth stage was significantly influenced by the foliar application of water soluble NPK (19:19:19) fertilizer.

Significantly less number of branches was in recommended dose of nitrogen through FYM only at 60 DAS and at harvest was 10.07 and 10.00 respectively over all other treatments. Whereas, 30 DAS there was no significant difference between treatments with respect to number of branches per plant. Application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage recorded significantly higher number of branches of 13.87 and 12.53 at 60 DAS and at harvest respectively over all other treatments. Next application RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher number of branches at 60 DAS and at harvest (12.73 and 11.07 respectively) and it was on par with RDF + foliar application of WSF @ 2 % at flowering stage.

4.1.3 Number of leaves

The data on number of leaves plant per plant of soybean at different growth stage were influenced by foliar application of water soluble NPK (19:19:19) fertilizer is presented in Table-4.3.

The number of leaves at 30 DAS was non-significant. Significantly higher number of leaves per plant at 60 DAS and at harvest (70.20 and 60.33 respectively) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all the treatments. Again RDF+ foliar application of WSF @ 2 % at pod filling stage recorded higher number of leaves per plant at 60 DAS (65.03) and harvest (55.33) and which was par with RDF + foliar application of WSF at 2 % at flowering stage.

Significantly lower numbers of leaves per plant were recorded at 60 DAS and harvest (61.40, 46.20 respectively) was with application of recommended dose of nitrogen through FYM only.

4.1.4 Leaf area

As per the data given in Table-4.4, indicated that leaf area at grand growth stages were significantly differed due to foliar application of water soluble NPK (19:19:19) fertilizer. Leaf area at 30 DAS in all treatments were found non significant and

significantly higher leaf area at 60 DAS and at harvest (1083.62 cm² and 847.53 cm² respectively) was recorded with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all the treatments. Next foliar application of WSF @ 2 % at pod filling stage recorded higher leaf area at 60 DAS and at harvest (947.68 cm² and 601.33 cm² respectively) and which was on par with foliar application of WSF @ 2 % at flowering stage.

Significantly lower leaf area was recorded with recommended dose of nitrogen through FYM only at 60 DAS and at harvest (806.03 cm² and 423.93 cm² respectively).

4.1.5 Leaf area index

The leaf area index was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer at different growth stage is presented in Table-4.5.

Leaf area index was significantly higher at 60 DAS (3.95) and at harvest (0.72) was with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all the treatments. Next higher leaf area index was recorded at 60 DAS (3.49) and at harvest (0.55) with application RDF + foliar application of WSF @ 2 % at pod filling stage and it was on par with RDF + foliar application of WSF @ 2 % at flowering stage at 60 DAS and at harvest.

Significantly lower leaf area index was recorded at 60 and at harvest (3.02 and 0.43 respectively) with application (recommended dose of nitrogen through FYM only).

4.1.6 Leaf area duration

Leaf area duration was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer at different growth stage of crop as indicate in Table-4.6.

Leaf area duration was significantly higher at 30-60 DAS and 60 DAS at harvest (53.10 and 96.80 respectively) with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all the treatments. Next higher leaf area duration

was recorded at 30-60 DAS and 60 DAS-at harvest was 45.65 and 70.45 respectively and which was on par with application of RDF + foliar application of WSF at 2 % at flowering stage.

Significantly lower leaf area duration was recorded at 30-60 DAS and 60 DAS at harvest (36.72 and 46.95 respectively) with recommended dose of nitrogen through FYM only.

4.1.7 Chlorophyll content (SPAD meter reading)

According to the result indicated in Table-4.7, there was significant difference in chlorophyll content (SPAD meter reading) due to treatment effects.

At 30 DAS there was no significant difference among the treatments. However significantly higher chlorophyll content (SPAD meter reading) of 20.02 was recorded at 60 DAS with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Again, foliar application of WSF @ 2 % at pod filling stage recorded higher chlorophyll content (SPAD meter reading) of 18.34 and which was on par with RDF + foliar application of WSF @ 2 % at flowering stage at 60 DAS soybean crop.

The significantly lower chlorophyll content (SPAD meter reading) was recorded in recommended dose of nitrogen through FYM only at 60 DAS was 13.22.

4.1.8 Number of nodules per plant

The data on numbers of nodule per plant of soybean was not significantly influence by foliar application of water soluble NPK (19:19:19) fertilizer and the data is presented in Table-4.8. However, relatively higher number of nodules were observed in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage (43.56 plant^{-1}) over all other treatments.

Lower numbers of nodules (42.10 plant^{-1}) per plant was observed with recommended dose of nitrogen through FYM only.

4.1.9 Dry weight of nodules per plant

The data on dry weight of nodules did not differ significantly due to foliar application of water soluble NPK (19:19:19) fertilizer is given in Table -4.8.

There was no significant difference among the treatments with respect to dry weight of nodules however higher nodule dry weight (1.33 g) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. The lower nodule dry weight (0.85 g) was recorded with recommended dose of nitrogen through FYM only.

4.1.10 Total dry weight of plant

As per the data shown in Table-4-8 Indicated that the total dry matter production at different stages were differed due to the application of water soluble NPK (19:19:19) fertilizer.

The significantly higher total dry weight of plant ($3654.36 \text{ kg ha}^{-1}$) of nodules was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. The next higher dry weight of plant ($3358.42 \text{ kg ha}^{-1}$) was observed with application of RDF + foliar application of WSF @ 2 % at pod filling stage and which was on par with foliar application of WSF at 2 % at flowering stage the total dry weight was ($3042.25 \text{ kg ha}^{-1}$).

Significantly lower total dry, weight of plant ($2333.33 \text{ kg ha}^{-1}$) was recorded in with recommended dose of nitrogen through FYM only.

Table 4.1: Plant height of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	Plant height 30 DAS (cm)	Plant height 60 DAS (cm)	Plant height at harvest (cm)
T ₁ - Recommended fertilizer dose (RDF)	14.00	34.13	38.47
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	14.09	34.27	39.67
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	14.67	35.00	41.80
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	14.03	39.87	44.13
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	14.23	42.43	47.60
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	14.93	46.53	50.20
T ₇ - Recommended dose of nitrogen through FYM only	13.98	33.23	35.13
S.Em±	0.46	1.24	0.77
CD. (p=0.05)	NS	3.82	2.37

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.2: Number of branches of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	30 DAS	60 DAS	at harvest
T ₁ - Recommended fertilizer dose (RDF)	4.60	10.53	10.27
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	4.53	11.53	10.40
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	4.63	11.87	10.67
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	4.67	11.90	11.00
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	4.93	12.73	11.07
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	5.07	13.87	12.53
T ₇ - Recommended dose of nitrogen through FYM only	4.40	10.07	10.00
S.Em±	NS	0.22	0.41
CD. (p=0.05)	0.49	0.68	1.26

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.3: Number of leaves of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	30 DAS	60 DAS	at harvest
T ₁ - Recommended fertilizer dose (RDF)	19.13	61.87	37.27
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	19.98	62.53	41.13
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	20.67	63.33	41.33
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	20.13	64.20	43.20
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	21.67	65.03	45.33
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	22.77	70.20	50.33
T ₇ - Recommended dose of nitrogen through FYM only	18.40	61.40	36.20
S.Em±	1.27	1.52	1.75
CD. (p=0.05)	NS	4.68	5.39

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.4: Leaf area of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	Leaf area (cm ²) at 30 DAS	Leaf area (cm ²) at 60 DAS	Leaf area (cm ²) at harvest
T ₁ - Recommended fertilizer dose (RDF)	432.93	879.22	515.60
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	437.97	897.20	560.80
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	442.20	914.60	564.60
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	454.43	920.90	598.43
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	465.23	947.68	601.33
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	478.43	1083.62	847.53
T ₇ - Recommended dose of nitrogen through FYM only	428.32	806.03	423.93
S.Em±	22.65	39.74	74.11
CD. (p=0.05)	NS	122.45	228.36

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.5: Leaf area index of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	30 DAS	60 DAS	At harvest
T ₁ - Recommended fertilizer dose (RDF)	1.72	3.26	0.44
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	1.87	3.32	0.46
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	1.88	3.38	0.47
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	1.99	3.40	0.51
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	2.00	3.49	0.55
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	2.10	3.95	0.72
T ₇ - Recommended dose of nitrogen through FYM only	1.59	3.02	0.43
S.Em±	0.25	0.13	0.08
CD. (p=0.05)	NS	0.41	0.24

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.6: Leaf area duration of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	LAD(cm²/day) 30-60 DAS	LAD 60 DAS at harvest (cm²/day)
T ₁ - Recommended fertilizer dose (RDF)	40.61	59.90
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	41.76	60.12
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	42.84	65.24
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	43.77	64.41
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	45.65	70.45
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	53.10	96.80
T ₇ - Recommended dose of nitrogen through FYM only	36.72	46.95
S.Em±	2.31	6.72
CD. (p=0.05)	7.13	20.69

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.7: Chlorophyll content (SPAD meter reading) of soybean at different growth stages as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	30 DAS	60 DAS
T ₁ - Recommended fertilizer dose (RDF)	26.27	13.58
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	26.52	14.12
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	26.67	15.50
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	27.23	15.29
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	26.66	18.34
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	30.09	20.02
T ₇ - Recommended dose of nitrogen through FYM only	25.74	13.22
S.Em±	1.04	0.48
CD. (p=0.05)	NS	1.47

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.8: Number of nodules per plant, Dry weight of nodules per plant and Total dry weight (at harvest) of soybean as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	No. of nodules plant ⁻¹	Dry weight of nodules(g) plant ⁻¹	Dry weight of plant (kg)ha ⁻¹
T ₁ - Recommended fertilizer dose (RDF)	42.98	0.99	2718.33
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	42.83	0.98	2611.11
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	43.07	1.00	2914.81
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	43.00	1.01	3042.25
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	43.19	1.04	3358.42
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	43.56	1.33	3654.26
T ₇ - Recommended dose of nitrogen through FYM only	42.10	0.85	2333.33
S.Em±	0.38	0.27	90.90
CD. (p=0.05)	NS	NS	280.10

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

4.2 Effect of foliar application of water soluble NPK (19:19:19) fertilizer on yield parameters

The data on days taken for 50 % flowering, number of pods per plant, seed weight per plant, 100 seed weight, seed yield, haulm yield harvest index influenced as foliar application of water soluble fertilizer are shown in table 4.9-4.10.

4.2.1 Days taken for 50 per cent flowering

The data on days taken for 50 per cent flowering as influenced by foliar application of water soluble NPK (19:19:19) fertilizer is presented in Table 4.9.

Among the different treatments days taken for 50 per cent flowering was more (40.33 days) with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next application of RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher (38.98) days taken for 50 per cent flowering and which was on par with application of RDF + foliar application of WSF @ 2 % at flowering stage.

Significantly fewer days (36.33) were taken for 50 per cent flowering in treatment where RDN 50 per cent nitrogen as basal and 50 per cent nitrogen as top dressing.

4.2.2 Number of pods per plant

According to the results given in Table-4.9 indicated that number of pods per plant was varied significantly due to the foliar application of water soluble NPK (19:19:19) fertilizer. Significantly higher number of pods per plants was recorded (86.18) with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. The next RDF + foliar application of WSF @ 2 % at pod filling stage recorded more number of pods per plant (71.31) and which was on par with RDF + foliar application of WSF 2 % at flowering stage.

Lowest number of pods (57.87) per plant was recorded in treatment with recommended dose of nitrogen through FYM only.

4.2.3 Seed weight per plant

The data pertaining to seed weight (Table-4.9) per plant revealed that it was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer.

Significantly higher seed weight per plant (17.55 gm) was recorded in application RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher seed weight per plant (15.03 g) and which was on par with foliar application of WSF @ 2 % at flowering stage.

The significantly lower seed weight per plant (12.42 g) was recorded in the treatment with recommended dose of nitrogen through FYM only.

4.2.4 100 seed weight

The 100 seeds weight was significantly influence by foliar application of water soluble NPK (19:19:19) fertilizer and the data is given in Table-4.9.

Among the all treatments, significantly higher 100 seed weight (14.53 g) was recorded in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next application of RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher 100 seed weight (13.63 g) and which was on par with RDF + foliar application of WSF @ 2 % at flowering (13.53 g).

Significantly lower 100 seeds weight (12.63 g) was recorded with recommended dose of nitrogen through FYM only.

4.2.5 Seed yield

The results presented in Table-4.10 indicated that the seed yield was significantly differed due to foliar application of water soluble NPK (19:19:19) fertilizer.

Significantly higher seed yield is recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage (2283.89 kg ha⁻¹) over all

other treatments. Next application of RDF + foliar application of WSF @ 2 % at pod filling stage ($2006.56 \text{ kg ha}^{-1}$) and which was on par with application RDF + foliar application of WSF @ 2 % at flowering stage was $1782.99 \text{ kg ha}^{-1}$.

The significantly lower seed yield of soybean was recorded with recommended dose of nitrogen through FYM only ($1296.30 \text{ kg ha}^{-1}$).

4.2.6 Haulm yield

As per the data given in Table-4.10 indicated that different treatments differed significantly due to foliar application of water soluble fertilizers NPK (19:19:19).

Significantly lower haulm yield ($1129.63 \text{ kg ha}^{-1}$) was recorded with recommended dose of nitrogen supply through FYM only over all other treatments. Whereas significantly higher haulm yield ($1611.11 \text{ kg ha}^{-1}$) was recorded in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. The next application of RDF + foliar WSF @ 2 % at pod filling stage given higher haulm yield ($1481.48 \text{ kg ha}^{-1}$) and was on par with foliar application of WSF @ 2 % at flowering stage ($1388.89 \text{ kg ha}^{-1}$).

4.2.7 Harvest index

The data on harvest index was differed significantly due foliar application of water soluble NPK (19:19:19) fertilizers and values are given in Table-4.10

Significantly higher harvest index (0.59) was recorded in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments and significantly lower harvest index was observed (0.43) in recommended dose of nitrogen through FYM only. RDF + foliar application of WSF @ 2 % at pod filling stage recorded more harvest index (0.55) and which was on par with RDF + foliar application of WSF @ 2 % at flowering stage (0.50).

Table 4.9: Days taken for 50 per cent flowering, number of pods per plant, seed weight per plant and 100 seed weight as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	Days taken for 50% flowering	No. of Pods plant ⁻¹	Seed weight (g) plant ⁻¹	100 seed weight (g)
T ₁ - Recommended fertilizer dose (RDF)	37.33	63.93	14.80	13.03
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	36.33	64.27	13.03	13.37
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	36.67	64.67	14.63	13.60
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	38.78	69.13	13.33	13.53
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	38.98	71.31	15.03	13.63
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	40.33	86.18	17.55	14.53
T ₇ - Recommended dose of nitrogen through FYM only	35.67	57.87	12.42	12.63
S.Em±	0.33	3.87	0.92	0.29
CD. (p=0.05)	1.00	11.92	2.84	0.88

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.10: Seed yield (kg ha⁻¹), haulm yield (kg ha⁻¹) and harvest index of soybean as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	HI
T ₁ - Recommended fertilizer dose (RDF)	1533	1185	0.51
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	1518	1166	0.49
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	1637	1370	0.44
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	1782	1388	0.50
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	2006	1481	0.55
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	2283	1611	0.59
T ₇ - Recommended dose of nitrogen through FYM only	1296	1129	0.43
S.Em±	44.74	94.73	0.02
CD. (p=0.05)	137.87	291.89	0.05

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

4.3 Effect of foliar application of water soluble NPK (19:19:19) fertilizer on quality parameter

4.3.1 Crude protein content and yield

The crude protein content of soybean was not significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and which is presented in Table 4.11.

The higher crude protein content (37.29 %) and crude protein yield (8.52 t ha⁻¹) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage when compared to all the treatment and comparatively lower crude protein content (35.00 %), crude protein yield (4.54 t ha⁻¹) was recorded in recommended dose of nitrogen through FYM only.

4.4 Effect of foliar application of water soluble NPK (19:19:19) fertilizer on nutrient concentration of soybean crop

The data on the NPK concentration at harvest was given in Table- 4.12.

The concentration of nitrogen, phosphorus and potassium at harvest did not differ significantly among different treatments. However, higher concentration of nitrogen, phosphorus and potassium were recorded due to application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. Next RDF + foliar application of WSF @ 2 % at pod filling stage and application of RDF + foliar application of WSF @ 2 % at flowering stage recorded more nutrient concentration.

The Less nitrogen, phosphorus and potassium concentration were recorded with recommended dose of nitrogen through FYM only.

4.5.1 Nitrogen uptake by soybean

The uptake of nitrogen was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and the results are presented in Table-4.13.

Table 4.11: Protein content and protein yield of soybean as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	Protein (%)	Protein yield (t ha ⁻¹)
T ₁ - Recommended fertilizer dose (RDF)	35.33	5.46
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	35.92	5.45
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	36.17	5.92
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	36.71	6.55
T ₅ -RDF + foliar application of WSF @ 2 at % pod filling stage	37.05	7.43
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	37.29	8.52
T ₇ - Recommended dose of nitrogen through FYM only	35.00	4.54
S.Em±	0.74	0.31
CD. (p=0.05)	NS	0.89

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.12: NPK concentration (%) in plant of soybean at harvest as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	N %	P %	K %
T ₁ - Recommended fertilizer dose (RDF)	2.82	0.34	2.53
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	2.89	0.37	2.55
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	2.93	0.34	2.50
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	2.96	0.38	2.56
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	2.98	0.41	2.61
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	3.11	0.43	2.76
T ₇ - Recommended dose of nitrogen through FYM only	2.80	0.33	2.29
S.Em±	0.13	0.02	0.14
CD. (p=0.05)	NS	NS	NS

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

The significantly higher nitrogen uptake ($121.13 \text{ kg ha}^{-1}$) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Again, application of RDF + foliar application of WSF @ 2 % at pod filling stage recorded more nitrogen uptake ($103.94 \text{ kg ha}^{-1}$) and which was on par with of RDF + foliar application of WSF @ 2 % at flowering stage (93.88 kg ha^{-1}).

The significantly lower nitrogen uptake was recorded with recommended dose of nitrogen through FYM only.

4.5.2 Phosphorus uptake by soybean

The uptake of phosphorus by soybean was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and the results are presented in Table 4.13.

The significantly higher phosphorus uptake (16.74 kg ha^{-1}) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next RDF + foliar application of WSF @ 2 % at pod filling stage resulted in more phosphorus uptake (14.30 kg ha^{-1}) and which was on par with application of RDF + foliar application of WSF at 2 % at flowering stage (12.05 kg ha^{-1}).

The significantly lower phosphorus uptake (8.00 kg ha^{-1}) was recorded with recommended dose of nitrogen through FYM only.

4.5.3 Potassium uptake by soybean

The uptake of potassium by soybean crop was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and the data was given in Table 4.13.

Significantly higher potassium uptake ($107.50 \text{ kg ha}^{-1}$) was recorded in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next treatment T₅ (RDF + foliar application of WSF @ 2 % at pod filling stage) recorded higher potassium uptake of (91.03 kg ha^{-1}) and which was on

par with application of RDF + foliar application of WSF @ 2 % at flowering stage (81.20 kg ha⁻¹).

The significantly lower potassium uptake by soybean was recorded with recommended dose of nitrogen through FYM only was 53.18 kg ha⁻¹.

4.6 Available NPK in soil after harvest of crop

4.6.1 Available nitrogen in soil after harvest of crop

The available nitrogen in soil after harvesting crop was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and data is presented in Table-4.14.

Significantly higher nitrogen in soil (191.92 kg ha⁻¹) was recorded with recommended dose of nitrogen through FYM only over all other treatments. Whereas, significantly lower (112.27 kg ha⁻¹) value was recorded with application of RDF+ foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments.

4.6.2 Available phosphorus in soil after harvest of crop

The available phosphorus in soil after harvesting crop was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and results are presented in Table 4.14.

The significantly lower phosphorus (27.94 kg ha⁻¹) was recorded with application of application RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Whereas significantly higher phosphorus (35.94kg ha⁻¹) with recommend nitrogen through FYM only.

4.6.3 Available potassium in soil after harvest of crop

The available potassium in soil after harvesting crop was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer and data is presented in Table-4.14.

The significantly higher potassium was recorded ($355.67 \text{ kg ha}^{-1}$) after harvest of soybean was in of (Recommended dose of nitrogen through FYM only). Application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage resulted in significantly lower potassium (217.44 kg).

4.7 Effect of foliar application of water soluble NPK (19:19:19) fertilizer on economics of soybean cultivation

RDF + foliar application of WSF @ 2 % at flowering + pod filling stage given higher gross returns, net returns and B:C ratio when compared to all other treatments and lower gross return, net return and B:C ratio was recorded with recommended dose of nitrogen through FYM only (Table 4-15).

Table 4.13: NPK uptake of soybean as influenced by foliar application of water soluble fertilizer NPK (19:19:19) fertilizer

Treatments	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)
T ₁ - Recommended fertilizer dose (RDF)	76.67	9.24	68.78
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	77.60	9.93	66.47
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	88.11	10.22	75.18
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	93.88	12.05	81.20
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	103.94	14.30	91.03
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	121.13	16.74	107.50
T ₇ - Recommended dose of nitrogen through FYM only	67.92	8.00	55.55
S.Em±	5.56	0.64	5.23
CD. (p=0.05)	16.12	1.98	16.13

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.14: NPK present in soil (kg ha^{-1}) after harvest of soybean as influenced by foliar application of water soluble NPK (19:19:19) fertilizer

Treatments	N (kg ha^{-1})	P ₂ O ₅ (kg ha^{-1})	K ₂ O (kg ha^{-1})
T ₁ - Recommended fertilizer dose (RDF)	142.94	34.42	316.31
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	137.93	33.97	298.87
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	134.89	33.53	254.65
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	127.44	32.01	230.83
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	120.00	29.83	223.67
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	112.027	27.94	217.44
T ₇ - Recommended dose of nitrogen through FYM only	191.92	35.94	355.67
S.Em±	6.21	22.33	16.19
CD. (p=0.05)	19.12	17.82	49.90

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

Table 4.15: Economics of soybean as influenced by foliar application of water soluble (NPK) fertilizer

Treatment	Yield ha ⁻¹ (kg)	Price kg ⁻¹ (₹)	Gross income (₹) ha ⁻¹	Total cost (₹) ha ⁻¹	Net income (₹) ha ⁻¹	B:C ratio
T ₁ - Recommended fertilizer dose (RDF)	1533	35	53660	26075	27585	2.05
T ₂ - RDF (50 % N as basal and 50 % N as top dressing)	1518	35	53148	26075	27073	2.03
T ₃ - RDF + foliar application of WSF @ 2 % at 8-12 leaf stage	1637	35	57296	27743	29553	2.06
T ₄ - RDF + foliar application of WSF @ 2 % at flowering stage	1782	35	62405	27743	34662	2.24
T ₅ -RDF + foliar application of WSF @ 2 % at pod filling stage	2006	35	70230	27743	42487	2.53
T ₆ - RDF + foliar application of WSF @ 2 % at flowering + pod filling stage	2283	35	79936	29410	50526	2.71
T ₇ -Recommended dose of nitrogen through FYM only	1296	35	45370	29547	15823	1.53

RDF- Recommended dose of fertilizer

WSF- Water soluble fertilizer

V DISCUSSION

The results of the field experiment conducted during summer 2017 at Zonal Agricultural Research Station, UAS, GKVK, Bengaluru to study the **Effect of foliar application of water soluble fertilizers on growth, yield and quality of soybean [*Glycine max* (L.) Merrill]** are discussed in this chapter.

5.1 Influence of weather on crop performance

Environment plays a key role in growth of plants. Hence crop growth, development and yield are affected by fluctuation in weather condition. The fluctuation in yield is primarily a result of variable weather conditions that prevail in an agro climatic situation apart from soil fertility status. In this context, the weather conditions prevailed during the period of experimentation would definitely have a direct bearing on the potentiality of any crop in general and soybean corn in particular.

The meteorological data (Table 3.2 and Fig. 3.1) revealed that during the experimental period, the total rainfall received was 356.80 mm and that was 0.6 mm more than the average normal rainfall (356.02 mm) for past 40 years (1972-2012). Total rainfall of 356.8 mm was recorded during the period of experimentation (Jan to July, 2017). The soybean crop was grown as irrigated crop and whenever rainfall was received irrigation was not given and rest of the days regular intervals irrigation was given based on the crop requirement. The mean maximum temperature recorded during experimentation was in the range from 35.1° C (April 2017) to 27.3° C (January 2017), while minimum temperature ranged from 14.5° C (January 2017) to 21.9° C (April 2017) and relative humidity ranged from 36.0 per cent (April 2017) to 5.0 per cent (July 2017). Temperature and relative humidity during the period of experimentation were conducive for the better growth and development of soybean. The crop did not experience abiotic and biotic stress during the growth stage of soybean.

5.2 Effect of water soluble fertilizers on growth parameters of soybean

The height of plants significantly differed among the treatments at different stage of crop growth. Application of RDF + foliar application of WSF @ 2 % at flowering +

pod filling stage has recorded significantly taller plant over all other treatments at 30, 60 DAS and at harvest. The next best treatment was RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher plant height and which was on par with RDF + foliar application of WSF @ 2 % at flowering stage at all the stages of crop growth.

The significantly lowest height was recorded at 60 DAS and at harvests with recommended dose of nitrogen through FYM only at all the stages of crop (Table 4.1 and Fig.5.1).

The increase in plant height might be due to application of nutrients at later stages which increased the availability of nutrients for plant growth and development and better utilization of applied major nutrients in addition to biological nitrogen fixation. The results are in agreement with findings of Amany (2007) that foliar application of 1 per cent urea on growth of chick pea at pod filling stage resulted in higher plant height. Phosphorus has positive significant interaction with nitrogen absorption and plant growth (Sumner and Farina, 1986).

Significantly less number of branches were with recommended dose of nitrogen supply through FYM only at 60 DAS and at harvest of the crop whereas significantly higher number of branches were recorded in RDF + foliar application of WSF @ 2 % at flowering + pods filling stages at 60 DAS and at harvest (5.57, 13.87 and 12.53 respectively) over all other treatments. At 30 DAS there was no significant difference among the treatments. Next higher number of branches was recorded with RDF + foliar application of WSF @ 2 % at pod filling stage at 60 DAS and at harvest (4.93, 12.73 and 11.07 respectively) and it was on par with RDF + foliar application of WSF @ 2 % at flowering stage given in Table-4.2 and Fig.5.2. More number of branches was due to improved growth of morphological character like plant height resulted in more number of pods per plant leading to more number of branches. The results are in confirmation with the findings of Amany (2007) and (Krishnaveni, 2004).

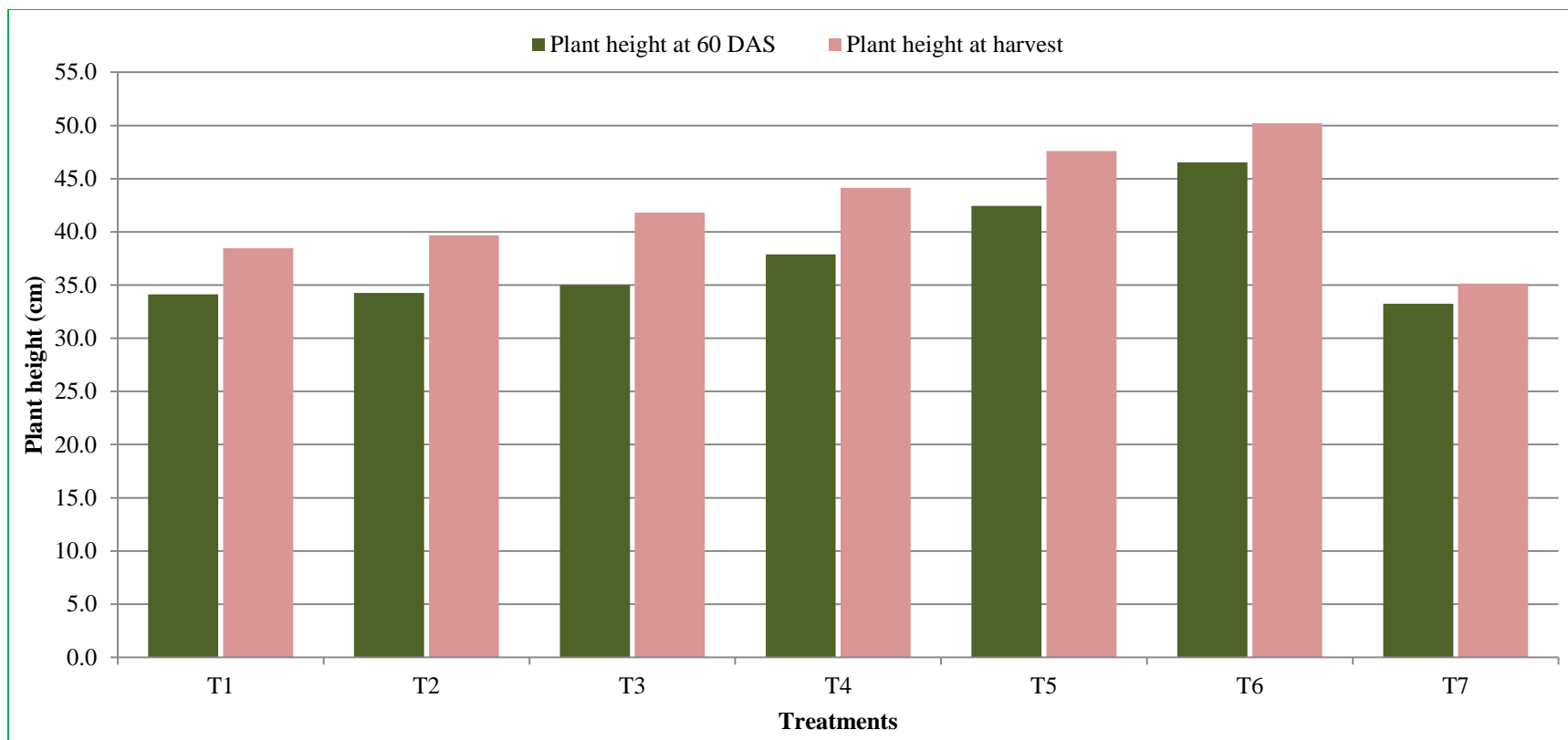


Fig. 5.1: Plant height of soybean as influenced by foliar application of water soluble fertilizer at different growth stages

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

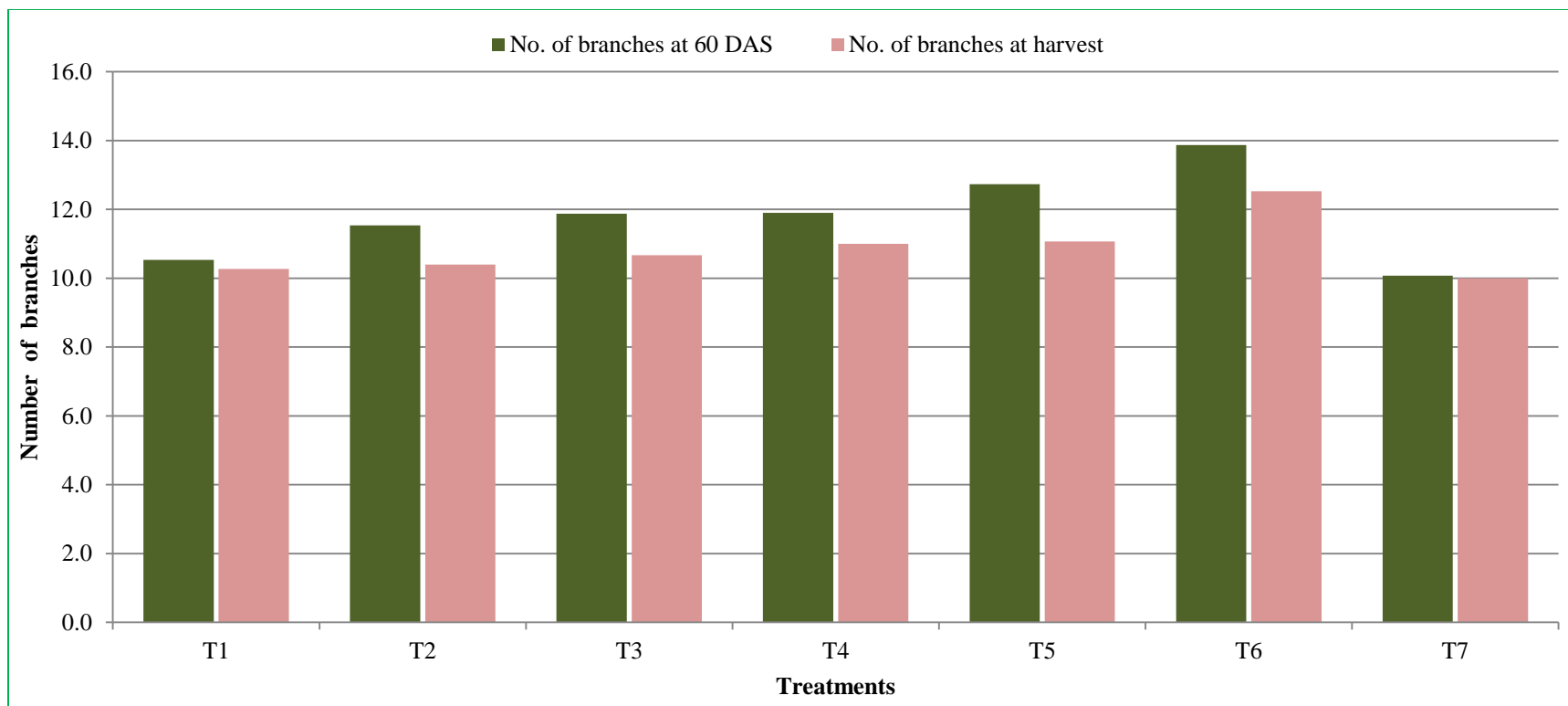


Fig. 5.2: Number of branches of soybean as influenced by foliar application of water soluble fertilizer at different growth stages

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

The data on number of leaves per plant of soybean at different growth stage as influenced by foliar application of water soluble NPK (19:19:19) fertilizer was presented in Table-4.3 and Fig.5.3.

At 30 DAS there was no significant difference among different treatment with respect to number of leaves per plant. Significantly higher number of leaves at 60 DAS and harvest were recorded in RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. Next higher number of leaves was recorded in foliar application of WSF 2 % at pod filling stage at 60 DAS and at harvest. Significantly lower numbers of leaves were recorded with recommended dose of nitrogen through FYM only at 60 DAS and at harvest.

The higher number of leaves with RDF + foliar application of WSF at 2 % at flowering + pod filling stage due to improved growth of morphological characters like plant height and number of branches led to more of leaves additional nitrogen from foliar fertilizer application influenced vegetative growth in plant and reduced fertilizer loss resulted in higher number of leaves per plant. The results are in corroborate with the results of Garud (2012).

The leaf area was significantly differed due to foliar application of water soluble NPK(19:19:19) fertilizer at different growth stages. Leaf area at 30 DAS in all treatments were found non-significant and significantly higher leaf area at 60 DAS and harvest were recorded in RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Next foliar application of WSF @ 2 % pod filling stage was recorded higher leaf area at 60 DAS and at harvest which was on par with foliar application of WSF @ 2 % at flowering stage.

The lower leaf area recorded in recommended dose of nitrogen through FYM only at 60 DAS and at harvest (Table-4.4 and Fig.5.4).

The leaf area index (LAI) was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer at different growth stages were given in the Table- 4.5).

Leaf area index was significantly higher in RDF + foliar application of WSF @ 2 % at flowering + pod filling stage at 60 DAS and at harvest over all other treatments. Next higher leaf area index was recorded with application of RDF + foliar application of WSF @ 2 % at pod filling stage at 60 DAS and at harvest which was on par with RDF + foliar application of WSF @ 2 % at flowering stage at 60 DAS and at harvest.

Significantly lower leaf area index was recorded at 60 DAS and at harvest was with recommended dose of nitrogen through FYM only.

Leaf area duration was significantly influenced by foliar application of water soluble NPK (19:19:19) fertilizer at different growth stages of crop.

Leaf area duration was significantly higher at 30-60 and 60-at harvest with application of RDF + foliar application of WSF at 2 % at flowering + pod filling stage over all other treatments. Next higher leaf area duration was recorded in RDF + foliar application of WSF @ 2 % at pod filling stage at 30-60 and 60-at harvest and which was on par with RDF + foliar application of WSF @ 2 % at flowering stage.

The significantly less leaf area duration was recorded in recommended dose of nitrogen through FYM only at 30-60 and 60-at harvest (Table 4.6 and Fig.5.5).

Leaf area index was directly attributed to the higher leaf area. The formation of optimum photosynthetic stage for longer period was essential for increasing yield which was met through the foliar nutrients applied to the soybean crop. On the other side, improved photosynthetic capacity was influenced by the foliar fertilization of major nutrients *viz.*, N, P and K (Watson, 1952). The synergistic effect of macro nutrient help in rapid growth and development of plants as they help in photosynthesis and various biochemical processes which responds towards growth (Jasim Iqbal, 2016).

Significantly higher leaf area duration with the application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage was mainly due to enhanced nutrient availability made plants to stay green for longer duration when foliar nutrition

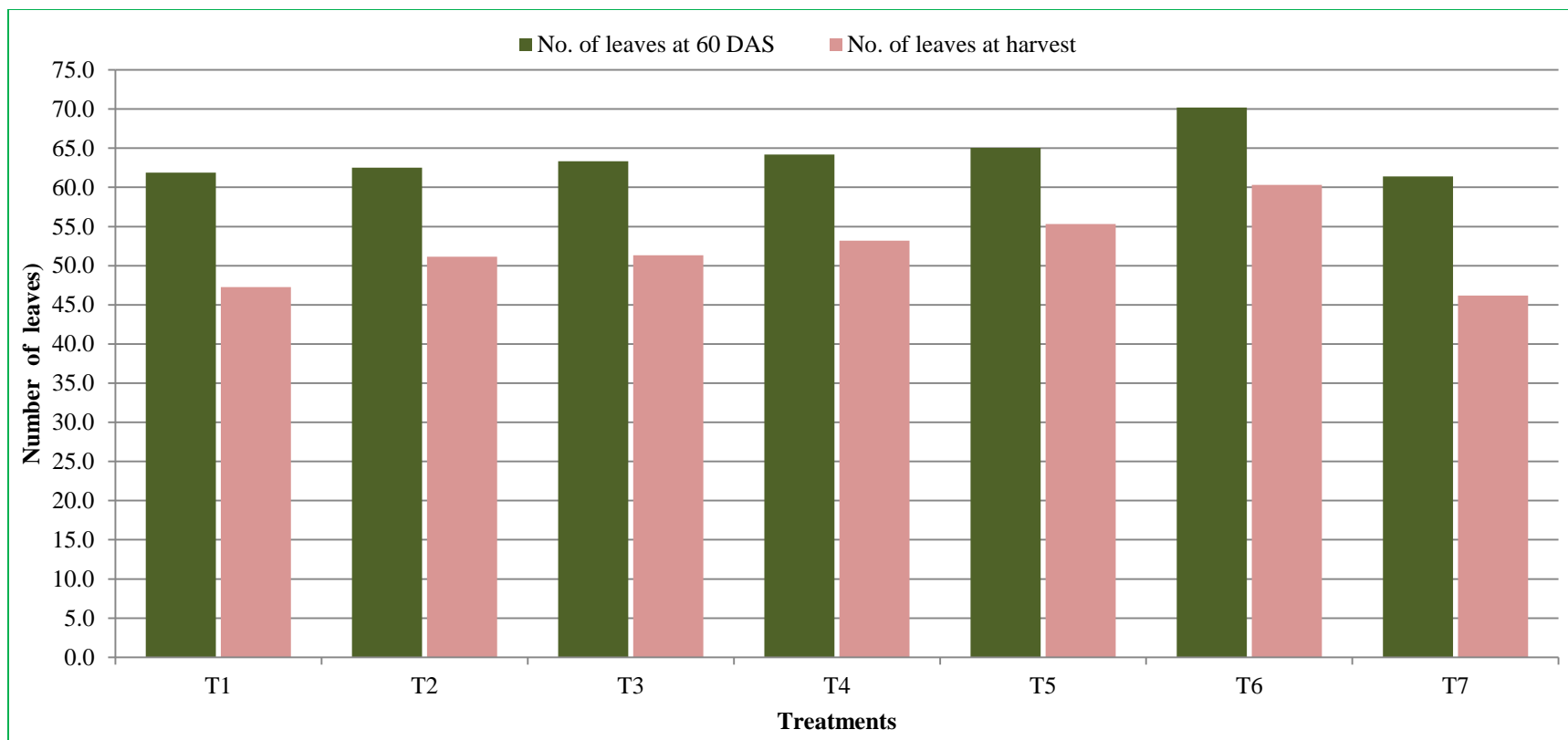


Fig. 5.3: Number of leaves of soybean as influenced by foliar application of water soluble fertilizer at different growth stages

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

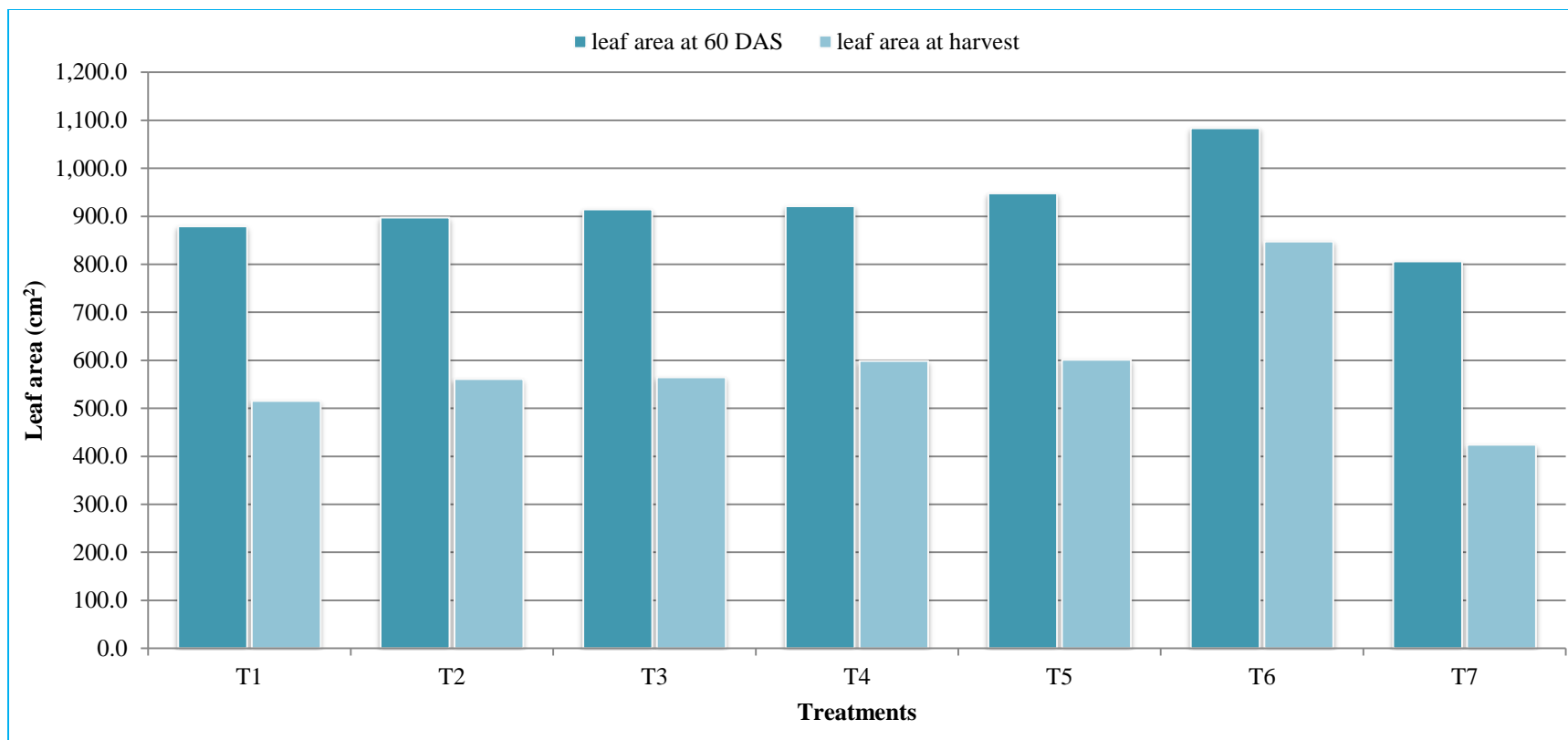


Fig. 5.4: Leaf area of soybean as influenced by foliar application of water soluble fertilizer at different growth stages

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

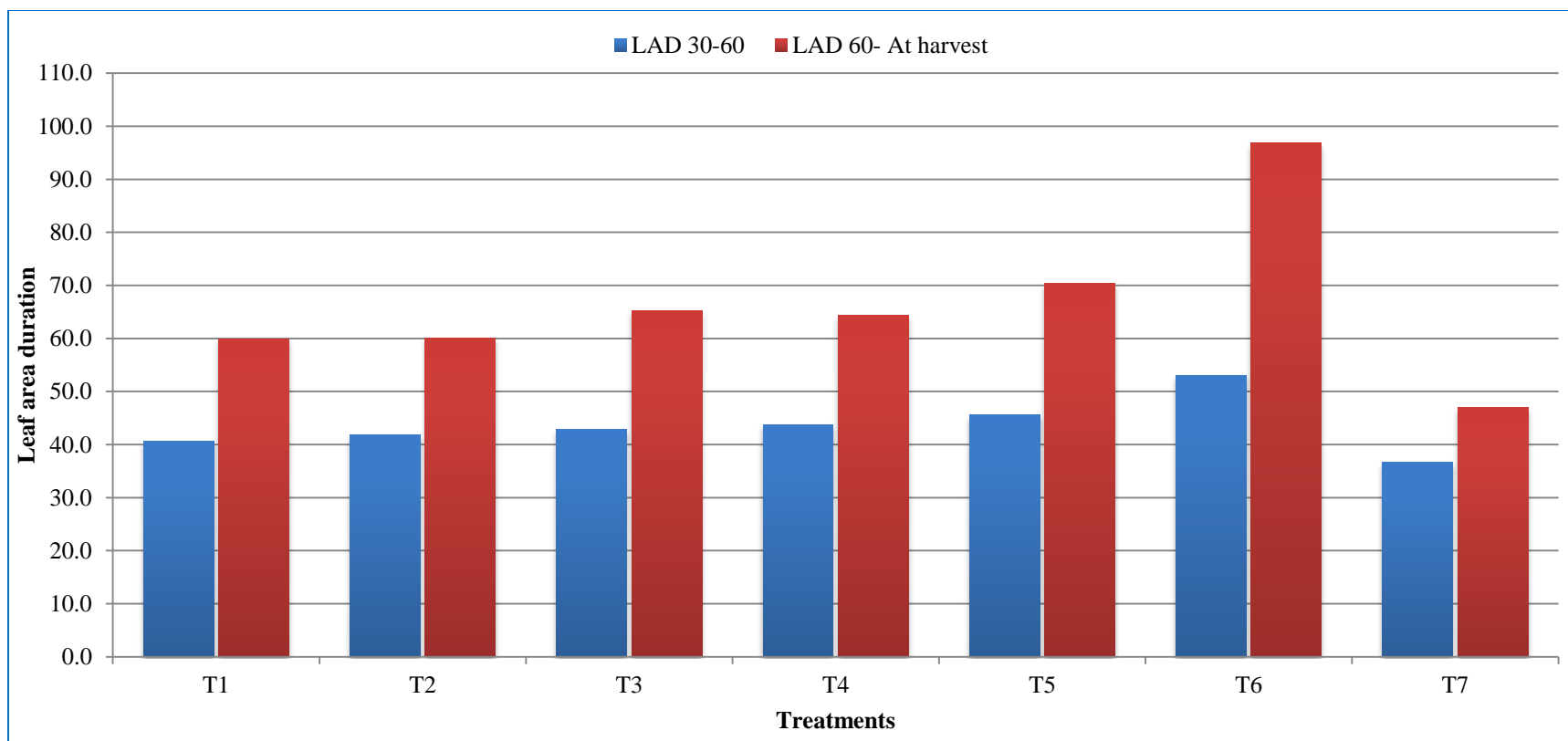


Fig. 5.5: Leaf area duration of soybean as influenced by foliar application of water soluble fertilizer at different growth stages

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

supplied twice at flowering and pod filling when compared to single application either at flowering or pod filling stage.

Chlorophyll content (SPAD meter reading) at all the stages of observation varied significantly among the treatment due to foliar application of water soluble NPK (19:19:19) fertilizer presented in (Table-4.7 and Fig.5.6).

Significantly higher chlorophyll content (SPAD meter reading) was recorded at 60 DAS with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Again foliar application of WSF @ 2 % at pod filling stage recorded higher chlorophyll content (SPAD meter reading) at 60 DAS which was on par with RDF + foliar application of WSF @ 2 % at flowering stage at 60 DAS.

The significantly lower chlorophyll content (SPAD meter reading) was observed in recommended dose of nitrogen through FYM only.

The higher chlorophyll content (SPAD meter reading) of the leaf is due to steady supply and better utilization of nitrogen applied through soil and foliar. Foliar application of nitrogen at flowering and pod filling stage along with RDF resulted in maximum photosynthesis due to more availability of nitrogen in turn enhancing the photosynthetic activity of leaf. The results are in line with work carried out by Senthil Kumar *et al.* (2008).

The significantly higher total dry weight of soybean was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. The next best treatment was application of RDF + foliar application of WSF @ 2 % at pod filling stage and which was on par with foliar application of WSF @ 2 % at flowering stage.

Significantly lower total dry weight was recorded in recommended dose of nitrogen through FYM only (Table-4-8 & Fig.5.7).

Increased dry matter production is due to balanced proportion of macro nutrients in the foliar fertilization which resulted in better crop growth and photosynthetic activity which has lead to better supply of photosynthates ultimately resulted in higher dry matter production per plant. Potassium foliar nutrition helped in osmotic regulation and increased metabolic activity of plants. Additional nitrogen from foliar nutrition influences vegetative growth in plant and reduced fertilizer loss resulted in higher dry matter production per plant. The results are in confirmation with the findings of Parasuraman *et al.* (2008), Thavaprakash *et al.* (2006) and AbdouEl-Nour (2002). Again stimulated photosynthetic activity and synthesis of chloroplast and protein which might have resulted in higher dry matter production as reported in soybean crop and the results are in line with Mishra and Agrawal (1984) as given in Table-4.12.

The data on number of nodules per plant of soybean was not significantly influenced by foliar application of water soluble fertilizers NPK (19:19:19) presented in (Table-4.8).

However, higher number of nodules was recorded with application of RDF + foliar application of WSF@ 2 % at flowering + pod filling stage.

Comparatively less number of nodules per plant was recorded with recommended dose of nitrogen through FYM only.

The dry weight of nodules did not differ among different treatments. Higher dry weight of root nodules is recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. Next application of RDF + foliar application of WSF @ 2 % at pod filling stage and RDF + foliar application of WSF @ 2 % at flowering stage.

The lower dry weight of root nodules is recorded with recommended dose of nitrogen through FYM only.

Foliar applied nitrogen does not have any positive effect on number and dry weight of nodules (Table-4.8).

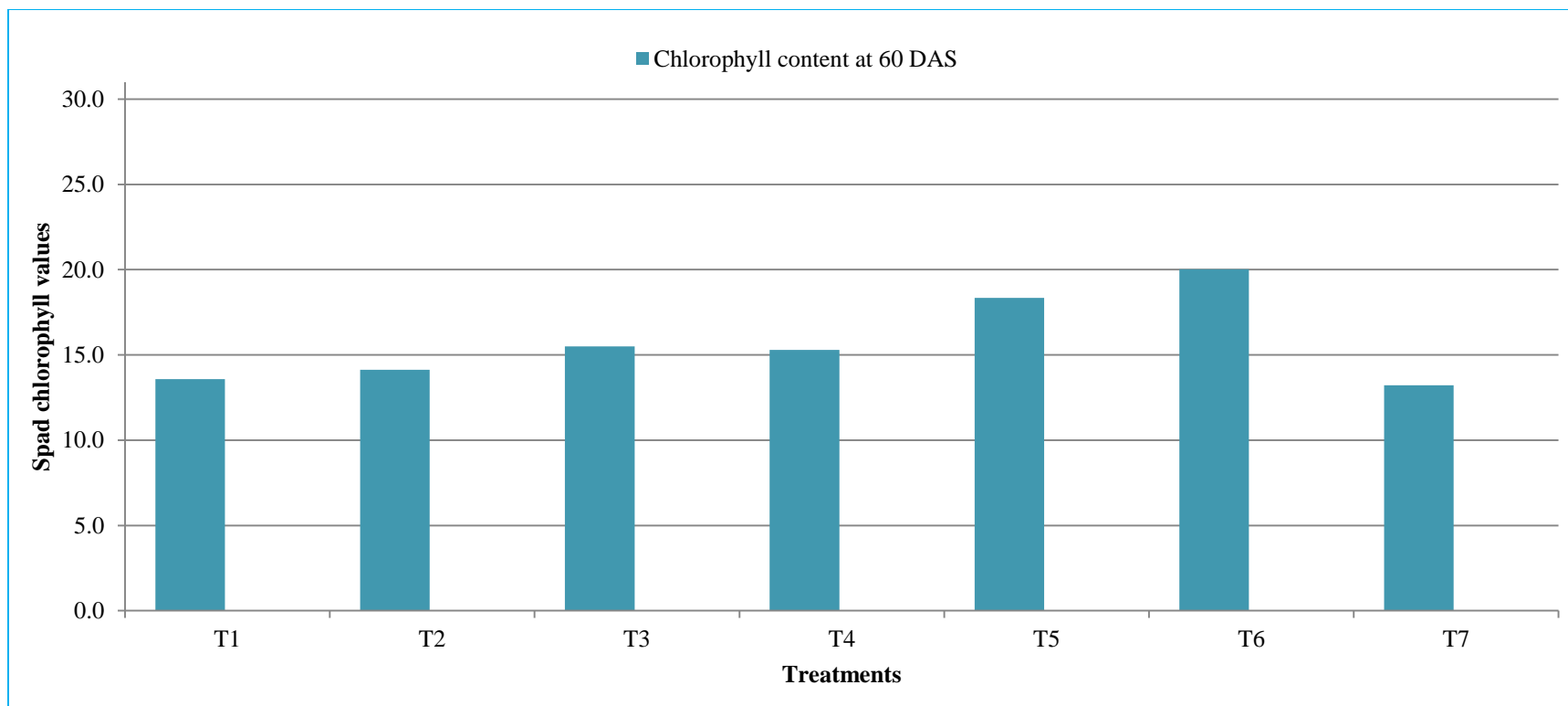


Fig. 5.6: Chlorophyll content (SPADE meter reading) of soybean as influenced by foliar application of water soluble fertilizer at different growth stages

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

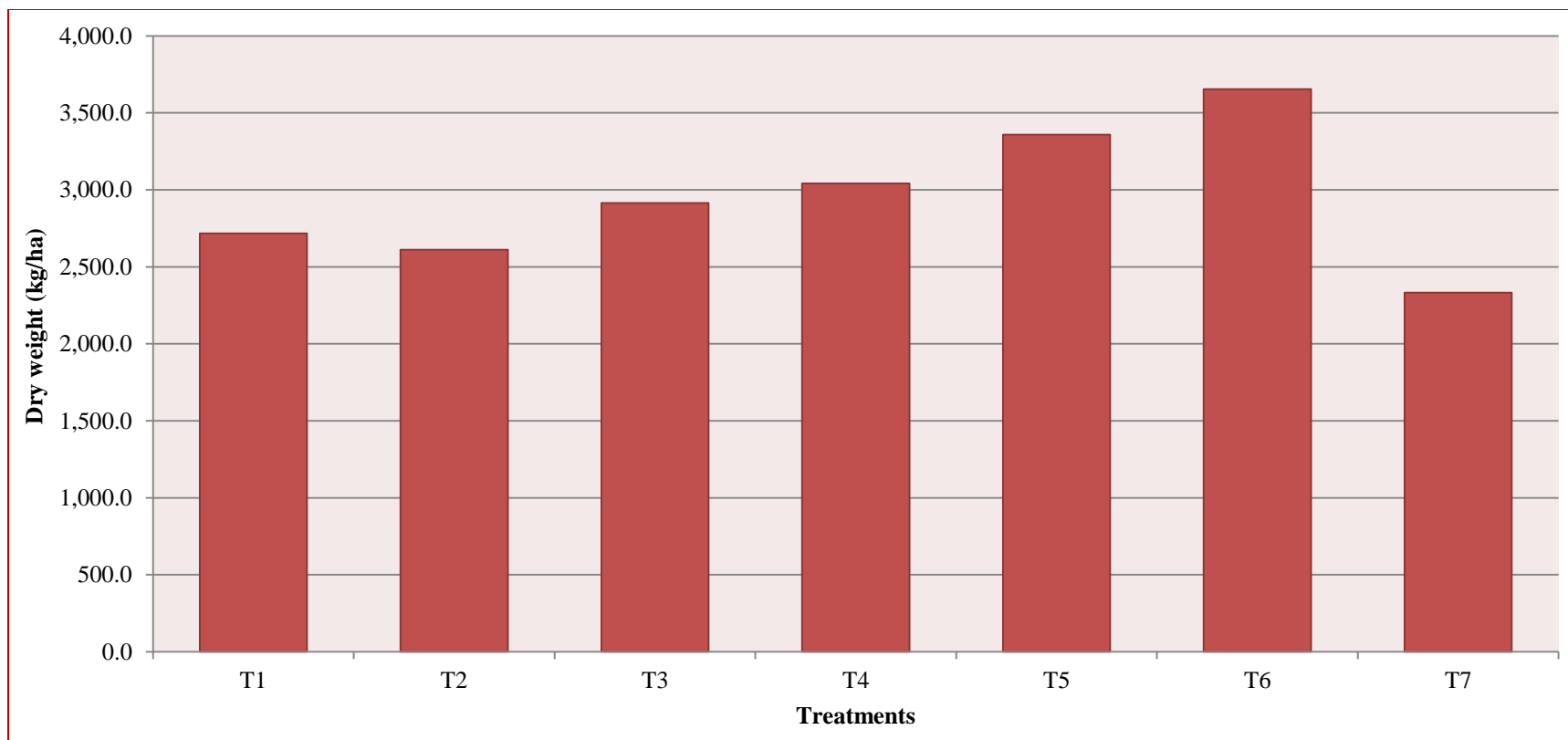


Fig. 5.7: Dry weight of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

5.3 Effect of water soluble NPK (19:19:19) fertilizer on yield and yield attributing parameters of soybean

Among the different treatments, days taken for 50 per cent flowering was more in RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatment. Next application of RDF + foliar application of WSF @ 2 % at 8-12 leaf stage).

Significantly less days (36.33) were taken for 50 per cent flowering in recommended dose of nitrogen through FYM only (Table-4.9 & Fig.5.8).

The number of pods per plant was varied significantly due to the foliar application of water soluble NPK (19:19:19) fertilizer. Significantly higher numbers of pods per plants were recorded with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. The next application of RDF + foliar application of WSF @ 2 % pod filling stage recorded higher number of pods per plant and which was on par with RDF + foliar application of WSF at 2 % at flowering stage.

Lowest number of pods per plant was recorded in recommended dose of nitrogen supply through FYM only (Table-4.9 & Fig.5.9).

The improvement in number of pods per plant was due to additive effect of macro nutrients and the results obtained are in confirmative with the findings of Roopashree (2013), Thakare *et al.* (2006), Ghosh and Joseph (2008) and Jyothi *et al.* (2013).

The 100 seeds weight was significantly influenced by foliar application of water soluble NPK(19:19:19) fertilizer at different growth stages and values are given in Table-4.9.

Among all the treatments, the significantly higher 100 seed weight was recorded in RDF + foliar application of WSF @ 2 % at flowering + pod filling stage and significantly lower 100 seeds weight was recorded in recommended dose of nitrogen through FYM only. Next best treatment was application of RDF + foliar application of

WSF @ 2 % at pod filling stage and which is on par with RDF + foliar application of WSF @ 2 % at flowering stage.

The data pertaining to seed weight per plant revealed that foliar application of water soluble NPK (19:19:19) fertilizers influenced significantly.

Significantly higher seed weight was recorded in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. Next RDF + foliar application of WSF @ 2 % at pod filling stage recorded higher seed weight and which was on par with foliar application of WSF @ 2 % at flowering stage.

The significantly lower seed weight was recorded in recommended dose of nitrogen through FYM only. The results presented in (Table 4.9 & Fig.5.10).

Significantly higher seed yield ($2283.89 \text{ kg ha}^{-1}$) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatment. Next best was with application of RDF + foliar application of WSF @ 2 % at pod filling stage recorded seed yield of $2006.56 \text{ kg ha}^{-1}$ and which was on par with ($1782.99 \text{ kg ha}^{-1}$) application of RDF + foliar application of WSF @ 2 % at flowering stage.

The significantly lower seed yield of soybean was recorded with recommended dose of nitrogen through FYM only ($1296.30 \text{ kg ha}^{-1}$).

The increased yield was in application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage significantly increased plant height, number of branches, number of leaves and total dry weight than single spray either at flowering and pod filling stage. The higher growth parameters helped to put forth significantly higher yield attributing characters like number of pods per plant higher seed weight per plant and 100 grain weight were finally led to increased soybean yield. The increased yield attributes with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage.

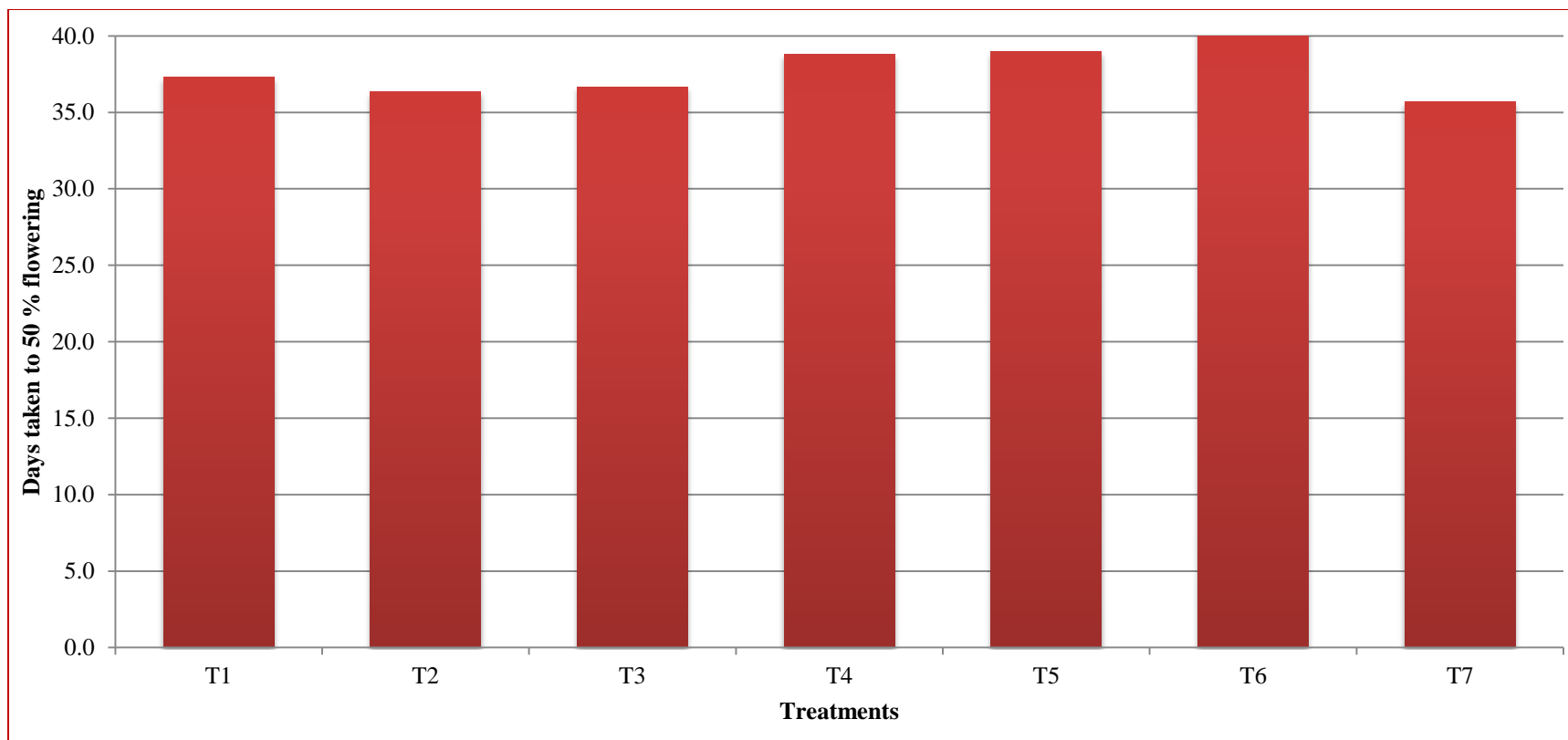


Fig. 5.8: Days taken 50% flowering of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

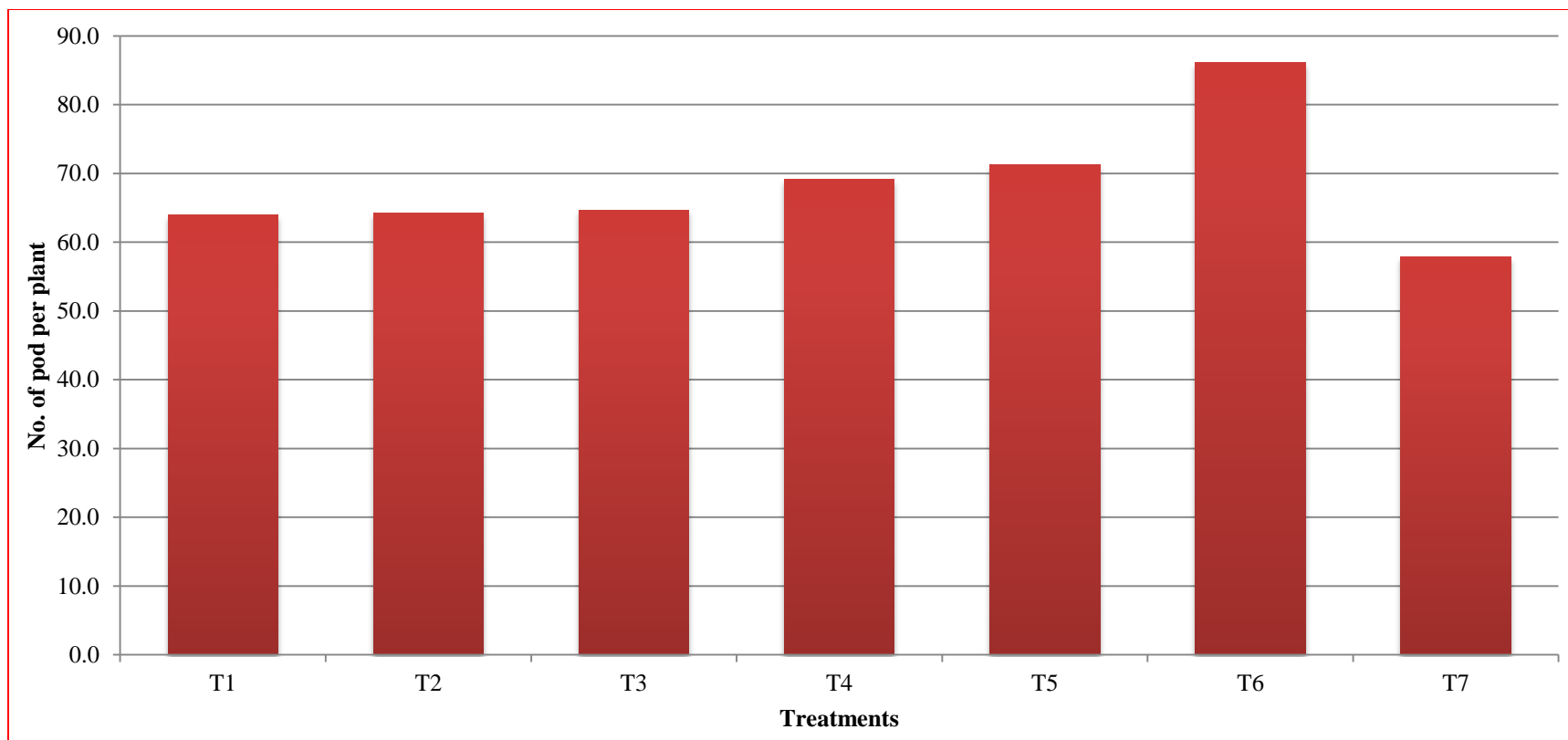


Fig. 5.9: Average number of pods per plant of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

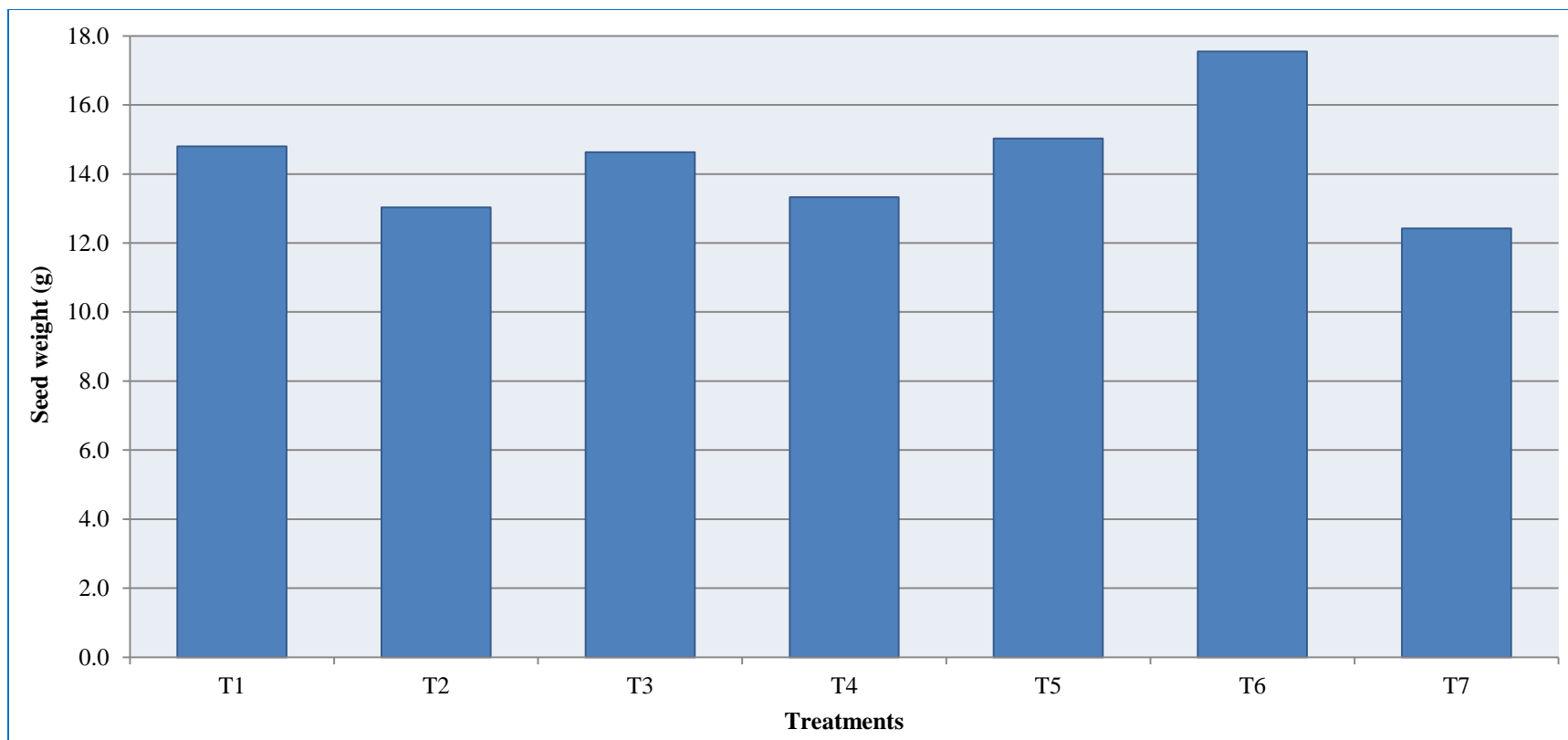


Fig. 5.10: Seed weight per plant of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

Foliar spray during flowering and pod filling stage might enhanced photosynthetic activity and higher uptake of nutrients and thereby increased plant dry matter production in the pod setting phase which might have improved the pod development and number of pods per plant. Similarly, Kalarani and Moosa Sheriff (1994) found increased number of pods with the foliar application of 1.5 % urea and 0.5 % DAP in green gram similar result observed by Patel and Patel (1994) in soybean crop. Again increased number of pods might be due to significantly higher value of growth attributes at 60 DAS and at harvest (Table-4.10 & Fig.5.11).

Significantly higher harvest index was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage and lowest was in recommended dose of nitrogen through FYM only.

The increased harvest index with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage was increased due to growth parameters *viz.*, plant height, number of branches, number of leaves, leaf area, leaf area index, lead area duration which led to development of more number of pods per plant, seed weight per plant and 100 seed weight. Again timely availability of nutrients at flowering and pod filling stage enabled plant to synthesis more photosynthates and in turn could translocate photosynthates from source to sink effectively. The results are in corroborate with the finding of Vinothkumar *et al.* (2013) are presented in Table-4.10.

Significantly higher haulm yield was also recorded with application of RDF+ foliar application of WSF at 2 % at flowering + pod filling stage and significantly lower haulm yield was obtained with supply of Recommended dose of nitrogen application through FYM only over all other treatments. The increased haulm yield (Table-4.10 & Fig.5.12) with foliar application twice at flowering and pod filing stage may be due to additional supply of nutrients through foliar spray which might have led to increased leaf area and number of branches per plant which resulted in higher dry matter accumulation and ultimately led to higher haulm yield. Further the enhancement of haulm yield might be due to the enhanced supply and subsequent mobilization of nutrients to plant parts.

Similar findings were reported by Maurya *et al.* (1993), Kadam *et al.* (2008) and Balusamy *et al.* (1996).

5.4 Effect of water soluble NPK (19:19:19) fertilizer on quality parameter of soybean

5.4.1 Crude protein content

Crude protein content did not differ significantly due to foliar application of water soluble NPK (19:19:19) fertilizer. Among the treatments, higher crude protein content was recorded with application of RDF+ foliar application of WSF @ 2 % at flowering + pod filling stage and lower crude protein content was recorded with recommended dose of nitrogen through FYM only, when compared to other treatments (Table-4.11). Similar results are also reported by Barik and Rout (1990) in soybean.

5.5 Effect of water soluble NPK (19:19:19) fertilizer on nutrient concentration

Nutrients concentration of NPK in plant at harvest was did not differ among the different treatments. However, higher NPK concentrations were recorded with application with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage was given in Table-4.12.

The significantly lower nitrogen, phosphorus and potassium concentration were recorded at all stages of observations in Recommended dose of nitrogen through FYM only compare to other treatments.

5.6 Effect of water soluble NPK (19:19:19) fertilizer on nutrient uptake by plant

Nitrogen, phosphorus and potassium uptake by soybean was influenced by foliar application of water soluble NPK (19:19:19) fertilizer. Significantly higher nitrogen, phosphorus and potassium uptake was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage (Table-4.13 & Fig.5.13).

The significantly lower nitrogen uptake by soybean was recorded with recommended dose of nitrogen through FYM only compared to other treatments.

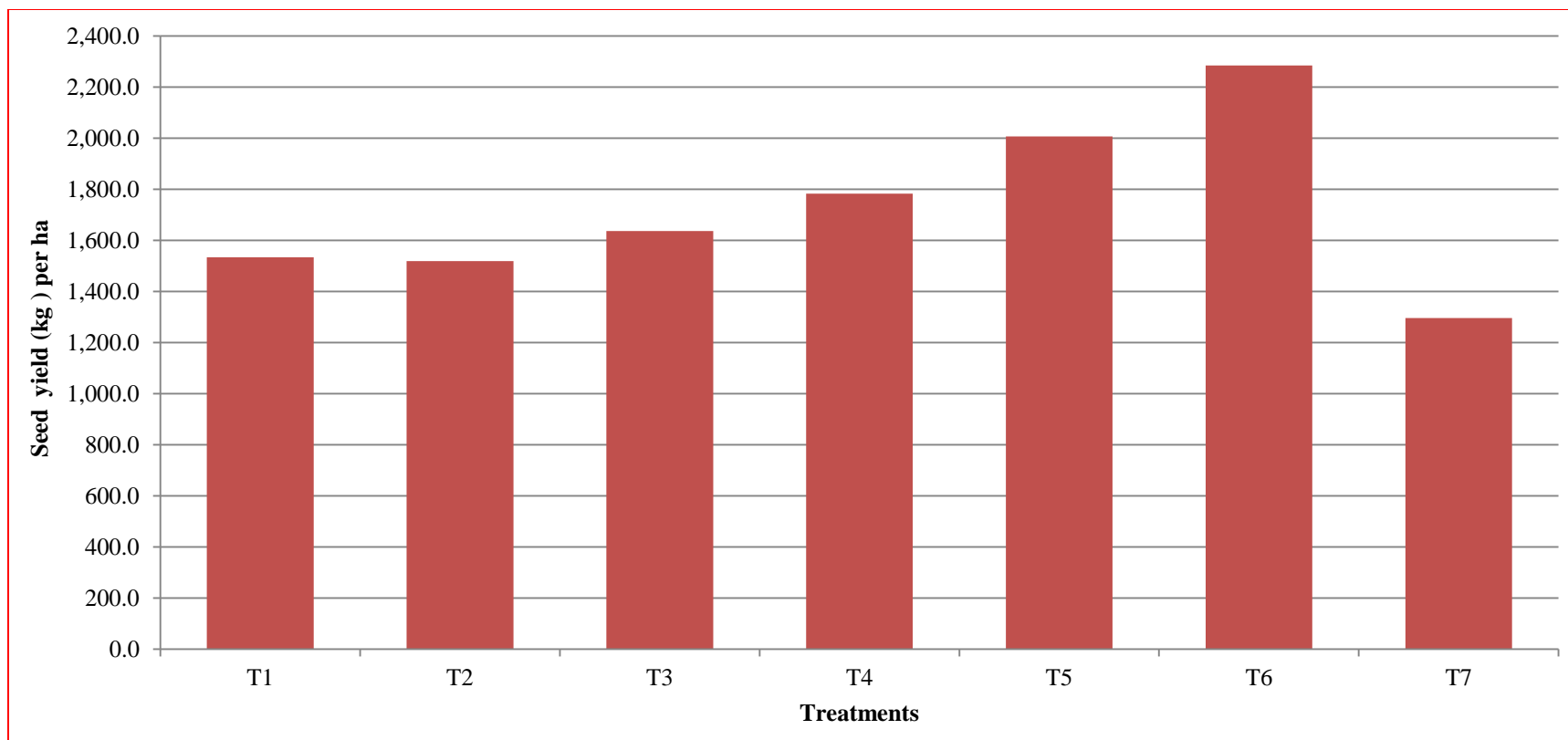


Fig. 5.11: seed yield (kg/ha) of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

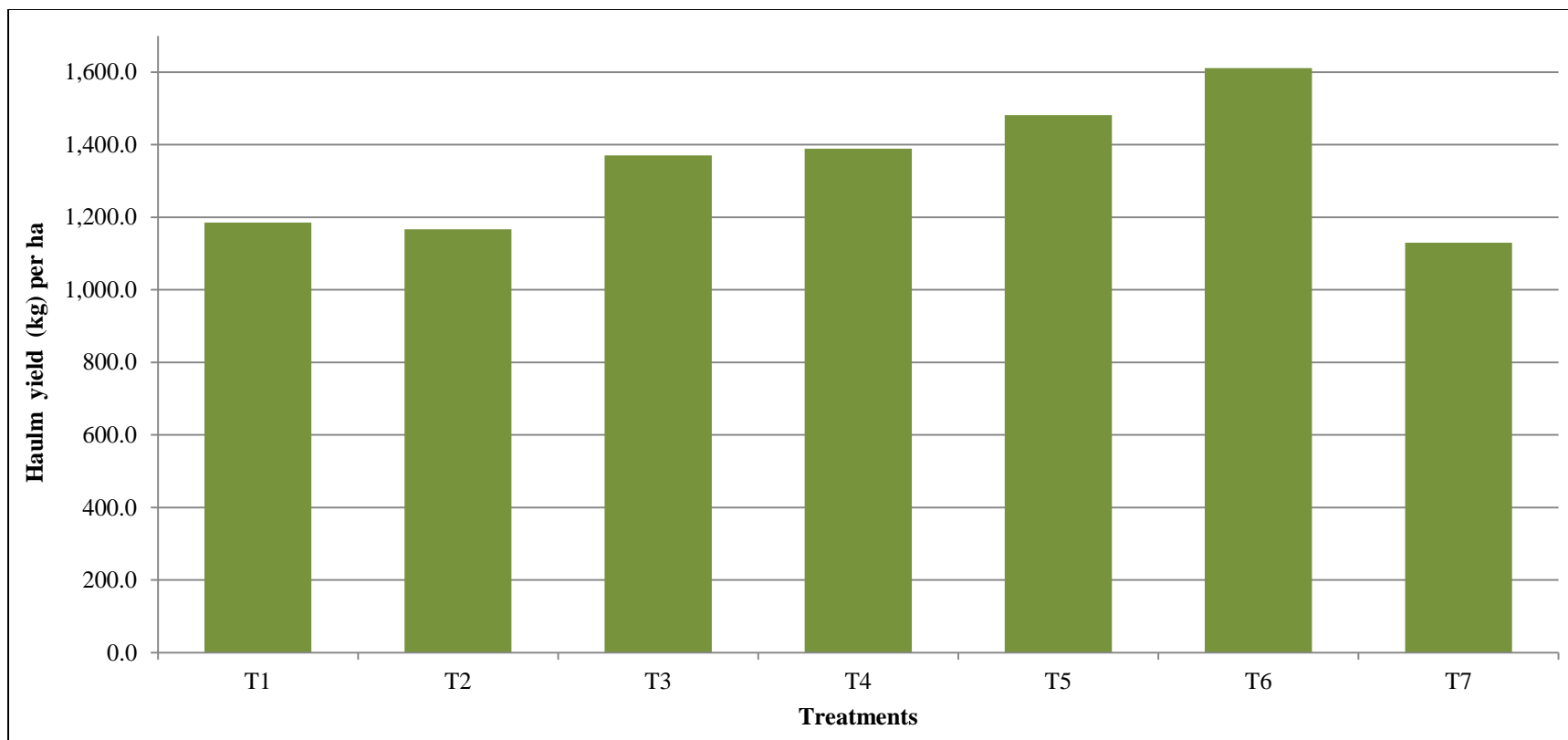


Fig. 5.12: Haulm yield (kg/ha) of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

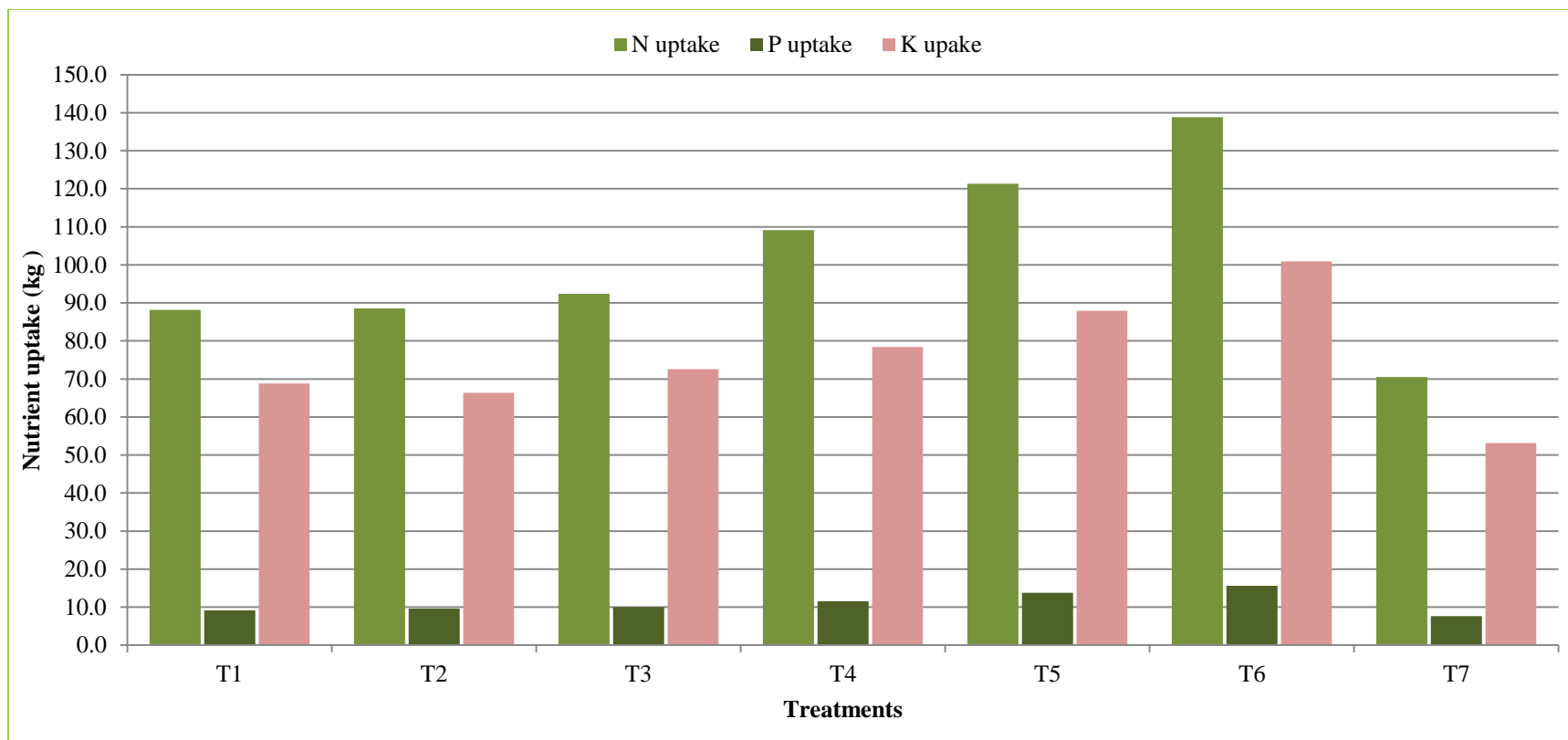


Fig. 5.13: NPK uptake by plant kg/ha of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

5.7 Available NPK in soil after harvest of soybean crop

The post-harvest soil analysis revealed that lower amount of available nitrogen, phosphorous and potassium were observed with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage compared to control as it might have depleted by the crop (Table-4.14 and Fig.5.14). The lesser amount of soil available nutrients was due to removal of more amount of nutrients by soybean crop. This could be regulated by increased plant height, number of branches per plant, number of leaves per plant, leaf area, dry matter accumulation and increased yield and yield attributing parameters of soybean. The higher soil available nutrients in recommended dose of nitrogen through FYM only treatment may be due to lesser uptake of nutrients by soybean may be due to timely availability of nutrients, mineralization process, etc., may be delayed and lack of timely availability of nutrients has not occurred which resulted on reduced growth and yield attributing parameters and ultimately resulted in low yield. The results are in corroborate with the findings of Sujatha (2001).

5.8 Effect of foliar application of water soluble NPK (19:19:19) on economics

The data on economics as influenced by foliar application of macro nutrients are presented in Table 4.15.

Higher gross returns, net returns and B:C ratio were recorded in treatment with application of RDF +foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments. Lower gross returns, net returns and B:C ratio were obtained in treatment with recommended dose of nitrogen through FYM only. This may be due to higher yield obtained in the treatment with application of RDF +foliar application of WSF @ 2 % at flowering + pod filling stage which resulted in getting higher return and high B:C ratio.

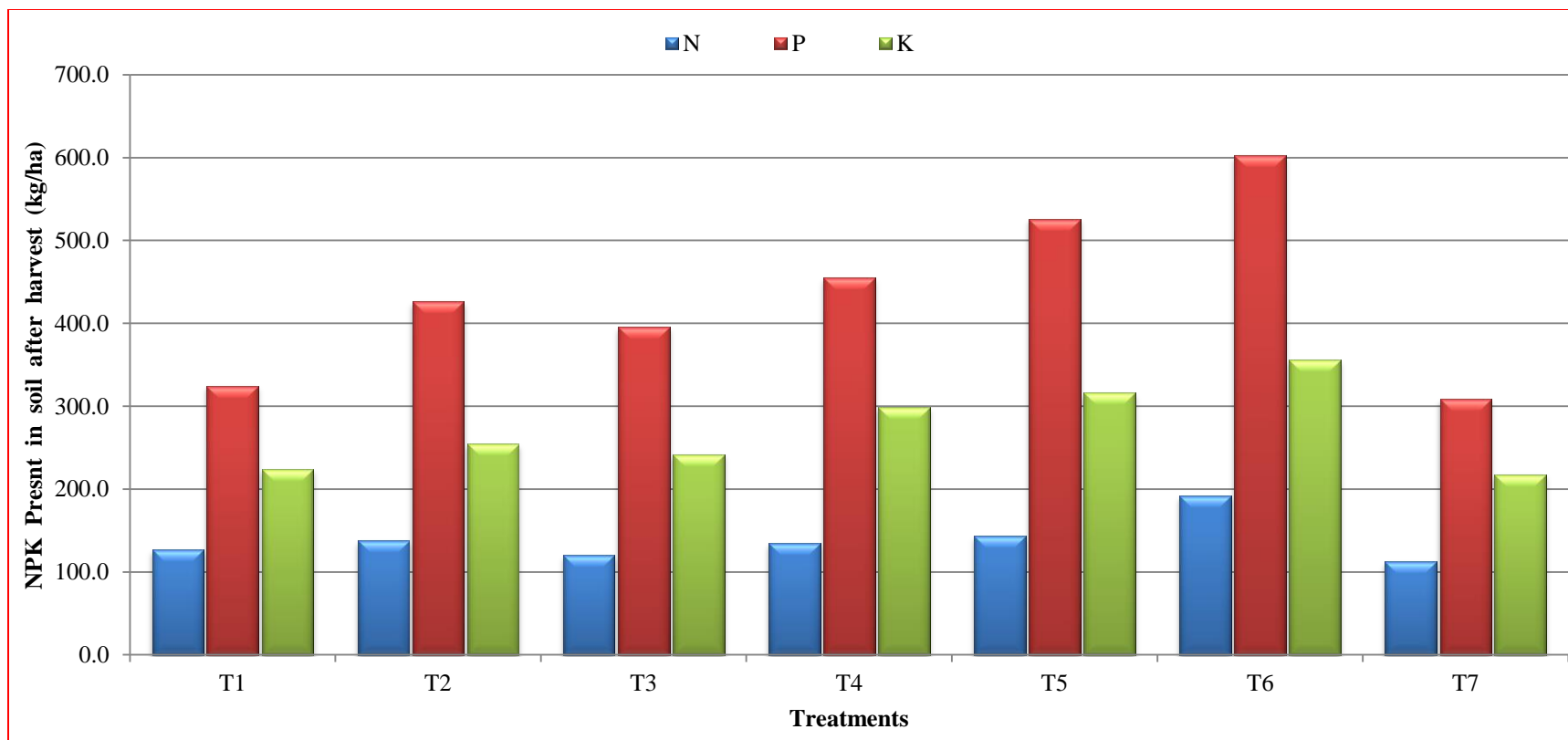


Fig. 5.14: NPK of soil after harvest of soybean as influenced by foliar application of water soluble fertilizer

T₁ Recommended fertilizer dose (30:80:38 kg N: P₂O₅: K₂O ha⁻¹ + FYM 6.5 t ha⁻¹)

T₂ RDF (50% N as basal and 50% N as top dressing)

T₃ RDF + foliar application of WSF @ 2 % at 8-12 leaf stage

T₄ RDF + foliar application of WSF @ 2 % at flowering stage

T₅ RDF + foliar application of WSF @ 2 % at pod filling stage

T₆ RDF + foliar application of WSF @ 2 % at flowering + pod filling stage

T₇ Recommended dose of nitrogen through FYM only

VI SUMMARY

The investigation entitled “**Effect of foliar application of water soluble fertilizer on growth, yield and quality of soybean [*Glycine max* (L.)Merrill]**” conducted at the Zonal Agricultural Research Station, University of Agriculture Sciences Bengaluru, GKVK during summer 2017. The salient findings of the experiment are presented in this chapter.

Among the different treatments, application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage recorded significantly higher plant height, number of branches per plant, number of leaves per plant, leaf area, leaf area index, leaf area duration and dry matter accumulation at 60 DAS and at harvest as compared to all other treatments.

Chlorophyll content (SPAD meter reading) was found non-significant at 30 DAS among the different treatments and whereas, at 60 DAS significantly higher chlorophyll content (SPAD meter reading) was recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage over all other treatments.

Foliar application of water soluble NPK (19:19:19) fertilizer did not influence the number of nodules per plant and nodule dry weight.

Total dry matter accumulation was significantly higher with RDF + foliar application of WSF @ 2 % at flowering + pod filling stage. Next best treatment was application of RDF + foliar application of WSF @ 2 % at pod filling stage and which was on par with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage.

Application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage was recorded significantly more number of days to 50 per cent flowering. Next best treatment was application of RDF + foliar application of WSF @ 2 % at pod filling stage and which is on par with application of RDF + foliar application of WSF @ 2 % at flowering.

Significantly higher number of pods per plant, seed weight per plant, 100 seed weight were recorded with application of RDF + foliar application of WSF @ 2 % at pod filling stage.

Soybean yield and haulm yield was significantly higher with the application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage and next best treatment was application of RDF + foliar application of WSF @ 2 % at pod filling stage and which was on par with application of RDF + foliar application of WSF @ 2 % at flowering.

The protein content and protein yield differed significantly among the different treatments. Significantly higher protein content and yield was recorded with the application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage and next best treatment was application of RDF + foliar application of WSF @ 2 % at pod filling stage and which was on par with application of RDF + foliar application of WSF @ 2 % at flowering stage.

There was significant difference among treatments with respect to concentration of nitrogen, phosphorus and nitrogen at harvest of soybean.

Nutrient uptake *viz.*, nitrogen, phosphorus and potassium was significantly higher with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage and significantly lower nitrogen, phosphorus and potassium uptake was obtained with recommended dose of nitrogen through FYM only.

Higher gross returns, net returns and B:C ratio were recorded with application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage and lower gross returns, net returns and B:C ratio was recorded with recommended dose of nitrogen through FYM only.

✓ Application of RDF + foliar application of WSF @ 2 % at flowering + pod filling stage can be adopted for higher yield and quality soybean.

Future line of work

- Application of RDF + foliar application of both macro and micro nutrients need to be studied at different growth stages.

VII REFERENCES

- ABOU EL-NOUR, E. A. A., 2002, Can supplemented potassium foliar feeding reduce the recommended soil potassium. *Pakistan J. Biol. Sci.*, **5** (3): 259-262.
- AMANY, A. B., 2007, Effect of plant density and urea foliar application on yield and yield components of chickpea (*Cicer arietinum* L.). *Res. J. Agric. & Biol. Sci.*, **3** (4): 220-223.
- ANANDA KRISHNAVENI, S., PALACHAMY, A. AND MAHENDRA, S., 2008, Effect of foliar spray of nutrients on growth and yield of green gram (*Phaseolous radiates* L.). *Legume Res.*, **27** (2): 149-150.
- ANONYMOUS, 2016, Directorate of Economics and Statistics, Department of Agriculture and Co-operation., **13**: 44-78
- ANONYMOUS, 2015. www.indiastate.com
- BALUSAMY, M., RAVIVHANDRAN, V. K. AND BALASUBRAMANIAN, 1996, Effect of zinc, boron and FYM on growth and yield of soybean. *Madras Agric. J.*, **83** (2):134-135.
- BARIK, T. AND ROUT, D., 1990, Effect of foliar spray of commercial micro-nutrient mixtures on growth, yield and quality of urdbean. *Legume Res.*, **13** (1): 50-52.
- BEG, M. Z., SOHRAB AHMAD AND DEEPAK, K. S., 2013, Foliar application of potassium on urdbean. *Indian. J. Sci.*, **2** (2): 67-70.
- BEHERA, NIGAMANDA AND ELAMATHI, S., 2007, Studies on the time of nitrogen, application of foliar spray of DAP, and growth regulators on yield attributes, yield and economics of green gram. *Intl. J. Agric. Sci.*, pp. 168-169.
- BOOTE, K. J., GALLAHER, R. N., ROBERTSON, W. K., HINSON, K. AND HAMMOND, L. C., 1977, Effect of foliar fertilization on photosynthesis, leaf nutrition and yield of soybeans. *Agron. J.*, **70** (5):787-791.

- CHANDRASEKHAR, C. N. AND BANGARUSAMY, U., 2003, Maximizing the yield of mungbean by foliar application of growth regulating chemicals and nutrients. *Madras Agric. J.*, **90** (1-3): 142-145.
- DIXIT, P. M. AND ELEMATHI, S., 2007, Effect of foliar application of DAP, micronutrients and NAA on growth and yield of green gram (*Vigna radiata* L.). *Legume Res.*, **30** (4): 305-307.
- DONALD, C. M. AND HAMBLIN, J., 1976, The biological yield and harvest index of cereals as agronomic and plant breeding criteria. *Adv. Agron.*, **28**: 361-405.
- ELAYARAJA, D. AND ANGAYARKANNI, A., 2005, Effect of foliar spray on the NPK uptake and yield of rice fallow blackgram (cv. ADT 3). *Mysore J. Agric. Sci.*, **39** (4): 480-483.
- GANAPATH, M., BARADHAN, G. AND RAMESH, N., 2008, Effect of foliar nutrition on reproductive efficiency and grain yield of rice fallow pulses. *Legume Res.*, **31** (2):142-144.
- GARUD, H. S., AWASARMAL, V. B., PAWAR, S. U. AND BHUSAWAR, P. V., 2015, Yield economics and quality of soybean as influenced by foliar and soil application of phosphatic fertilizer. *Intl. J. Trop. Agric.*, **33** (2): 709-712.
- GHOSH, M. K. AND JOSEPH, S. A., 2008, Influence of Bio fertilizers, 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.
- GOMEZ, K. A. AND GOMEZ, A. A., 1984, Statistical Procedure for Agriculture Research, 2nd Ed., John Willey 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. *Intl. J. Food, Agric and Vetr. Sci.*, **4** (3): 81-86.

- GUPTA, S. C., SANGEEV, K. AND KHANDWE, 2011, Effect of biofertilizer and foliar spray of urea on symbiotic traits, nitrogen uptake and productivity of chickpea. *J. Food legume*, **24** (2): 155-157.
- HAFIZ, S. I. AND EL-BRAMAWY, M. A. S., 2012, Response of sesame (*Sesamum indicum* L.) to phosphorus fertilization and spraying with potassium in newly reclaimed sandy soils. *Basic Res. J. Agril, Sci.*, **1** (5): 117-123.
- HEGAZI, E. S., SAMIRA, M., MOHAMED, EL-SONBATY, M. R., ABD EL-NABY, S. K. M. AND EL-SHARONY, T. F., 2011, Investigation of Fe and Zn foliar application on yield and its component of soybean (*Glycine max* (L.) Merrill) at different growth stages. *J. Agric. Biotech. Sustain. Dev.*, **3** (9): 189-197.
- HONNEGOWDA, 1992, Studies on nutritional requirement of bush type of lima bean (*Phaseolus lunatus* L.). M.Sc. (Hort.) Thesis, *Univ. Agric. Sci.*, Bangalore. pp. 80-87.
- HUGAR, A. B. AND KURDIKERI, M. B., 2000, Effect of application methods and levels of zinc and molybdenum on field performance and seed yield in soybean. *Karnataka J. Agri. Sci.*, **13** (2) 439-441.
- JACKSON, M. L., 1967, Soil chemical analysis, Prentice Hall of India, Pvt. Ltd., New Delhi.
- JASIM IQBAL, RAYYAN KHAN, ABDUL WAHID, KAMIL SARDAR, NANGIAL KHAN, MURAD ALI, MUJAHID HUSSAIN, WAQAR ALI, MUKHTIAR ALI AND RAFIQ AHMAD, 2016, Effect of nitrogen and zinc on maize (*Zea mays* L.) yield components and plant concentration. *Adv. Envi. Biol.*, **10** (10):203-208.
- JAYABAL, I. A., REVATHY, M. AND SAXENA, M. G., 1999, Effect of foliar nutrition on nutrient uptake pattern in soybean. *Andra Agric. J.*, **46**:243-244.

- JEYAKUMAR, P., VELU, G., RAJENDRAN, C., AMUTHA, R., SAVERY, M. A. J. R. AND CHIDAMBARAM, S., 2008, Varied responses of black gram (*Vigna mungo* L.) to certain foliar applied chemicals and plant growth regulators. *Legume Res.*, **31** (2): 110-113.
- 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.
- KADAM, J. R., PAWAR, S. U. AND PATIL, S. R., 2008, Effect of water soluble phosphatic fertilizers on chemical properties of soil and yield of soybean. *Maharashtra J. Agric.*, **39** (2): 151-153.
- KALARANI, M. K. AND MOOSA SHARIFF, M., 1994, Increasing yield due to delaying leaf senescence by the foliar fertilization of NPK & b. *Madras Agric. J.*, **81** (3): 171-172.
- KALPANA, R., SUBBIAN, P. AND SELVI, R. V., 2003, Effect of Irrigation Layouts and Foliar Nutrition on Grain Yield and Quality of Soybean. *Trop. Agril. Res.*, **18**:20-26.
- 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.*, **2** (49) 143– 150
- KUMAR, C. V., VAIYAPURI, K., AMANULLAH, M. M. AND GOPALASWAMY, G., 2013, Influence of Foliar Spray of Nutrients on Yield and Economics of Soybean (*Glycine max* L. Merrill). *J. Bio. 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 Performance of Blackgram (*Vigna mungo* L.), Nutrient Uptake and Economics under Dry Land Ecology. *Legume Res.*, **36**: 5-12.

- KUTTIMANI, R. AND VELAYUTHAM, A., 2011, Foliar application of nutrients and growth regulators on yield and economics of green gram. *Madras. J. Agric.*, **98** (4-6): 141-143.
- LALITHA, B. H., YELEDHALLI, N. A., RAVI, M. V., 2006, Effect of foliar application of potassium sulphate and boric acid on yield, nutrient uptake and quality of niger (*Guizotia abyssinica* L.). *Karnataka J. Agric. Sci.*, **21** (2): 282-283.
- LATHA, M. R., 2003, Foliar nutrition in crops. *Agril. Res.*, **24** (3): 229-34.
- MAHMOUD, SHAABAN, M., ABDALLA, FOUAD EL-SAYED, ABOU EL-NOUR, EL-ZANATY, ABDEL MOTTALEB, ALY, EL-SAADY AND ABDEL KAREEM MOHAMED, 2006, Boron/nitrogen interaction effect on growth and yield of fababean plants grown under sandy soil condition. *Intl J. Agric. Res.*, **1** (4):322-330.
- MALAY, K. AND BHOWMICK, 2008, Effect of foliar nutrition and basal fertilization in lentil under rainfed conditions. *J. Food Leg.*, **21** (2): 115-116.
- MANDIC, V., SIMIC, A., KRNJAJA, V., BIJELIC, Z., TOMIC, A., STANOJKOVIC, D. AND MUSLIC, R., 2015, Effect of foliar fertilization on soybean grain yield. *Biotechnology in Animal Husbandry*, **31** (1): 133-143.
- MANIVANNAN, V. K., THANUNATHAN, IMAYAVARAMBAN, V. AND RAMANATHAN, N., 2002, Effect of foliar application of NPK and chelated micronutrients on rice-fallow urdbean. *Legume Res.*, **25** (4): 270-272.
- MANNAN, M. A., 2014, Foliar and soil fertilization effect on seed yield and protein content of soybean. *Bangladesh J. Agro.*, **17** (1): 67-72.
- MANONMANI, V. AND SRIMATHI, P., 2009, Influence of mother crop nutrition on seed and quality of blackgram. *Madras Agric. J.*, **96** (16): 125-128.

- MAURAYA, B. R., KISHOR AND RAM P. C., 1993, Effect of iron and molybdenum on Urdbean., *Maharashtra Agric. Univ.*, **18** (1):128
- MAZHAR-HAQ, U. AND ANTONIO-MALLARINO, P., 2000, Soybean yield and nutrient composition as affected by early season foliar fertilization. *J. Agron.*, **92** (1): 16-24.
- MIRVAT, E., GOBARAH, MAGDA, H. MOHAMED AND M. M. TAWFIK, 2006, Effect of phosphorus fertilizer and foliar spraying with zinc on growth, yield and quality of ground nut under reclaimed sandy soil. *J. Applied Sci. Res.*, **2** (8): 491-496.
- MISHRA, A. K. AND AGARWAL, H. P., 1984, Effect of sulphur on growth, yield, protein and oil content of soybean. *J. oil seed Res.*, **11**: 99- 102.
- MOHAMMAD, F. AND KHAN, T., 1997, Response of three mustard genotypes to soil-applied and leaf applied nutrients. *J. Indian Bot. Soc.*, **76** (1-2): 33-38.
- MONDAL, M. M. A., RAHMAN, M. A., AKTER, M. B. AND FAKIR, M. S. A., 2011, Effect of foliar application of nitrogen and micronutrients on growth and yield in mungbean. *Legumes Res.*, **34** (3): 166-171.
- MUTHUVEL, P., SIVASAMY, R. AND SUBRAMANIAN, V., 1985, Mitigating the adverse effect of drought in rainfed blackgram. *J. Madras Agric.*, **72** (1): 22-24.
- NABIH, I., ASHOUR, AND ALICE THALLOOTH, T., 1982, Effect of soil and foliar application of nitrogen during pod development on the yield of soybean plants. *Field Crop Res.*, **6**: 225-229.
- NASEF, M. A., NADIA., BADRAN, M., AMAL. AND ABD EL-HAMIDE, F., 2006, Response of peanut to foliar spray with boron and/or rhizobium inoculation. *J. Appl. Sci. Res.* **2** (12): 1330-1337.

- NASIRI, Y., ZEHTAB-SALMASI, S., SASRULLAHZADEH, S., NAJAFI, N. AND GHASSEME-GOLEZANI, K., 2010, Effect of foliar application of micronutrients (Fe and Zn) on flower yield essential oil of chamomile (*Maricaria chamomilla* L.). *J. Medicinal Plant Res.*, **4** (17):1733-1737.
- NELSON, K. A., PETER MOTAVALLI, P. AND MANJULA NATHAN, 2004, Response of no-till soybean *Glycine max* (L.) Merril. to timing of pre plant and foliar potassium applications in a clay pan soil. *J. Agron.*, **97** (3): 832-838.
- NELSON, K. A., MOTAVALLI, P. P. AND NATHAN, M. 2005, Response of No-till soybean to [*Glycine max* (L.) Merrill] to timing of pre-plant and foliar potassium application in a clay pan soil. *J. Agron.*, **97** (3): 832-838.
- NIGAMANDA AND ELAMATHI, S., 2007, Studies on the time of nitrogen, application of foliar spray of DAP, and growth regulators on yield attributes, yield and economics of green gram. *Intl. J. Agric. Sci.*, pp. vol. 168-169.
- ODELEYE, F. O., ODELEYE, O. M. O. AND ANIMASHAUN, 2007, Effect of nutrient foliar spray on soybean growth and yield (*Glycine max* (L.) Merrill) in south west Nigeria. *Not. Bot. Hort. Agrobot. Cluj.*, **35** (2).
- OSMAN, A. S. ABIDO, Y. M. Y., ALLAM AND S. M. M., 2000, Response of soybean to phosphorus and zinc fertilization under irrigation regime. *Annals of Agril. Sci.*, **45** (1): 229-238.
- PANDE, M. MUDLAGIRI, B. AND BELLALOU G. N., 2014, Effect of foliar and soil application of potassium fertilizer on soybean seed protein, oil, fatty acids, and minerals. *American J. Plant Sci.*, **5**: 541-548.
- PARASURAMAN, P., 2008, Studies on integrated nutrient requirement of hybrid maize (*Zea mays* L.) under irrigated conditions. *Madras Agric. J.*, **92** (1&3): 89-94.

- PATEL, T. R. AND PATEL, Z. G., 1994, Effect of foliar fertilization of nitrogen and phosphorous on growth and yield of summer green gram. *Indian J. Agron.*, **39** (4): 578-580.
- PATRA, A. K., TRIPATHY, S. K. AND SAMUI, R. C., 1995, Effect of post flowering foliar application of nutrients on growth, yield and economics of rainfed groundnut (*Arachis hypogea* L.). *Indian J. plant. Physio.*, **38** (3):203-206.
- PIPER, C. S., 1966, Soil and Plant Analysis, Academic Press, New York, pp: 236.
- POWER, J. R., WILLID, W. O., GRUNES, D. I. AND REILHMAN, C. A., 1967, Effect of soil temperature, phosphorous and plant age on growth analysis of barley. *Agron. J.* **59**: 231-234.
- PRADEEP., M. D. AND ELAMATHI., S., 2007, Effect of foliar application of DAP, micronutrients and NAA on growth and yield of green gram (*Vigna radiata* L.). *Legume Res.*, **30** (4): 305 – 307.
- PRAKASA RAO, J. S., 2002, Amelioration of moisture stress by potassium and auxin in sesame (*Sesamum indicum* L.) *Madras Agric. J.* **89** (4-6): 329-331.
- RAJENDRAN, R., 1991, Effect of soil and foliar nutrition on growth and yield of mungbean. *Andhra. Agric. J.*, **38** (1) 15-18.
- RAMAN, R. AND VENKATARAMANA, K., 2006, Effect of foliar nutrition on N P K uptake, yield attributes and yield of green gram (*Vigna radiate* L.). *Crop Res.*, **32** (1): 21-23.
- RAMESH., K. AND THIRUMURUGAN., V., 2001, Effect of seed pelleting and foliar nutrition on growth of soybean. *Madras Agric. J.*, **88**: 465-468.
- RAMON GARCIA, L. AND JOHN HANWAY., 1976, Foliar fertilization of soybean during the seed filling period. *Agron. J.*, **68** (4): 653-657.

- 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. *Intl J. applied bio Sci & pharma.*, **6** (2):56-63.
- RAO, V. P. AND GANGAKISHAN, A., 1993, Response of rainfed groundnut to nitrogen application. *J. Maharashtra Agric. Univ.*, **18**: 460-461.
- REZAEI, R., ZARGHAMY, R. AND OVEYSEE, M., 2013, Evaluate the effect of foliar application and changes sink and sources on yield and yield components of soybean (*Glycine max* (L.) Merrill). *Technical J. Eng and App Sci.*, **3-16**: 1825-1828.
- ROOPASHREE, D. H., 2013, Effect of organic manures, mulching and potassium levels on growth, yield and quality of baby corn (*Zea mays* L.). *Ph. D. Thesis*, UAS, Bengaluru.
- SARKAR, R. K., CHANDRABORTHY, A. AND ANITHA SAHA, 1999, Effect of foliar application of potassium nitrate and calcium nitrate on groundnut (*Arachis hypogaea* L.). *Indian J. of Agronomy*, **44** (4): 809-812.
- SARKAR, S. K. AND MALIK, G. C. 2001, Effect of foliar application of potassium nitrate and calcium nitrate on grasspea (*Lathyrus sativus* L.) grown in rice fallows, *Lathyrus Lathyrism Newsleter*. **2**: 47-48
- 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.
- SENTHIL, K. G., MUTHUKRISHNAN, P., RAMASAMY, S. AND CHANDARAGIRI, K. K., 2008, Effect of organic and inorganic foliar spray on growth and yield of blackgram (*Vigna mungo* L.). *Madras Agric. J.*, **95** (1-6): 57-60.

- SESTAK, A. L., CATASKY, T. AND JARVIS, P. G., 1971, *Plant Photosynthetic Production Manual of Methods*, Ed. Dr. Junk, W. N. V., Publication, The Hague, pp : 343-345.
- SHARAWAT, K. L. AND BURFORD, J. R., 1982, Modification of alkaline permanganate method for assessing the availability of soil nitrogen in upland soils, *Soil Sci.*, **133**: 53- 57.
- SHINDE, S. H. AND BHILARE, R. L., 2003, Response of chickpea to soil and foliar application of DAP. *Madras Agric. J.*, **90** (4-6): 352-354.
- SHITTU, O. S. AND OGUNWALE, J. A., 2012, Phosphorus-zinc interaction for soybean production in soil development on charnockite in ekitistate. *J. Emerging Trends in Eng and App Sci.*, **3** (6): 414-422.
- SINGH, S. AND KAMATH, M. B., 1989, Phosphate utilization from full basal, split and foliar application by mustard. *J. Oilseed Res.*, **6**: 133-135.
- SRIVASTAVA, G. P. AND SRIVASTAVA, V. C., 1994, Effect of irrigation and foliar spray of nutrients on growth and seed yield of gram (*Cicerarietinum*). *The Ind J. Agril. Sci.*, **64** (4): 43-47.
- SUBBIAH, B. V. AND ASIJA, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.*, **25** (8):259-260.
- SUBHAMOY. G., KAJAL SENGUPTA AND HIRAK BANARJEE., 2010, Effect of foliar application of nutrients and brassinolide on summer green gram (*Vigna radiate*) crop. *Int. J. Tropical Agri.*, **28**: 1-2.
- SUJATHA, K. B. 2001, Effect of foliar spray of chemicals and bio regulators on growth and yield of greengram (*Vign aradiat L.*). M.Sc. (Agri.). Thesis.Tamil Nadu Agril.Univ.Coibatore.

- SUMNER, M. E. AND FARINA, M. P. W., 1986, Phosphorus interactions with other nutrients and lime in field cropping systems. *Adv. Soil Sci.*, **5**: 201-236.
- 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 and Crops.*, **16** (1):210-216.
- THALLOOTH, A. T., TAWFIK, M. M. AND MAGDA MOHAMED, H. A., 2006, comparative study on the effect of foliar application of zinc, potassium and magnesium on growth, yield and some chemical constituents of mungbean plants grown under water stress conditions. *World J. Agril. Sci.*, **2** (1): 37-46.
- THAVAPRAKAASH, N., VELAYUDHAM, K. AND PANNEERSELVAM, S., 2006, Foliar nutrition of baby corn. *Archives Agron. & Soil Sci.*, **52** (4): 419 – 425.
- VEKARIA, G. B., TALPADA, M. M., SUTARIA, G. S. AND AKBARI, K. N., 2013. Effect on soybean yield, leaf and boron concentration in seed. *World of Sci. J.* **1** (10):178-188.
- VENKATESH, M. S. AND BASU, P. S., 2011, Effect of foliar application of urea on growth, yield and quality of chickpea under rainfed conditions. *J. Food legume.*, **24** (2): 110-112.
- VINOTHKUMAR, C., VAIYAPURI, M., MAHAMED, A. AND GOPALSWAMY, 2013, Influence of foliar spray of nutrients on yield and economics of soybean (*Glycine max* L. Merrill). *J. Bi. Sci.*, **13** (6): 563-565.
- WATSON, D. J., 1952, The physiological basis for variation in yield. *Adv. Agron.*, **4**: 101-145.
- YAKADRI, M. AND THATIKUNTA, R., 2002, Effect of soil application of potassium and DAP spray in blackgram (*Vigna mungo* L.). *Madras Agric. J.*, **89** (1-3): 147-149.

APPENDIX

Fixed cost of soybean cultivation

Particular	Quantity required for one hectare	Rate/unite (Rs.)	Amount (Rs.)
Tractor hire charge	4 hrs	600/hr	2400
Irrigation charge	2000	2000
Men labor	35	200/day	7000
Women Labor	23	180/day	5760
Plant protection chemicals	1500
Seed	62.5	35/kg	2187
Total			20847
Cost of treatments			
T ₁	5229
T ₂			5229
T ₃			6896
T ₄			6896
T ₅			6896
T ₆			8563
T ₇			8700

Note: Urea= Rs. 6/kg

SSP= Rs. 5.5/kg

MOP= Rs. 15.6/kg

NPK (19:19:19)=Rs. 150/kg

FYM= Rs 600/t