

**STUDIES ON YIELD MAXIMIZATION OF SOYBEAN THROUGH SOIL
AND FOLIAR FEEDING OF NUTRIENTS, GROWTH REGULATORS AND
MONITORING GROWTH PROFILE BY SPECTRAL REFLECTANCE**

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**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE
VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH
PARBHANI – 431 402 (M.S.) INDIA**

2020

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AND FOLIAR FEEDING OF NUTRIENTS, GROWTH REGULATORS AND
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DISSERTATION

*Submitted to the
Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani
In partial fulfillment of the requirements
For the Degree of*

**DOCTOR OF PHILOSOPHY
(Agriculture)**

IN

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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PARBHANI – 431 402 (M.S.) INDIA**

2020



*Affectionately
Dedicated
To My Beloved
Parents, Wife,
Daughter, Son and
Research Guide*

CANDIDATE'S DECLARATION

I hereby declare that this dissertation

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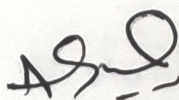
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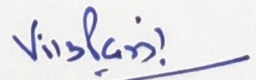
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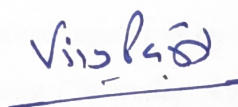
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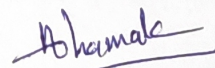
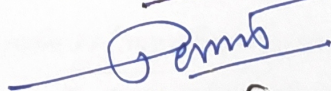

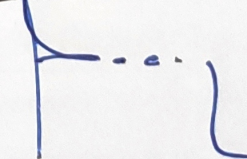
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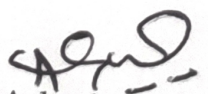
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ABBREVIATIONS

%	-	Per cent
/	-	Per
@	-	At the rate of
<	-	Less than
>	-	More than
μ	-	Micron
μl	-	Micro litre
°C	-	Degree centigrade
AAS	-	Atomic Absorption Spectrophotometer
AM	-	Ante meridiem
Avail.	-	Available
Ca	-	Calcium
CD	-	Critical difference
cm	-	Centimeter
Cu	-	Copper
dSm ⁻¹	-	Deci Siemens per meter
DTPA	-	Diethylene triamine penta acetic acid
EC	-	Electrical conductivity
EDTA	-	Ethylene di-amine tetra acetic acid
<i>et al.</i>	-	et alia and other
<i>etc.</i>	-	etcetera
Fe	-	Iron
fig.	-	Figure
g ha ⁻¹	-	Gram per hectare
<i>i.e.</i>	-	that is
<i>J.</i>	-	Journal
K	-	Potassium
Kg.	-	Kilogram
kg ha ⁻¹	-	Kilogram per hectare
max.	-	Maximum
mg.	-	Milligram
mg kg ⁻¹	-	Milligram per kilogram
Mg m ⁻³	-	Mega gram per cubic meter
Min.	-	Minimum
Mn	-	Manganese
OC	-	Organic carbon
SE±	-	Standard error
T.	-	Treatments
TC	-	Total carbon
<i>var.</i>	-	Variety
<i>viz.</i>	-	Namely
Zn	-	Zinc



INTRODUCTION



CHAPTER I

INTRODUCTION

Soybean (*Glycine max L.*) is important oil and protein crop belongs to family Leguminaceae, It plays a decisive role in oil economy of India. It is cheapest and main source of dietary protein of majority vegetarian. it contains high quality protein (40-42%), oil (18-20%) and other nutrients like calcium and iron. (Devi *and* Singh, 2012). Soybean is preferable for human nutrition due to its high protein content. It is a good source of is flavones and therefore, it helps in preventing heart disease, cancer and HIV's. (Kumar, 2006). Soybean oil is leading vegetable oil in the world and is used in many industrial applications including biodiesel. Because of its high nutritional value and myriad form of uses, it is recognized as “**Golden Bean**” in India.

The soybean production in India during 2014-2015 has been about 10.528 mt in 11.086 mha area with average productivity of 950 kg ha^{-1} (Anonymous, 2015). In India , Madhya Pradesh, Maharashtra and Rajasthan are the major soybean producing states contributing about 95 per cent of total area. Maharashtra stands second in soybean production contributing 29 per cent of the countries' soybean production. Andhra Pradesh, Karnataka, Chhattisgarh and other parts of India also produce the bean in small quantities.

In Maharashtra, the area under this crop is about 2.6 million hectare with annual production of 27.54 lakh mt with productivity 10.58 q ha^{-1} . The most important constraints to crop growth are those caused by shortage of plant nutrients (Bangar, 2014). Madhya Pradesh, Maharashtra grow soybean largely on Vertisol and associated soils and contributes about 86.8 % of total area. Considering the need to augment the supply of edible oil and protein, the productivity can be increased by expanding the soybean cultivation area. Low yield of soybean is mainly due to poor supply of nutrients.

Zinc was assumed to be greater significance due to wide occurrence of its deficiency. The magnitude of sulphur removal is much higher due to intensive cropping. (Jaga, 2013).

Sulphur is an essential macronutrient in plant growth and development. It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. Among the fertilizer elements, sulphur requirement of oilseed crops is quite high as compared to other crops. Sulphur deficiencies in crops have increasingly occurred due to less to no addition of sulphur to soil because of increased use of sulphur free fertilizers (Patil and Mali,2000) Greater sulphur removal from soil by crops with enhanced yield and under more intensive cropping systems Soils with coarse texture, low in organic matter and good drainage are often sulphur deficient. Recently, wide spread deficiencies of sulphur in the soil of crop fields has been noticed in many parts of India.

Soybean is sensitive to zinc deficiency, which is need for protein metabolism and involved in chlorophyll formation, growth hormone stimulation, enzymatic activity and reproductive processes. Further, under assured rainfall or irrigated conditions there is a vast scope for growing soybean and with better micronutrients management in the *khariif* season. Secondly, boron is a micronutrient of special importance because of its role in pollination, fruit and seed setting and translocation of sugars and phosphorous etc. Boron is essential not only for development of roots but also formation of root nodules in leguminous plants. Boron is essential for all plant growth. It aids in transfer of sugars and nutrients from leaves to reproductive organs and increasing pollination and seed development. If it is deficient, one of the first adverse effects is on flowering and fruiting and therefore on yield and quality of produce occurs even though no deficiency. Boron deficiency is often an unsuspected energy of crop production. Boron catalyses the metabolism of carbohydrates in to oils and fats, as it regulates K/Ca ratio, peroxide, polyphone oxides and other phosphorylating enzymes and protein synthesis. Soybean requires boron especially during flowering and seed development.

Potassium is one of the three major essential nutrient element required by plants. Potassium exists in mobile organic form (K^+) and its function appears to be primarily catalytic in nature. Plant absorbs potassium in larger amount than any nutrient except N.. Potassium involved in activation of enzymes of many physiological processes such as photosynthesis, photosynthetic translocation, protein and starch synthesis, water energy relations, translocation of assimilates improves the water use efficiency (Singh *et al.*, 1998) through its influence on maintenance of

turgor potential. High availability of K enhances root development, producing branching and lateral roots. The increase in K deficiency in agronomical crops has increased in recent years due to the effects of drought condition due to erratic rainfall and soil compaction resulting in decreased K availability. Reduced amount of applied K fertilizers, higher fertilizer requirements, because of increasing crop yields and larger soybean acreage.

Pulses growing regions of India consists of different soil types and available K status vary from low to high. Patil *et al.* (2001) reported that average use of K in Maharashtra was 11.10 kg ha^{-1} causing K depletion in very high rate. Potassium is rarely applied to pulse crops despite layer requirements of pulses and continued mining of soil K resulting in imbalanced nutrient supply and lower crop yield.

Foliar fertilization is an effective way of quickly supplying plant nutrients during critical periods of flowering, grain filling at which time soil or root conditions are often unfavorable for optimum root uptake and there is insufficient uptake to supply demand. Foliar nutrition is an excellent tool to deliver micronutrients when the soybean plant needs it the most. **Foliar fertilization:** “It is the practice of applying nutrients for plant leaves through ground or aerial spraying equipment or through sprinkler irrigation system.”

Micronutrients are important in plant biochemistry as constituents of enzymes and hormones which control biological metabolic processes such as respiration, energy exchange and synthesis of chlorophyll, carbohydrates and proteins. The availability of micronutrient depends on their abundance in their forms, which can be assimilated by the plant mechanism by which the concentration in solution can be maintained. Availability of the micronutrients is also influenced by soil pH. Some of there views on micronutrients pertaining to Zinc, Boron, Potassium nitrate and other with reference to soybean and related crops are reviewed here under. The practice of foliar feeding with plant nutrients gives quick benefits and economizes nutrient element as compared to soil application (Verma and Sahani, 1963). Foliar feeding is often effective when roots are unable to absorb sufficient nutrients from the soil due to a high degree of fixation, losses due to leaching, low soil temperature and lack of soil moisture.

The soils of Marathwada region, which are largely deficient in nutrients like N, P, K, S, Zn and B are mainly responsible for the greenness of the crops. Among all these nutrients S, Zn and B deficient in pulses growing regions of Marathwada, Maharashtra. Therefore most of the spectral studies in nutrient stress have been concentrated in spectral response in relation to nutrient stress condition. Vegetation indices based on Red and Infra-red reflectance have been developed as spectral parameters for distinguishing plant canopy under fertilized and nutrient stress condition. The frequently used spectral indices for monitoring the plant health and vigor are Relative Vegetation Index (Jordan, 1969), Normalized Difference Vegetation Index (Rouse *et al.*, 1973), Soil Adjusted Vegetation Index (Huete, 1988) and Infrared Percentage Vegetation Index (Crippen, 1990). Much lower values of NIR/R reflectance ratio and NDVI for nitrogen deficient crops were reported as compared to that of nitrogen fertilized by Ajay *et al.*, 1984, Das *et al.*, 1985, Rao *et al.*, 1997. Further Patil, *et al.*, 2003 also reported the change in cotton crop canopies like reduced LAI, chlorophyll content and biomass caused by nitrogen deficiencies resulting detectable spectral reflectance variation. The use of spectral data in nutrient deficiency not only helps in delineating the nutrient stress areas but also in recommending the corrective measures at right time.

Berger (1949) classified that alfa-alfa and clover under high requirement of boron for their growth and development. Datta and Gurubasavaraj (1955) observed that boron could increase the nodulation of berseem and there was increase in the total yield. Blany *et al.*, (1981) observed that boron application increases boron concentration in leaves at early pod fill stage, but had no benefit of vegetative growth in groundnut. Boron plays a regulatory role in carbon metabolism cell division and cell elongation (Cohen and Lepper, 1977). The critical concentration of boron was estimated to be one ppm in forage legumes (Sherrell, 1983).

The plant growth regulators are classified into different categories *viz.*, auxins, gibberellins, cytokines, naturally hormone, ethylene, dormine, flowering hormone, synthetic growth retardants. Gibberellins have been extended to several important phenomena in plant life, such as elongation of stem, expansion of leaves, production of dry matter, elongation of dwarfism, root growth, cell division and several metabolic processes, increase in plant height, number of branches, leaves, no. of flowers and increase in various growth parameters *i.e.* GA (Sapkal *et al.*, 2011).

Growth regulators improve physiological efficiency including photosynthetic ability and can enhance effective partitioning of assimilates from source to sink in field crops (Devi *et al.*, 2018). The synthetic auxins, naphthalene acetic acid (NAA) promotes rooting in soybean hypocotyls.

Therefore for the efficient exploitation of high yielding potential and oil content of soybean and monitoring growth attributes by spectral reflectance, with this background the present investigation is undertaken on “***Studies on Yield Maximization of Soybean through Soil and Foliar Feeding of Nutrients, Growth Regulators and Monitoring Growth Profile by Spectral Reflectance***” was planned and executed with following objectives for two consecutive years.

1. To study the effect of soil application of sulphur and zinc on growth, yield and quality of soybean.
2. To find out the response of soybean for foliar application of KNO₃, Borax, NAA and GA.
3. Monitoring growth profile of soybean under various treatments by spectral reflectance studies.
4. To work out the soil nutrient balance and economics.



REVIEW OF LITERATURE



CHAPTER II

REVIEW OF LITERATURE

Present investigation on studies on yield maximization of soybean through soil and foliar feeding of nutrients, growth regulators and monitoring growth profile by spectral reflectance. The review of the work done on these aspects have been collected and presented under the following heads.

- 2.1 Effect of soil application of sulphur and zinc on growth, yield and quality of soybean.
- 2.2 Response of soybean for foliar application of KNO₃, Borax, NAA and GA.
- 2.3 Monitoring the growth profile of soybean under various treatments by spectral reflectance studies.
- 2.4 Workout the soil nutrient balance and economics.

2.1 Effect of soil application of sulphur and zinc on growth, yield and quality of soybean

Wood *et al*, (1993) reported that, grain yield response to N fertilization appeared to be dependent on soil nitrate-N- concentration at planting. Nitrogen applied at R₅ was the most reliable application time for increasing grain yields, however, yield decreases from N applied at R₅ were also observed for both cultivars. Nitrogen fertilization affected seed oil and protein concentrations at only one location. Results of this work suggest that fertilizer-N application to soybean is, at best, a risky proposition.

Ahmad *et al* , (1999) revealed that, seed yield, biological yield and harvest index were improved by 38.3, 26.3 and 9.5%, respectively by S₂N₂ over the results obtained with S₁N₂. In the case of V₂, three split applications of S and N (S₃N₃) resulted in maximum growth and yield. Increase in biomass accumulation, LAI, LAD, CGR and photosynthetic rates due to application of S₃N₃ were 48.4, 81.3, 77.9, 101.1 and 28.6, respectively, over the results of S₁N₂. Seed yield, biological yield and harvest index improved by 41.3, 26.9 and 11.6%, respectively, with this treatment.

Rajurkar *et al*, (1999) found that, it revealed that growth and yield of cowpea were significantly increased in the plant receiving 100 ppm KH₂PO₄ plus *Rhizobium* plus 30% less nitrogen dose as compared to recommended dose of NPK.

Patil *et al.*, (1999) indicated that, application of boron through boronated superphosphate (BSP) was significantly superior to single superphosphate (SSP) irrespective of the test crops. Economic analysis of the treatments further supported the application of boron through boronated superphosphate showing increased net returns in different crops studied (Rs. 3487 to 4429/ha) than single superphosphate (Rs. 1779 to 2553/ha) suggesting that the use of BSP is more profitable than that of SSP for boosting the yields of mustard, sunflower and cowpea in lateritic soil of Konkan.

Choubey and Choubey (1999) reported that, there was a linear relation between spectral reflectance and rice plant height ($r=0.97$), for band 1 (0.45-0.52 μm) reflectance values. On the other hand, in band 2 (0.52-0.60 μm) and 3 (0.63-0.69 μm), reflectance values decreased until 70 days after planting (DAP) and then increased during the reproductive phase of the crop. The near infrared band 4 (0.76-0.90 μm) showed a maximum reflectance at 59 DAP (panicle initiation stage) and a decline in reflectance thereafter through maturity. The peak value of IR/R ratio was 16.39 at 62 DAP during the early reproductive phase; thereafter, it declines gradually with the maturity of the crop. Chlorophyll '2' concentration was high during early growth (vegetative and early reproductive stages) and decreased during the flowering and maturity stages. The rice plant canopy show high chlorophyll 'a' concentration at 64 and 59 DAP for sites A and B, respectively. Chlorophyll 'a' concentration is higher in site A plant canopies than it is in site B during the entire crop cycle. A good inverse correlation ($r=0.91$) has been found between chlorophyll 'a' and band 1, while the IR/R ratio and the normalized difference vegetation index (NDVI) showed a relationship ($r=0.78$) with the chlorophyll 'a' concentration during the crop cycle. Band 2, 3 and 4 radiance values show a biphasic linear relationship with chlorophyll 'a' concentrations, negative for early growth and positive for flowering and maturity stages. Results indicate that the period between 66 to 70 DAP is most suitable for the assessment of rice crop yield based on chlorophyll 'a' concentration.

Hatwar *et al.*, (2003) noticed that, combined application of Zn, Fe and B @ 0.1% was found most effective in respect of height of the plant (70.36 cm), number of branches plant⁻¹ (11.2), diameter of stem (1.54 cm), spread of plant (53.54 cm) and yield attributes such as number of fruits plant⁻¹ (184.12), yield plant⁻¹ (497 g), yield

of red ripe chilli (120.48 q ha⁻¹) and yield of dry chilli (28.82 q ha⁻¹) as compared to other treatments.

Nasreen and Farid (2006) concluded that, greater sulphur utilization was observed at lower levels of fertilizer application. Seed yield and sulphur uptake were increased with the application of 40 kg/ha for sohag and 60 kg/ha for Bangladesh soybean-4. Response of seed yield to added sulphur was quadratic. The economic optimum doses were found to be 49 kg S/ha for Sohag and 52 kg S/ha. for Bangladesh soybean-4, yielding 2060 and 2354 kg/ha, respectively.

Dayem *et al*, (2007) pointed out that, the treatments with B at 25 ppm and K at 500 ppm with 60% of available soil moisture gave the highest values of vegetative growth compared with the control especially root length.

Rahman *et al*, (2008) noticed that, the highest grain (5.76 t ha⁻¹) and straw (7.32 t ha⁻¹) yields were recorded in the S20 Zn3 treatment (100% recommended dose). The S0Zn0 (control) had the lowest grain yield with 4.35 t ha⁻¹ as well as the lowest straw yield with 5.47 t ha⁻¹. The application of both S and Zn fertilizers significantly increased S and Zn contents as well as their uptake over control.

Patil and Dhonde (2009) reported that, the mean grain yield was significantly highest at 50 kg K₂O ha⁻¹ (11.98 q ha⁻¹) and was statistically at par with 37.5 kg K₂O ha⁻¹ (11.55 q ha⁻¹).

Mollah *et al*, (2010) indicated that, the nutrient content in grain was the highest N, P, K, Na, Ca, Mg, S are 1.279, 0.0415, 0.2017, 0.0785, 0.1607, 0.3187, 0.187% and Zn, Cu, Fe, Mn are 10.77, 8.963, 185.30, 61.33 ppm, respectively. on the other hand, the highest content of N, K, Na, Ca, S are 0.709, 5.040, 0.0760, 0.3739, 0.208% was found in straw, respectively and Zn, Cu, Fe, Mn are 56.65, 55.79, 263.7, 548.8 ppm, respectively. It is apparent that Zn-2 induced highest accumulation of P, Zn, Cu and Mn in rice grain, whereas in straw this brand induced the highest concentration of N, Fe and Mn. The concentration of Zn in both rice grain and straw appeared less in amount in most of the treatments as compared to control except that grain due to Zn-2.

Deshbhratar *et al*, (2010) noted that, significant increase in grain yield (14.81 q ha⁻¹) and straw yield (41.26 qha⁻¹) of pigeon pea after 20 kg S ha⁻¹ and 50 kg P₂O₅ ha⁻¹ treatment with common dose of nitrogen @ 30 kg ha⁻¹. The increase in grain and

straw yield was 102.77 and 52.87% as compare to higher over control. Maximum number of pods plant⁻¹, maximum number of grains pod⁻¹ and test weight by this treatment was also observed as compared to control. Application of S and P improved soil fertility status and S alone did not influence P availability. Hence, in order to maintain the fertility status of the soil at high level, combine application of 20 kg S ha⁻¹ with 50 kg P₂O₅ ha⁻¹ is essential. The residual fertility status of soil is advocated for *rainfed* pigeonpea crop grown on Vertisol in Vidarbha region

Farhad *et al.*, (2010) reported that, potassium showed significant effect on yield and yield attributes of soybean. Application of potassium @ 40 kg ha⁻¹ produced the highest plant height, seed yield, 1000 seed weight and straw yield. Sulphur fertilizer also had significant effect on yield and yield attributes of soybean. Application of sulphur @ 20 kg ha⁻¹ produced the highest plant height, seed yield, 100 seed weight and straw yield. Potassium in combination with sulphur showed significant effect on yield and yield attributes of soybean combined application of potassium @ 40 kg ha⁻¹ and sulphur @ 20 kg ha⁻¹ resulted the highest seed yield, plant height, 1000 seed weight, straw yield, protein and oil contents of soybean. On the other hand, in all the cases the lower response was found from the control treatment.

Arbad and Ismail (2011) reported that, the maximum nutrient total uptake of N, P and K in soybean and safflower was recorded due to application of 100% NPK+FYM @ 10 Mg/ha where as maximum total sulphur uptake in soybean (19.58 kg/ha) and in safflower (18.19 kg/ha) was recorded in treatments applied with 150% NPK and 100% NP + on residual effect of FYM respectively. Zinc uptake was maximum with 100% NPK + FYM @ 10Mg/ha and in safflower it was recorded highest in 100% NP + residual effect of FYM. And also noticed that after contiguous intensive cropping under various fertilizers with FYM treatment improvement occurred in the grain and straw yield and status of soil pH, EC, organic carbon, available N, P₂O₅, K₂O, S and DTPA extractable Zn. Use of FYM and micronutrients helped in maintain soil fertility. Highest net returns were recorded with 100% NPK+FYM.

Lee *et al.*, (2011) reported that, plants with higher N content not only had higher chlorophyll content but also had thicker, flatter and more turgid leaves, which enhances visible light absorption while stimulating near infrared reflection. Derivative

type predictors, using the transition region from red and near infrared wavebands, not only accumulated from changes in leaf chlorophyll content and structures induced by varied N content, but helped eliminate background soil interferences. Therefore, derivative type predictors may be more appropriate than reflectance values at specific bands and band ratios in establishing a robust model for plant N status assessment.

Sule and Huseyin (2012) revealed that, the application of sulphur and zinc could be a good approach for the nutrition of wheat plants. However, the generated salinity was high for sulphur applications, which means that plants might be faced high salinity problems. Also, with the application of high sulphur to plants, it should be considered that an N-S imbalance can occur. On the other hand, N:S imbalance can occur in crops grown in high N fertility in especially, S-deficient soils. Therefore, the levels of electrical conductivity, pH, texture, CaCO₃ organic matter, sulphur and nitrogen of soils and cultivated plant species should be taken into consideration when recommending sulphur and zinc application to soils.

Singh *et al*, (2012) reported that, maximum (281.2 kg/ha) nitrogen uptake was recorded with 6 kg zinc treatment. However highest uptake of P (91.1 kg/ha) and K (150.4 kg/ha) was recorded in the plot supplemented with no Zn and sulphur at 40 kg/ha, respectively. Soil parameters *viz.*, pH, EC and organic carbon content did not influenced with the S and Zn. N, P, K, S and Zn were affected significantly due to sulphur and zinc nutrition.

Chauhan *et al*, (2013) indicated that, during both the form of zinc oxide i.e. seed yield and oil content were highly significant at K₂₀S₂₀Zn₅ combination dose among all other combination doses. Due to application of K 20kg/ha, S 20kg/ha and Zn 5kg/ha in combination dose, number of nodules increased significantly as compared to control by 91% seed yield increased by 43.2% and 32.7 % oil percentage increased by 1.3% and 1.1% in both the years respectively. It was also observed that when doses of potash and sulphur were increased from 20 kg/ha to 40 kg/ha each, nodule number, seed yield and oil content all decreased.

Kabir *et al*, (2013) noticed that, among the growth parameters plant height, number of branches plant, dry weight plant, LAI and CGR were highest at 100 DAS in P₂ X Ca₁ X B₂ treatment combination. Among the yield attributing characters number of total pods plant⁻¹ was highest for P₁ X Ca X B₂. 100 pod weight plant⁻¹ for

$P_1 \times Ca \times B_1$ shelling percentage, pod yield, biological yield, straw yield and harvest index for $P_2 \times Ca_1 \times B_2$. The lowest values of all these parameters were found at control treatment. The combined dose of P_2 , Ca_1 and B_2 produced the highest values for almost all the above parameters. Thus it can be concluded that the fertilizer level for P, Ca and B should be 50 kg ha^{-1} , 110 kg ha^{-1} and 2.5 kg ha^{-1} , respectively for obtaining the highest yield of groundnut under this particular soil.

Jaga *et al.*, (2013) noticed that, zinc has assumed greater significance due to wide occurrence of its deficiency. The magnitude of sulphur removal is much higher due to intensive cropping.

Ram and Katiyar (2013) reported that, the interaction effect between S X Zn on various parameters of summer mugbean was found significant and test weight was found non-significant during both the years. The interaction effect in seed yield was synergistic. The increasing dose of zinc increased the seed yield with increasing dose of sulphur up to 40 kg S ha^{-1} . The highest seed yield (13.69 and 14.40 q ha^{-1}) was observed in combination with 40 kg S ha^{-1} and 10 kg Zn ha^{-1} which was significantly superior over rest of the combinations except 60 kg S ha^{-1} and 10 kg Zn ha^{-1} during 2008-09 and 2009-10, respectively. The minimum seed yield (9.56 and 10.06 q ha^{-1}) was achieved with treatment having 20 kg S ha^{-1} and 5 kg Zn ha^{-1} and least was in control during both the years.

Jyothi *et al.*, (2013) reported that, yield and yield attributes, quality parameters and nutrient uptake of soybean were significantly influenced by foliar application of nutrients at different stages of crop. An increment of 50, 27.2 and 56.9% was noticed in 100 seed weight, number of pods/plant and grain yield, respectively with 2% urea as foliar application at flowering and at early pod development stage, when compared with control. Higher protein and oil contents (43.9 and 20.9%) and uptake of Zn, N by soybean plants were recorded with the 2% urea as foliar application at flowering and at early pod development in addition to soil application of NPK fertilizer was found to be more beneficial to improve the productivity of soybean than NPK application alone.

Thenua *et al.*, (2014) indicated that, the highest yield of soybean was recorded under 40 kg S/ha , it was closely followed by 30 kg S/ha and application of Zinc @ 30

kg/ha recorded higher yield as compared to its lower levels. Available status of sulphur and zinc in soil after harvest of soybean crop was found non-significant.

Gowthami and Ramarao (2014) concluded that, foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% (T₇) at 30 and 60 DAS was found to be superior in increasing plant height, number of branches, number of leaves, leaf area, total drymatter, number of pods per plant, test weight and seed yield followed by potassium nitrate @ 2 % + boric acid @ 50 ppm at 30 and 60 DAS (T₄), boric acid @ 50 ppm + zinc sulphate @ 1 % at 30 and 60 DAS (T₆) and potassium nitrate @ 2 % + zinc sulphate @ 1% zinc sulphate @ 1% at 30 and 60 DAS (T₅) where as lower values were recorded in control.

Jiang *et al*, (2014) observed that, lower zinc concentration was ineffective in alleviating stress and higher zinc concentration was ineffective in alleviating stress and higher zinc concentration inhibited plant growth because of toxicological damage to plants. The zinc sulfate spray of 15 $\mu\text{mol L}^{-1}$ was found to be the most appropriate at all salinity stress levels. The growth measurements such as true levels part and dry weight of total seedlings were in agreement with the chlorophyll fluorescence parameters, indicating a visible enhancement of leaf photosynthetic activity at 10-20 $\mu\text{mol L}^{-1}$ zinc concentration.

Sharma *et al*, (2014) reported that, the protein quality parameters viz. total soluble protein, free amino acids, sulphur amino acids (methionine and cysteine) and glutathione significantly increased whereas trypsin inhibitor activity decreased under treatments of sulphur and nitrogen in soybean. Nitrogen and sulphur application decreased oil content in soybean. Sulphur alone or in combination with nitrogen significantly increased the proportion of palmitic and linoleic acids and decreased oleic acid in soybean seed.

Ram *et al*, (2014) concluded that, the pH, EC and organic C status of soil did not vary significantly with the application of S, Zn and B. The available N, P and K content in soil ranged between 130 to 134, 34.1 to 40.1 and 200 to 217 kg ha⁻¹, respectively and the variation was also not significant. The CaCl₂ extractable -S content in soil increased significantly due to application of S, Zn and B, however, variation in DTPA-extractable-Zn and hot water extractable B was not significant. The available S, Zn and B content in soil ranged from 15.3 to 24.1, 0.54 to 0.68 and

0.54 to 0.61 mg kg⁻¹. Maximum S content of 24.1 mg kg⁻¹ was observed in T8 and T10 in which S was applied whereas, minimum 15.3 mg kg⁻¹ was recorded in treatment T₁ : (RDF). The study indicated that there is need to apply S, Zn and B along with recommended rate of fertilizer NPK to achieve higher yield of rice in soils of Varanasi. Application of S in rice left residual effect in soil which could be utilized for succeeding wheat crop in the rotation.

Dhage *et al*, (2014) observed that, grain and straw yield, uptake of phosphorus and sulphur increased with increase in the rate of application of P and S individually as well as in various combinations. Applied various levels of P and S also influenced the quality parameters of soybean i.e. protein content and test weight. Available P in soil increased with increasing levels of phosphorus. Similarly available S in the soil increased with increasing levels of sulphur.

Thenua *et al*, (2014) revealed that, the highest yield of soybean was recorded under 40 kg S ha⁻¹, it was closely followed by 30 kg s ha⁻¹ and application of zinc@30 kg/ha recorded higher yield as compared to its lower levels.

Singh *et al*, (2015) reported that, application of 120 kg N+60 kg P₂O₅+40 kg K₂O+15 kg B ha⁻¹ gave maximum plant height plant⁻¹ (65.33cm), number of leaves plant⁻¹ (18.26), length longest leaf (52.99 cm), width of longest leaf (17.98 cm), spread of plant (55.53 cm) and stem diameter (4.47 cm), whereas in control was minimum pronounced plant height plant⁻¹ (58.66 cm), number of leaves plant⁻¹ (12.33), length longest leaf (42.70 cm) width of longest leaf (14.18 cm), spread of plant and stem diameter (3.04 cm). Similar, pattern on the curd diameter (13.69 cm), length of curd (16.33 cm), weight of curd plant⁻¹ (286.89 g), weight of sprout plant⁻¹ (126.89 g), weight of curd and sprout plant⁻¹ (0.390 kg) and total yield Curd + sprout (148.51 q ha⁻¹) was recorded with the application of 120 kg N+60 kg P₂O₅+40kg K₂O+15kg B ha⁻¹ and minimum was under control treatment.

Kobraee and Shamsi (2015) indicated that, zinc and iron had significant effects weingt (p<0.01). Manganese had significant effects on oil, pod, seed and total dry dry weight and plant dry weight, while maximum oil and protein contents and seed dry weight was reduced, although was not statistically significant. The effect of zinc and manganese applications on oil percent in soybean seed was more than protein content.

Gedi *et al*, (2015) found that, the maximum estimated yields on average for the 2 years were obtained with application of 49.9 and 63.0 kg ha⁻¹ in the Typic haplorthox and Typic Eutrorthox soils, for an overall average of 56.4 kg ha⁻¹, with concentrations of available S-SO₄²⁻ in the 0 to 20 cm depth of 16.9, 19 m and 17.1 mg kg⁻¹, respectively, values greater than the 10 mg kg⁻¹ indicated as the adequate concentration for soybean plant. In turn, at the 21-40 cm depth, the S concentrations were 49.5, 74.2 and 56.4 kg ha⁻¹. The efficiency of the fertilization diminished with increasing S rates, in both soil types, while the greater yield efficiency was obtained in the plants grown in the Typic Haplorthox soil.

Dash *et al*, (2015) noticed that, highest significant grain yield of 76.70 q ha⁻¹ was recorded when the crop received all the nutrients (N, P, K, S, B and Zn). The yield was decreased by 19.4-27% due to omission of N, P, K or P, K and by 17.1 - 32.6% in absence of S, B, Zn individually or in combination. Combined application of all the nutrients increased nutrient accumulation and uptake. Omission of N, P, K or N & P from the fertilizer schedule decreased the N, P and K uptake by 40.7-50.5, 13.9-20.4 and 33.0-46.9% respectively. Among the micro and secondary nutrients, deletion of B greatly affect the N, P and K uptake as compared to Zn and S. Integrated use of N, P and K with S, B and Zn recorded highest grain yield response (37.23 kg grain per kg of the fertilizer applied.) It was reduced by 44-49% in absence of P or K and by 8% in absence of B, Zn, S.

Singh *et al*, (2015) concluded that, application of 120 kg N+60 kg P₂O₅+40 kg K₂O+15 kg B ha⁻¹ gave maximum plant height plant⁻¹ (65.33 cm), number of leaves plant⁻¹ (18.26), length longest leaf (52.99 cm), width of longest leaf (17.98 cm), spread of plant (55.53 cm) and stem diameter (4.47 cm), whereas in control was minimum pronounced plant height plant⁻¹ (58.66 cm), number of leaves plant⁻¹ (12.33), length longest leaf (42.70 cm) width of longest leaf (14.18 cm), spread of plant and stem diameter (3.04 cm). Similar, pattern on the curd diameter (13.69 cm), length of curd (16.33 cm), weight of curd plant⁻¹ (286.89 g), weight of sprout plant⁻¹ (126.89 g), weight of curd and sprout plant⁻¹ (0.390 kg) and total yield Curd+sprout (148.51 q ha⁻¹) was recorded with the application of 120 kg N+60 kg P₂O₅+40 kg K₂O+15 kg B ha⁻¹ and minimum was under control treatment.

Suganiya and Harris (2015) concluded that foliar application of H_3BO_3 at 150 ppm (at flowering stage) could increase the percentage of flowering, fruits set and fruit yield per plant of ratoon crop of brinjal.

Adsul *et al.*, (2015) revealed that the treatment RDF+S @ 30kg/ha +B @ 1kg/ha to *kharif* sunflower recorded maximum seed yield (1377 kg/ha) and at par with treatment T₆ (RDF+S @ 30kg /ha+B@1kg/ha). T₇ (RDF+S 20 kg/ha +B spray @ 0.2%) and T₉ (RDF+S @ 30kg/ha +B spray @ 0.2%) and was found significantly superior over rest of treatments. Lowest seed yield 1035 kg/ha was recorded in treatment receiving RDF only (T₁) maximum number of filled seeds per plant (544) was found in treatment T₈ as compared to other treatments. As regards straw yield the treatment T₉ (RDF+S 30kg/ha + B spray @ 0.2% recorded maximum straw yield (1465 kg/ha) and was found at par with treatment T₄ (RDF+B @ 1 kg/ha) T₃ (RDF+B spray @ 0.2%) and T₈.

Seidel *et al.*, (2015) concluded that the application of the foliar fertilizer with calcium and Boron, applied 30 days after germination did not affect yield components and soybean yield during successive seasons 2009-2010 and 2010-2011.

Madhavi *et al.*, (2015) concluded that the mean seed yield of soybean was highest (1643 kg/ha) when S was applied in two splits (1/2 as basal +1/2 at 30 DAS) followed by full dose as basal (1513 kg/ha) and at 30 DAS (1395 kg/ha). It was found that a minimum of 30 kg S/ha is needed to obtain good yields of soybean although higher level of its application had beneficial effect on the crop, albeit, to an extent of 4-5% for increase of sulphur to 40 kg/ha. Sulphur application in two equal splits as basal and at 30 DAS has increased the S use efficiency in soybean seeds by 128.6 and 150.7% compared to single time application either as basal or at 30 DAS respectively. Though the utilization of applied S by soybean was found to be higher at 30 kg S/ha. level (16.8%) compared to 40 kg S/ha. (14.60%) the difference was not much.

Jaliya *et al.*, (2016) concluded that, mean grain protein content of quality protein maize (QPM) was significantly affected by interaction effects of nitrogen and sulfur rates. Higher grain protein content were observed with interaction of 120 kg N/ha. and 5 kg S/ha. in 2006, 120 kg N/ha and 10 kg S/ha. in 2007, 60 kg N/ha and 15 kg /ha in 2008 cropping season. This indicates application of nitrogen with sulfur rates enhances grain protein content of quality protein maize; hence consumption of

QPM will in addition to carbohydrate provide protein required by the body. This study therefore recommends QPM producers should apply nitrogen along with sulfur in order to improve grain protein content of quality protein maize in Zaria area and similar agro ecology.

Dar *et al*, (2017) indicated that, full dose of calcium nitrate (1450 g) and boron (50 g) was applied in spring recorded maximum total sugars (2.71 %) after 4 days of storage. Similar trend was recorded for total sugars at 8, 12, 16 and 20 days of storage. Application of calcium nitrate @ 1450 in spring was beneficial for minimum physiological loss in weight and maximum total soluble solids and total sugars for storing Santa Rosa plum for 20 days under ambient conditions.

Jyothi *et al*, (2017) noticed that, among the different treatment combinations, a significantly higher seed cotton yield (2283 kg ha⁻¹) was recorded in treatment receiving 150:50:75 kg N:P₂O₅:K₂O ha⁻¹ (N₃P₁K₂) during both the years of experimentation. However, the treatment N₂:P₂:K₃ (125:50:100 kg N:P₂O₅:K₂O ha⁻¹) was on par with N₂P₁K₂. The interaction effect of nitrogen, phosphorus and potassium failed to exert significant influence on fiber quality parameters except for ginning out turn.

Singh *et al*, (2017) concluded that, application of sulphur and zinc to soybean increased all the growth and yield attributes of soybean but significant increase up to 40 kg s ha⁻¹ and 30 kg Zn ha⁻¹ were observed in plant height, number of branches per plant at all stages, seed yield and protein content in seed of soybean. The zinc level also had significant influence on number of pods/ plant, number of grain per plant, pod length, pod weight per plant, test weight, grain weight per plant. Highest level of zinc @ 30 kg/ha was found at par with Zn@20 kg/ha during the investigation.

2.2 Response of soybean for foliar application of KNO₃, Borax, NAA and GA.

a) Response of soybean for foliar application of KNO₃ and Borax.

Howard *et al*, (2000) found that, foliar K and/or B solutions buffered to pH 4 increased first harvest and total lint yields more than unbuffered or solutions buffered to pH 6 did. Foliar B+K solutions buffered to pH 4 increased total yields by 15.9%, while foliar K solutions buffered to pH 4 increased yields by 13.8% and foliar B solutions buffered to pH 4 increased yields 10.3% above the check yields.

Manurkar, (2001) reported that, the grain and straw yield of soybean influenced by application of potassium at different rates. Significantly maximum grain yield (15.98 qha^{-1}) of soybean noted with recommended dose of nitrogen and phosphorus along with K_2O @ 90 kgha^{-1} . Similarly, maximum straw yield (28.82 qha^{-1}) was recorded with soybean crop receiving recommended dose of nitrogen and phosphorus along with K_2O @ 90 kgha^{-1} .

Kharwade, (2002) reported that, significantly maximum pod yield (2480 kgha^{-1}) and kernel yield (1700 kgha^{-1}) of groundnut crop was recorded with application of RD NP with K @ 75 kgha^{-1} in combination with S @ 60 kgha^{-1} . Similarly, quality parameters of groundnut viz., oil yield (711 kgha^{-1}) and test weight ($32.47 \text{ g/100 seeds}$) were recorded with groundnut crop fertilized with RD NP + $75 \text{ kg K}_2\text{O/ha}$. Among sulphur levels, the groundnut crop receiving S @ 60 kg/ha produced maximum oil yield (781 kgha^{-1}) and highest test weight ($32.26\text{g}/100 \text{ seeds}$).

Kausadikar *et al*, (2003) reported that, among graded levels of nitrogen 90 kg N ha^{-1} significantly out yielded for pods plant^{-1} , 1000 seed weight, crude protein, seed yield and straw yield. Among the different levels of phosphorus $90 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$ produced significantly maximum pods plant^{-1} , crude protein and seed yield but straw yield and 1000 seed weight could not reach the level of significance. Application of potassium did not affect any of the yield components. Interaction effect of the different treatment combinations were found to be non significant except crude protein which was significantly enhanced up to 40.52 per cent with 90 kg N ha^{-1} and $90 \text{ kg P}_2\text{O}_5 \text{ ha}^{-1}$.

Dhawan *et al*, (2006) revealed that, all the treatments of soil and foliar potassium application were significantly superior in producing number of sympodia, open bolls per plant, plant height, boll weight and seed cotton yield than application of N and P alone. The cotton crop with NPK and K foliar spray @ $5 \text{ kg K}_2\text{O/ha}$ at early and peak boll formation stages has produced significantly higher number of sympodia (13.9 per plant), open bolls (21.00 per plant), boll weight (2.86 g per boll), height (116.9 cm and seed cotton yield 1229 kg/ha .) over potassium fertilization to soil alone followed by NPK+ K foliar at peak boll formation stage. Among the fiber quality parameters, GOT per cent was found to be significantly higher in cotton crop fertilized with NPK and K foliar spray @ $5 \text{ kg K}_2\text{O/ha}$ at early and peak boll formation stages.

Karthikeyan and Shukla (2008) reported that, the interaction effect between boron and sulphur significantly and synergistically influenced the dry matter and seed yields of sunflower and mustard crops, which were observed the highest at 60 mgkg⁻¹ of S in conjunction with 2 mgkg⁻¹ of boron. The oil and protein content of sunflower and mustard were significantly and synergistically improved by the application of both sulphur and boron.

Dhar *et al*, (2009) observed that, recommended dose of fertilizer K, mining of native K under rice sequence would be to the extent of 9%, which could be reduced by applying higher rate of K than the recommended level. This will help in sustaining the productivity of these crops

Farhad *et al*, (2010) concluded that, potassium showed significant effect on yield and yield attributes of soybean. Application of potassium @ 40 kg ha⁻¹ produced the highest plant height, seed yield, 1000 seed weight and straw yield. Sulphur fertilizer also had significant effect on yield and yield attributes of soybean. Application of sulphur @ 20 kg ha⁻¹ produced the highest plant height, seed yield, 1000 seed weight and straw yield. Potassium in combination with sulphur showed significant effect on yield and yield attributes of soybean. Combined application of potassium @ 40 kg ha⁻¹ and sulphur @ 20 kg ha⁻¹ resulted the highest seed yield, plant height, 1000 seed weight, straw yield, protein and oil contents of soybean. On the other hand, in all the cases the lower response was found from the control treatment.

Ahmed *et al*, (2011) found that, maximum dry matter yield was achieved by addition of 3.0 kg B ha⁻¹. Crop planted during season 2005 produced higher quantity of biological yield compared to year 2004. The addition of various levels of boron caused substantial increase in the uptake of nitrogen, phosphorus, potassium, copper, iron, zinc and boron nutrients, while lowering down of calcium magnesium and manganese in different parts of the cotton plant. The enhanced assimilation of macro-nutrients resulted in greater production of biological yield and better growth and development of cotton plant.

Kumar and Sidhu (2013) reported that the combined applications of sulfur and boron yielded highest oil content with B0.44S13.4 (21.7%) treatment level. Chlorophyll 'a' and 'b' increased significantly with successive levels of sulphur and

boron addition at 55 DAS. The mean sulfur and boron uptake in straw and grains increased significantly with increasing levels of sulfur and boron up to 13.4 mg kg⁻¹ and 0.44 mg kg⁻¹ and decreased non-significantly thereafter. At both the growth stages, a synergistic interactive effect of combined application of sulfur and boron was observed with B0.44 S13.4 treatment level for sulfur and boron uptake in straw and grains.

Chauhan *et al*, (2013) observed that, during both the years, number of nodules, seed yield and oil content, were highly significant at K₂₀S₂₀Zn₅ combination dose among all other combination doses. Due to application of K 20 kg/H, S 20kg/h and Zn 5 kg/h in combination dose, number of nodules increased significantly as compared to control by 91% seed yield increased by 43.2% and 32.7% oil percentage increased by 1.3% and 1.1% in both the years respectively. It was also observed that when doses of potash and sulphur were increased from 20 kg/ha to 40 kg/h each, nodule number, seed yield and oil content all decreased.

Radhika *et al*, (2013) found that, foliar application of micronutrient mixtures during flower and boll development stages have been shown to be effective in efficient utilization of nutrients by cotton and thereby reduce boll shedding and increase the yield. Keeping this in view, the literatures on foliar application of micronutrients on the growth, yield and quality of cotton are reviewed in this paper.

Ram *et al*, (2014) reported that, the highest grain yield, protein, oil content, gross and net returns of soybean were recorded with 40 kg S/ha., which were statistically at par with 30 kg S/ha but significantly higher than higher levels of S. The productivity in 40 kg S/ha were enhanced 61.9% over the absolute control. The B level of 1.5 kg/ha. Recorded highest grain yield, gross and monetary returns, being statistically at par with 1.0 kg B/ha, respectively. The highest grain yield recorded in 40 kg S/ha. and 1.5 kg. B/ha. was statistically at par with 40 kg S/ha. and 1 kg B/ha, 20 kg S/ha and 1.5 kg B/ha. and 30 kg S/ha and 1.5 kg B/ha. Treatments but was significantly higher than all other combinations of sulphur and boron.

Gowthami and Ramarao (2014) concluded that, foliar application of potassium nitrate @ 2%+ boric acid@ 50 ppm+ zinc sulphate @ 1% at 30 and 60 DAS was found to be superior in increasing the CGR , RGR, NAR, LAI, SLW, LAR and seed yield followed by potassium nitrate @ 2 % + boric acid @ 50 ppm at 30 and 60 DAS,

boric acid @ 50 ppm+ zinc sulphate @ 1% at 30 and 60 DAS and potassium nitrate @ 2%+zinc sulphate @ 1% at 30 and 60 DAS where as lower values recorded at control.

Dey *et al*, (2014) reported that, five soil B fractions were determined along with hot CaCl_2 extractable (available) B. Readily soluble, specifically adsorbed and organically bound B fractions were significantly greater under continuous use of NPK+FYM compared with other treatments, resulting in higher values of available B in NPK+FYM treatment. Soil organic C and cation exchange capacity were the important soil characteristics that governed the distribution of soil B in different fractions. Organically bound and specifically adsorbed B appeared pivotal regarding the availability of native B for plant uptake.

Seidel *et al*, (2015) concluded that, the treatments consisted of applying commercial fertilizer on the basis of calcium and boron (10% Ca^{2+} and 0.5% of B). Foliar fertilizer containing Ca^{2+} and B was applied 30 days after germination, when the plants were at the R3 stage. Also, five rates of commercial product (0, 1.5, 2.5, 3.5 and 4.5 L ha⁻¹) were applied. Analyzing the results, it was concluded that the application of the foliar fertilizer with calcium and boron, applied 30 days after germination did not affect yield components and soybean yield during successive seasons 2009-2010 and 2010-2011.

Ali *et al*, (2015) reported that, application of boron significantly increased the concentrations of boron nutrients ratios such as K/B; Cl/B and Mn/Fe were decreased while K/Cl and Zn/Cu ratios were increased at lower boron concentrations but decreased at higher concentrations of boron. The fertilizer use efficiency of both the cultivars showed similar trend; The overall results revealed that the application of boron should be encouraged for balancing nutrients concentration, thus getting higher yield in the prevailing conditions.

Rathod *et al*, (2016) reported that, the grain (25.52 q/ha) and straw yield (37.29 q/ha) of soybean was significantly increased due to application of 1 LR + Zn and B through soil and foliar spray showed maximum uptake of zinc (260.10 g/ha. By grain and (375.65g/ha) by straw.

Chaithra and Hebsur (2018) revealed that, RPP along with Soil (@ 2.5 kg ha⁻¹) + foliar (@0.5%) application of solubor improved the growth and yield parameters

of soybean significantly. However, soil application of solubor @ 5 kg ha⁻¹ recorded the higher number of effective nodules per plant (18.64). Seed yield (2806 kg ha⁻¹) response of soybean (16.97% more yield than RPP) recorded with RPP + soil (2.5 kg ha⁻¹) and foliar (0.5%) application of solubor was significant except that recorded with soil (5 kg ha⁻¹), soil (5 kg ha⁻¹) + foliar (0.5%) and only foliar (0.5%) application of solubor. However, slightly higher benefit cost ratio (2.97) was observed with foliar application of solubor (@ 0.5%).

Hanwate *et al.*, (2018) noticed that, foliar applications of micronutrients on soybean influenced significant and maximum nutrient uptake of soybean i. e. 174.18, 181.55 and 186.39 kg N ha⁻¹, 16.84, 17.81 and 19.23 kg P ha⁻¹, 128.17, 134.35 and 141.13 kg K ha⁻¹ and 18.96, 21.12 and 24.34 kg S ha⁻¹ were recorded at flowering, pod formation and harvesting stage of soybean crop with application of T9 treatment, which received RDF along with seed fortification of Mo and foliar application of Zn and Fe.

Krishna and Kaleeswari (2018) recorded that, application of 0.5 % KNO₃ + 2% DAP + micronutrient spray along with soil application of 100% RDF to red gram recorded the maximum value of yield attributes. Quality parameters such as seed protein content and seed total free amino acid content were enhanced by the foliar application of 0.5% KNO₃ + 2% DAP + micronutrient spray. Application of 100 % RDF and foliar spraying of 0.5% KNO₃ + 2% DAP + micronutrient recorded the highest macro and micronutrient uptake. Availability of N, P, K, Fe, Mn, Zn, Cu and B contents in soil at different stages was significantly influenced by the various foliar applications. The chlorophyll a, b and total chlorophyll contents were found to be highest in the treatment that receiving 100% RD NPK + foliar spray of 0.5% KNO₃ + 2% DAP + micronutrients.

b) Response of soybean for foliar application of NAA and GA.

Bensen *et al.*, (1990) concluded that, the GA, content in the elongating region of hypocotyls had declined to 38% of the 0 time value at 24 hours after transfer to low vermiculite, a level which was only 13% of the GA, content in control seedlings at the same time (24 hours post transfer). Dewatering seedlings following 24 hours growth in low vermiculite resulted in a complete recovery in elongation rate, an increase in GA, 20% at 2 hours, two fold at 8 hours, eightfold at 24 hours, and a decrease in

ABA levels (tenfold at 2 hours). Treatment of well watered seedlings with the GA-synthesis inhibitor tetcyclacis (TCY) resulted in lowered GA₃ levels and increased ABA levels. When seedling grown 24 hours in low vermiculite were re watered with TCY, recovery of the elongation rate was delayed and reduced, and the decline in ABA levels was slowed. Addition of GA₃ restored the elongation rate inhibited by TCY. Seedlings were growth responsive to exogenous GA₃, and this GA₃ promoted growth was inhibited by exogenous ABA. The data are consistent with the hypothesis that changes in GA₃ and ABA levels play a role in adjusting hypocotyls elongation rates. However, the changes observed are not of sufficient magnitude nor do they occur rapidly enough to suggest they are the primary regulators of elongation rate responses to rapidly changing plant water status.

Bhagel and Yadav (1991) reported that, growth regulators promote growth in urdbean. The AGR for dry matter was very fast during active growth period of 51-60 days after sowing i.e., pod development stage. The application of planofix 40 ppm and ethrel 50 ppm recorded higher AGR for dry matter during active growth phase of the crop. The RGR was very fast during growth period (31-40 DAS). The application of planofix 40 ppm or ethrel 100 ppm recorded maximum value of RGR at 31-40 days stage. The mean NAR computed from the total dry matter and leaf area revealed that it was maximum during 41-50 DAS. The maximum NAR was recorded with application of planofix 40 ppm or ethrel 50 ppm during 41-50 DAS.

Liu *et al.*, (1996) revealed that, decline of peroxidase activity was accompanied by a decrease of lignin content during root formation. Caffeic acid and ferulic acid, two critical phenolic compounds for lignin synthesis, accumulated in NAA-treated tissues. Consequently, the increased IAA levels with a decrease of IAA oxidase activity accompanied a lower lignin content and a reduced peroxidase activity in NAA-treated tissues suggests that the induction of adventitious roots by NAA in soybean cuttings may be due to the higher IAA levels accumulated in tissues.

Fatima and Bano (1998) reported that, greater seed oil content were found in ABA and Kinetin treatment. Maximum ash content and seed weight were found in kinetin treated seed as compared to control. The absorbance for ethylene at 412 nm of nodules was found to be significantly different from that of the control with maximum value recorded in Kinetin and minimum in IAA treated seeds.

Tagade *et al*, (1999) found that, 100 ppm IAA and 25 ppm kinetin were found to be the most effective in increasing growth and seed yield of the crop. Both the treatments were significantly superior over the rest of the treatments and control.

Sarkar *et al*, (2002) reported that, GA₃ at 100 ppm had regulatory effect to enhance the plant height, number of branches, number of leaves, leaf area per plant, number of flowers, number of pods, percentage of fruit set, number of seed per plant, seed yield per plant, 100 seeds weight and seed yield (t ha⁻¹). On the other hand, 100 ppm IAA produced the highest plant height, number of flowers, number of pods, percentage of fruit set, number of seed per plant, seed yield per plant and seed yield (t ha⁻¹), as compared to other plant growth regulators and control IAA at 200 ppm increased number of branches, number of leaves, leaf area per plant, 100 seeds weight and net assimilation rate.

Kalpana *et al*, (2003) found that the combined application of DAP, KCl, boron and NAA registered higher mean grain yield (1612 kg ha⁻¹) over DAP 2% (1423 kg ha⁻¹) and water spraying (1353 kg ha⁻¹) and was significantly higher over these two treatments during both the seasons. The irrigation layouts failed to produce any significant effect on seed quality and nutrient uptake. The protein content was significantly higher in foliar treatments receiving DAP either alone or in combination. The oil content recorded was higher due to foliar application of DAP and KCl with or without boron.

Senthil *et al*, (2003) showed that all the treatments increased the chlorophyll, soluble protein content, nitrogenase and peroxidase activity significantly high over the control. Among the treatments, salicylic acid (SA) (60 ppm) performed well over all other treatments in all the physiological parameters.

Basole *et al*, (2003) reported that, application of hormone and nutrients increased chlorophyll, phosphorus, potassium and nitrogen content significantly in treatments ½ RDF + NAA + KNO₃ (T₈) ½ RDF + NAA + ZnSO₄ (T₉) and ½ RDF + NAA + MgSO₄ (T₁₀) over RDF (T₀) and other treatments. Protein and oil content in seed were also increased significantly in ½ RDF + NAA + ZnSO₄ (T₉), and ½ RDF + NAA + KNO₃ (T₈) treatments respectively. Yield plant⁻¹ also increased significantly in treatments ½ RDF + NAA + ZnSO₄ (T₉) and ½ RDF + NAA + KNO₃ (T₈).

Leite *et al*, (2003) observed that, foliar application of GA, led to an increase in plant height, first node height and stem diameter. Leaf area and dry matter production also increased as a result of GA₃ foliar application. There was no effect of exogenous gibberellin and cytokinin on the number of soybean leaves, number of stem branches and root dry matter. Joint application of gibberellins and cytokinin tended to inhibit gibberellins effects. Cytokinin applied to leaves during soybean vegetative growth was not effective in modifying any of the evaluated plant growth variables.

Kothule *et al*, (2003) revealed that, among all the treatments SA @ 200 ppm was found to be most significant in increasing number of pods per plant (59.00), number of grains per pod (3.00), weight of grains per pod (0.467 g), weight of straw per plant (17.98 g), 100 seed weight (14.10 g), grain yield per plant (58.80 g) and harvest index (48.55 %). Also the study of correlation between yield and yield components of soybean revealed that seed yield per plant possesses significant positive association with dry matter, leaf area, number of pods per plants, number of grain per pod, 100 seed weight, harvest index and plant height.

Rahaman *et al*, (2004) founded that, GA, was more effective than MH GA, at 100 ppm followed by GA₃ at 200 ppm produced the highest number of branches, leaves, flowers, pods per plant, number of seeds per pod, seed yield per plant, 100-seed weight and seed yield (t ha⁻¹) while 200 ppm MH was least effective to produce them. The present study clearly shows that almost all the plants treated with growth regulators performed better than control. However, interaction effect indicated that 100 ppm GA, treated plants sprayed at 30 DAS (T₂C₃) showed the best performance.

Singh *et al*, (2005) found that, proline content is embryo -axis increased with increasing salinity but it decreased in cotyledons. IAA treatments also enhanced the proline content in comparison to control in embryo-axis, where as it reduced in cotyledons. Pre-sowing seed soaking in IAA enhanced protein and total sugar content in embryo-axis but decreased it in cotyledons showing the enhanced mobilizing of the reserve food materials. IAA at 100 ppm was the best treatment in alleviating the adverse effect of salinity on protein and sugar content in embryo-axis.

Kumar *et al*, (2006) founded that, the application of growth retardants, TIBA, mepiquat chloride and cycocel were more beneficial in terms of translocation of photo assimilates towards developing reproductive parts as compared to growth promoter

kinetin and control. The genotype JS-335 recorded significantly higher percentage of dry weight of reproductive parts and higher shelling percentage as compared to the genotype MACS-124 which was mainly due to its determinate growth habit.

Kalyankar *et al.*, (2007) reported that, GA at 150 ppm increased plant height, number of leaves and leaf area. NAA at 100 ppm level was effective to increase total dry weight. CCC at 250 ppm was effective to increase number of grains/pod, 100 seed weight and grain yield in soybean variety MAUS 61-2.

Salunke *et al.*, (2008) reported that, the foliar sprays of plant growth regulators were given at four times from 21 DAS at an interval of 15 days. The variety V1 (JS-335) recorded higher grain yield ($q\ ha^{-1}$) than Phule Kalyani and were at par with each other. The treatment T₂ (NAA 50 ppm) recorded highest grain yield ($14.39\ q\ ha^{-1}$). The treatment differences were statistically significant indicating differential response of PGRs. The treatments T₁, T₂, T₃ and T₅ were found superior over T₆ (water spray), whereas the treatments T₁, T₂, T₃, T₄ and T₅ exhibited superiority over T₇ (Absolute control.). Therefore, it can be broadly concluded that the variety, JS-335 (V₁) was found to be promising followed by variety Phule Kalyani (V₂) in major yield contributing characters and morphological traits. Among the PGR treatments NAA (50 ppm) was found to be the best.

Aucharmal *et al.*, (2008) revealed that, application of planofix at 40 ppm and ethrel at 50 ppm recorded higher AGR during active growth period as compared to other treatments of the same growth regulators.

Kakad *et al.*, (2008) revealed that, seed lots treated with various chemicals increases the oil %, protein %, yield and yield attributing characters $plant^{-1}$. Among the seed lots seed lot (L₁) recorded higher oil % protein per cent and seed yield $plant^{-1}$.

Kalyankar *et al.*, (2008) founded that, all the concentrations of GA₃, NAA and CCC increased the number of pods per plant, number of grains per pod, 100 seed weight, harvest index, grain yield and biological yield significantly than the control. The use of NAA 50 ppm and 100 ppm had significant positive effects on number of pods per plant and biological yield (q/ha). Similar results in soybean due to growth regulators were reported by mehetre and Lad (1995). The treatment CCC 250 ppm (T₇) was found significantly superior over control to increase number of grains per

pod, 100 seed weight, however, it was found at par with rest of all treatments. The next best treatment was CCC 200 ppm (T_6) to increase number of grains per pod over control. However, it was found at par with all the treatments. The same treatment (T_6) was found to be significantly superior for grain yield (q/ha) and harvest index over control.

Khandagale *et al*, (2009) concluded that, among the growth substances GA₃ 200 ppm maintain highest chlorophyll content in leaves. The varietal differences due to spray of growth regulators significantly influenced the yield and yield contributing characters such as number of capitula, number of seeds, 100 seed weight and harvest index. The variety Parbhani 12 recorded highest oil content amongst other varieties. All the growth regulators sprayed recorded significant increase in oil content over control. Amongst all treatments IBA 200 ppm recorded higher oil content. Application of IBA 200 ppm had most positive effect on yield and yield contributing characters. The interaction effect of variety Parbhani 12 and IBA 200 ppm was found to be best to increase seed yield as compared to other treatments.

Ameyaw *et al*, (2009) found that, the chemical significantly increased the chlorophyll and total soluble carbohydrate contents while that of the carotenoid was not significant, although the chemically treated plants maintained higher levels than the control. Finally, the 30 ppm treated plants yielded more than the 20 ppm as well as 0 ppm.

Kaya *et al*, (2010) reported that, significant differences were detected for cultivars, sowing dates and seed treatments. 100 seed weight, harvesting index, seed yield and protein content were recorded as 32.7-44.2g, 38.7-54.1%, 63.1-180.3 kg/da and 20.1-27.3%, respectively. 100 seed treatments. On the other hand, protein content was highly affected from late sowing and gibberellic acid (GA₃) treatments. It was concluded that early sowing along with 100 ppm GA₃ and dH₂O treatments could be practiced to obtain higher seed yield in chickpea.

Kalpande *et al*, (2010) concluded that, foliar application of nutrients using water soluble fertilizers is one possible way to avoid such losses of phosphoric fertilizer. The foliar application of super phosphate and diammonium phosphate was found beneficial than soil application.

Shinde *et al*, (2010) revealed that, the growth parameters *viz.*, leaf area, LAI, LAD, SLW, BMD, CGR, AGR, RGR and NAR increased significantly due to PGRs. The cycocel was effective in increasing CGR, SLW and BMD whereas, progibb was very effective in increasing in leaf area, LAI and LAD. Biochemical parameters *viz.*, chlorophyll 'a' chlorophyll 'b' total chlorophyll content and NRA were significantly higher with the application of CCC (500 ppm). Seed oil content was found to be superior with the application of PGRs. The seed yield plant-1, number of seeds plant-1, number of pods plant-1 and 100 seed weight increased significantly due to growth regulators. The application of CCC (500 ppm) recorded significantly highest seed yield in both the genotypes followed by Progibb (60 ppm) and TIBA (100 ppm). From the economic point of view, CCC (500 ppm) was more profitable in terms of net returns.

Aslam *et al*, (2010) concluded that, it was concluded that plant growth regulator (NAA) with 80% Available soil moisture depletion level may be better to achieve higher seed yield and yield components in chickpea.

Chohan and Raina (2010) founded that, these growth regulators were applied at bud initiation stage and 50 per cent flowering of the crop. Among the physiological parameters, maximum grain yield (24.83) g/plant, biological yield (50.60 g /plant), test weight (172.67 g/plant) and leaf area, dry matter accumulation, RGR, NAR, CGR were recorded in NAA 20 ppm concentration. Correlation analysis revealed that grain yield was positively correlated with all the physiological parameters of different stages of crop.

Yadlod and Kadam (2010) concluded that, maximum pulp to peel ratio (2.83) was recorded in treatment, IAA 80 ppm and minimum in control (2.41). Maximum total sugar (15.90%) and reducing sugar (12.09%) was observed in GA, 80 ppm and two sprays of 1% micronutrient mixture, respectively. Highest TSS (20.71%) were recorded in IAA 80 ppm. Highest non reducing sugar (3.92%) and maximum Vit. C (0.96) was recorded in GA, 80 ppm while maximum pH (5.39) was found in two spray of 1% micronutrient mixture.

Mondal *et al*, (2011) revealed that, foliar application of N and N plus micronutrients had no significant influence on harvest index and grain protein content but had significant influence on yield attributes and yield. The effects were much

more pronounced in bold seeded genotype, MB-16 compared to small seeded genotype, MB-35. Results suggest that foliar application of N and micronutrients at reproductive stage appears effective in improving mungbean seed yield.

Deotale *et al*, (2011) found that, considering the cow urine concentrations 6% cow urine spray and 50 ppm NAA alone and in combination were found more effective in enhancing the morphophysiological, chemical biochemical and yield and yield contributing parameters when compared with control.

Sapkal *et al*, (2011) found that, foliar application of GA3 (50 ppm) recorded significantly more plant height (41.66 cm) at 50% flowering stage which was at par with T2 NAA 50 ppm (40.83 cm). GA3 50 ppm showed maximum final plant count in net plot recorded 188 plants per plot which was at par with T2 NAA 50 ppm 187 plants per plot. The growth hormone GA3 50 ppm was significantly produced more number of pods per plant (39.18), number of seeds per plant (90.7), yield per plant (8.13 g), yield per plot (1.33 kg) and yield per ha (27.23 q/ha) followed by T2 NAA 50 ppm over other PGRs.

Azizi *et al*, (2012) found that, the highest seed yield (4240 kg/ha) was achieved with 125 PPM of GA3 and the M11 genotype while the lowest seed yield (1620 kg/ha) was produced from 375 PPM of GA3 and the L17 genotype. The main impact of different levels of GA3 was a decreasing effect on the parameters of pod number per plant, 1000-seed weight, biological yield, and seed yield. There was a significant positive correlation (0.903) between biological yield and seed yield that indicated the highest correlation among all the measured parameters ($p < 0.01$).

Rahdari and Sharifzadeh (2012) found that, by increasing NAA hormone concentration, the amount of chlorophyll a has increased and in BA treatment up to 1.5 mg/l it was seen increasing and then decreasing and in combination treatment of two hormones, by increasing hormones, the amount of chlorophyll a has been decreased and about chlorophyll b and total chlorophyll and carotenoids, by increasing hormones concentration used, increasing was seen, respectively.

Kaur *et al*, (2012) reported that, SNP 200 μ M applied at V+P+G gave the best results in terms of improved plant height, better canopy characteristics, increased stem diameter, higher physiological attributes, maximum biomass accumulation and finally

highest seed yield per plant. Ethrel decreased seed yield per plant at all the concentrations compared to control.

Yakubu *et al.*, (2013) found that, the highest pod, kernel and haulm yields was obtained at 100 mg levels of gibberellic acid during wet and dry seasons. SAMNUT 23 had the highest pod, kernel and the haulm yields also across seasons. There were no significant interactions between gibberellic acid concentrations and the varieties in all the traits evaluated. Regression analysis however, pointed out that 172.7 and 161.4 mg L⁻¹ gibberellic concentrations during the wet and dry seasons respectively are the optimum levels required in enhancing growth and yield in groundnuts. Further studies with respect to the best performance of varieties during growing seasons under the influence of gibberellic acid to be ascertain in a further research.

Ramesh *et al.*, (2013) found that, the application of brassinosteroid at 25 ppm, mepiquat chloride 5% AS and chlormequat chloride applied at 187.5 g a. i/ha, 162.5 g a.i/ha and 137.5 g a.i./ha had also resulted in higher seed yield, compared to control and water spray. The study revealed the superiority of NAA (20 ppm) treatment for majority of the morphological, physiological, growth, biochemical, quality and yield parameters at different growth stages, in addition to seed yield, compared to other growth regulator and control treatments. Suggesting the use of NAA will have many positive benefits on yield and yield attributing characters in *rabi*-soybean.

Sadak *et al.*, (2013) founded that exogenous application of benzoic acid and salicylic acid led to marked increase in growth characters (plant, height, branches and leaves number/plant as well as plant dry weight), photosynthetic plgments (chlorophyll a, chlorophyll b, chlorophyll (a+b). carotenoids and consequently total pigments). All treatments increased seed yield and its components (number and dry weight of pods/plant, seeds number/pod, seeds weight/plant and seed index) as well as seed biochemical constituents (protein, carbohydrate, oil, flavnoid and phenolic content). Different treatments improved oil quality as it affected fatty acids composition of soybean oil.

Ramesh and Ramprasad (2014) concluded that, the morphophysiological parameters, namely, plant height, number of branches, number of trifoliates per plant, dry matter accumulation in leaf, stem and reproductive parts, LAI, CGR and RGR was observed to increase significantly with the application of NAA (20 ppm) and

brassinosteroid (25 ppm). However, it decreased with the application of chlormequat chloride and mepiquat chloride. The biochemical parameters, namely, chlorophyll content was observed to increase significantly with application of NAA (20 ppm), brassinosteroid (25 ppm), mepiquat chloride 5%, AS (5%) and chlormequat chloride 50% SL at different concentrations compared to control and water spray but whereas fluorescence emission and photosynthetic rate were noticed to be non-significant. A significant increase in the seed protein content was also noticed with the application of NAA (20 ppm), brassinosteroid (25 ppm), mepiquat chloride 5%. AS (5%) and chlormequat chloride at different concentrations, compared to control and water spray. In conclusion, the study revealed the superiority of NAA (20 ppm) treatment for majority of the morphological, physiological and biochemical parameters at different growth stages, compared to other growth regulator and control treatments studied in the present investigation for *rabi* soybean.

Dalai *et al*, (2015) noted that, a dose of GA₃ 20 ppm + NAA 100 ppm was found significantly superior in terms of growth parameters i.e. vine length per plant, number of primary branches per plant, number of leaves per plant, as compare to control and other applied treatments. Similarly, a positive effect was also reported in various flowering, yield and yield attributing characters with GA₃ 20 + NAA 100 ppm. In context of yield a dose of GA₃ 20 + NAA 100 ppm was produced highest yield of cucumber as compared to control and other treatments during experimentation.

Sable *et al*, (2015) reported that maximum height of gladiolus plant (59.43cm); number of leaves (13.9), leaf area (64.8 cm²) was recorded by treatment GA₃ 200 ppm foliar spray. Lowest plant height was observed in treatment CCC 750 ppm spray. Minimum number of leaves/plant (10.8) and leaf area (64.8 cm²) were recorded in CCC 250 ppm/plant as foliar spray. In flower quality parameters, maximum number of florets/ spike (13.4), floret length (8.4 cm), length of spike (80.28 cm) and length of rachis (41.50 cm) recorded with foliar spray of GA₃ 200 ppm. Maximum weight of floret (10.1 gm), diameter of floret (9.5 cm) and girth of spike (2.60 cm) were produced by CCC 750 ppm foliar spray. Minimum number of florets/ spike (8.2) and floret length (7.1 cm) were recorded in CCC 250 ppm foliar spray. Lowest weight of floret (8.3 g), diameter of florets (8.2 cm) and girth of spike

(1.90 cm) were recorded in GA3 100 ppm spray. Lowest length of spike (74.20 cm) and length of rachis (35.09 cm) were recorded in CCC 750 ppm foliar spray.

Upadhyay, (2015) concluded that, the significantly highest plant height (cm), leaf area (cm²/plant), number of leaves/plant, RGR, C.G.R and NAR were recorded in NAA-20 ppm and lowest in control. The flowering pattern were influenced by application of various concentration of NAA, GA3 and Kinetin. The significantly highest NR activity was recorded in all the treatment of NAA followed by GA3 and Kinetin. The significantly maximum Chlorophyll content were observed in Kinetin 20 ppm followed by NAA and GA3. The significantly highest Protein content was recorded in all the treatment of NAA followed by GA3 and Kinetin. The significantly highest grain yield (g/plant) recorded in NAA-20 ppm and 30 ppm followed by all the concentration of GA3 and Kinetin.

Sahane *et al*, (2015) revealed that, all morphophysiological parameters including plant height, number of branches, leaf area, dry matter production, RGR and NAR as well as yield ha⁻¹ of soybean plants showed positive and significant responses with the foliar application of 150 ppm ethrel followed by 100 ppm ethrel when compared with control.

Basuchaudhuri, P. (2016) noted that, plant growth regulators play important role in plant growth and development. Plant growth regulators when applied in proper stage of growth and concentration influenced positively the yield components and yield of soybean.

Behera *et al*, (2017) observed that, highest percentage of sesame seed germination was recorded in GA₃ 20 ppm (98.51%). Due to spraying of growth regulators there was increase of plant height, number of branches and leaf area per plant in all the treatments. The LAI, RGR, NAR, CGR and LAD were found to be increased in PFRs treatments over the control. Due to the spraying of plant growth regulators the percentage of increase in yield ranged from to a tune of 0.5% in GA3 10 ppm conc. To 24% in GA3 20 ppm conc. over the control.

Raut *et al*, (2017) reported that, the maximum number of root nodules, fresh and dry weight of root nodules, yield and quality attributes of soybean was found at application of RDF + NAA @ 40 ppm + GA₃@ 40 ppm (20 & 35 DAS) + KNO₃ @1% (30,45 & 60 DAS) was found significantly superior over RDF alone. This

showed that the foliar application of growth regulator NAA @ 40 ppm (20 & 35 DAS)+ KNO₃ @ 1% (30,45 & 60 DAS) along with RDF enhancing root nodules, yield and quality attributes of soybean.

Devi *et al*, (2018) revealed that, application of GA₃ @ 50 ppm increases plant height and improved leaf length and number of leaves per plant while GA₃ @ 100 ppm increases weight and volume of onion bulb, the highest bulb yield can be obtained with 200 ppm GA₃ @ 100 ppm, GA₃, NAA and combination treatments as pre- harvest foliar application have gained prominence.

Jadhav *et al*, (2019) indicated that, the growth of soybean significantly influenced with application of RDF and two spraying of urea (30 and 45 DAS) followed by RDF and two spraying of KNO₃ (30 and 45 DAS) and RDF and two spraying of ZnSO₄ (30 and 45 DAS) over control and single spraying of these nutrients. The growth parameters *viz.*, plant height, number of branches, number of nodules and number of pods was found to be superior in treatments T6 as compared to T8.

2.3 Monitoring growth profile of soybean under various treatments by spectral reflectance studies

Wood *et al*, (1993) revealed that, there was high correlation between chlorophyll meter readings and extractable leaf chlorophyll, as well as high correlation between chlorophyll meter readings and crop n status. Some research has identified critical chlorophyll meter reading levels that allow confirmation of N responsive sites. However, identification of appropriate N rates with chlorophyll meters at N responsive sites is more difficult at this time. Moreover chlorophyll meter readings for a particular crop n status likely vary with crop varieties, cultural practices and environmental factors.

Shigeto *et al*, (1998) found that, although red-blue and green-blue wavelengths show the highest correlation with chlorophyll content under a limited range of meteorological conditions, the normalized difference (red-blue) / (red+blue) is the most applicable function which can use data collected under different meteorological conditions. The accuracy in estimating chlorophyll content from video images could be improved by correcting with solar radiation data. It is shown that, for practical

purposes, the chlorophyll content of leaves can be estimated with sufficient accuracy using a portable video camera.

Kawashima and Nakatani (1998) indicated that, relationships between chlorophyll content and various functions derived from red, green and blue wavelengths are examined. Although red blue and green blue wavelengths show the highest correlation with chlorophyll content under a limited range of meteorological conditions, the normalized difference $(\text{red}-\text{blue})/(\text{red}+\text{blue})$ is the most applicable function which can use data collected under different meteorological conditions. The accuracy in estimating chlorophyll content from video images could be improved by correcting with solar radiation data. It is shown that, for practical purposes, the chlorophyll content of leaves can be estimated with sufficient accuracy using a portable video camera.

Choubey and Choubey (1999) indicated that, the peak value of IR/R ratio was 16.39 at 62 DAP during the early reproductive phase; there after it declines gradually with the maturity of the crop. Chlorophyll 'a' concentration was high during early growth (vegetative and early reproductive stages) and decreased during the flowering and maturity stages. The rice plant canopy show a high chlorophyll 'a' concentration is higher in site a plant canopies than it is in site B during the entire crop cycle. A good inverse correlation ($r=0.91$) has been found between chlorophyll 'a' and band 1, while the IR/R ratio and the normalized difference vegetation index (NDVI) showed a relationship ($r=0.78$) with the chlorophyll 'a' concentration during the crop cycle. Band 2, 3 and 4 radiance values show a biphasic linear relationship with chlorophyll 'a' concentrations, negative for early growth and positive for flowering and maturity stages. Results indicated that, the period between 66 to 70 DAP is most suitable for the assessment of rice crop yield, based on chlorophyll 'a' concentration.

Hyunseok *et al*, (2000) reported that, the fitted thickness was in good agreement with the thickness measured by scanning electron microscopy. Furthermore, the peak positions of SR spectra increased linearly to longer wavelength with thickness. This strongly implies that thickness information can be obtained in real time by measuring the peak shift of SR spectra, not by fitting the whole spectrum at that moment.

Guo *et al.*, (2001) reported that, the spectral measurements were made with a handheld ADS spectroradiometer, which covers wavelengths from 350 nm to 2500 nm with 2151 bands. Results showed that remote sensing can be used to indicate different crop conditions. The spectral and LAI differences among input levels were significant at early to mid growing seasons. Mid July was the best season and the red over near infrared spectral ratio as well as the normalized difference vegetation index based on these two bands were the best vegetation indices to use for crop vigor monitoring.

Boggs *et al.*, (2003) reported that, hyper spectral reflectance in the 807.6 nm region had the highest significant correlation with cotton leaf chlorophyll. Cotton leaf chlorophyll correlated significantly with soil nitrate nitrogen and cotton yield. Because leaf chlorophyll is an indicator of nitrogen deficiency, our results suggest that hyper spectral reflectance may be used as a tool to help farmers determine nitrogen deficiency.

Zheng *et al.*, (2003) reported that, LAI was measured with an LAI-2000 plant canopy analyzer. The spectral measurements were made with a handheld ADS spectroradiometer, which covers wavelengths from 350nm to 2500 nm with 2151 bands, remote sensing can be used to indicate different crop conditions. The spectral and LAI differences among input levels were significant at early to mid growing seasons. Mid July was the best season and the red over near infrared spectral ration as well as the normalized difference vegetation index based on these two bands were the best vegetation indices to use for crop vigor monitoring.

Dhoble *et al.*, (2004) reported that, growth of wheat was monitored by collecting data on LAI, chlorophyll content and total biomass. Spectral observations were recorded in red and NIR band. The ratios RVI and NDVI were used for assessment of growth and chlorophyll content. Four bands Optomech Ground Truth Multiband radiometer was used for spectral observations. The spectral data was collected on cloud free day between 10.30 and 13.30 hrs. The results of 3 years showed that protecting the crop against pests and diseases, and irrigating the crop as and when required, showed higher values of biometric and spectral parameters than unprotected and rain fed crop. Reduced leaf area index, chlorophyll content and biomass were among the effects seen in nitrogen deficient crop. Further, physiological changes in cotton crop canopies caused by nitrogen deficiency resulted in detectable

spectral reflectance variation. Relative vegetation Index (RVI) and Normalized Difference Vegetation Index (NDVI) were found to be reliable indices for discriminating stressed vegetation and normal vegetation. However, NDVI showed superiority in smoothening of reflectance curves.

Patil *et al*, (2004) concluded that, LAI had significant relationship with RVI and NDVI. The biomass of crop established significant relationship with NIR (0.77-0.86 nm) and has association with RVI than NDVI, suggesting that for assessment of growth of maize RVI is a better indicator than NDVI. Chlorophyll and carotene pigment absorption radiation lies in B₁ and B₃. Hence, these pigment concentration established significant relationship with spectral reflectance in blue and red band of EMR. Further, it was noticed from R² values that both indices (RVI and NDVI) were highly correlated with chlorophyll and N concentration of leaves. Among RVI and NDVI, NDVI had more close relationship with chlorophyll and nitrogen concentration of leaves. This suggests that NDVI is a better index for diagnosing chlorophyll and N leaf concentration.

Stroppiana *et al*, (2006) concluded that, rice reflectance is significantly influenced by nitrogen supply at certain wavelengths. Regression analysis highlighted that the visible region of the spectrum is the most sensitive to plant nitrogen concentration when reflectance measures are combined into a spectral index. An automated procedure allowed the analysis of all the possible wavelength combinations to derive a Normalized Difference Index (NDI) correlated to Plant nitrogen Concentration (PNC). The derived index, which appeared to be least influenced by plant biomass and Leaf Area Index (LAI), and the simple ratio index, widely used as an indicator of vegetation conditions, have been specialized over the experimental field. The output maps have been discussed in terms of ability in describing the spatial variability of Aboveground Biomass (AGB) and PNC.

Teresa *et al*, (2007) reported that, reflectance curves corresponding to N₁ and N₂ showed higher reflectance values in the near-infrared (NIR) plateau than N₀ treatments. Wavelengths within the NIR region (from 710-900 nm) were selected in both years for discrimination between N treatments, with an overall accuracy of up to 99.2%. When K was not applied, leaf K content was below the critical threshold, indicating that olive trees were under a nutritional deficiency. Wavelengths from 7110 to 890 nm, and the normalized difference vegetation index [NDVI= (R780-R670) /

(R780+R670)] were selected for discriminating K treatments with an overall accuracy of up to 94.4 %. Classification matrices for cross-validation classified and misclassified cases into the nearest category. The results suggest that the induction of N or K nutritional deficiency for more than 10 years in olive trees resulted in different leaf nutrient contents, and this consistently affected hyper spectral reflectance curves, mainly in the NIR region. These results are promising and could provide information for further work on the identification of N or K deficient olive trees using remote sensing.

Ramarao *et al.*, (2007) noticed that the potential of the EO-01 Hyperion hyper spectral sensor was investigated for the estimation of total chlorophyll and nitrogen concentrations of cotton crops in India by developing regression models between hyper spectral reflectance and laboratory measurements of leaf total chlorophyll and nitrogen concentrations. A comprehensive and rigorous analysis was carried out to identify the spectral bands and spectral indices for accurate retrieval of leaf total chlorophyll and nitrogen concentrations of cotton crop. The performance of these critical spectral reflectance indices was validated using independent samples. A new vegetation index, named the plant biochemical index (PBI), is proposed for improved estimation of the plant biochemicals from space borne hyper spectral data; it is simply the ratio of reflectance at 810 and 560 nm. Further, the applicability of PBI to a different crop and at a different geographical location was also assessed.

Wang *et al.*, (2015) reported that, firstly the spectral differences are clear for the canopy and leaves of spring-wheat under different density levels, and the canopy spectral reflectance are gradually getting smaller in the visible region and bigger in the near infrared region along with density level increasing at jointing,, booting, heading and filling stage, but this change is not evidence at ripening stage; secondly, there are obviously difference in four kinds spring-wheat in canopy and leaf scales spectral reflectance; thirdly, There are “**double peak**” phenomena for the spring-wheat at nutrition grown stage. Additionally, there were ‘blue shift’ phenomena for the position of red edge (red); Fourthly, the relationship between the spectral vegetation indices and the biochemical parameters indicated that the LAI have the best relationship with DVI and the relativity are the best between the spectral index (red) and the chlorophyll among the selected spectral index, PVI and FW,, plant height (pH) are good correlation. This indicated that some right spectral variables would be

used to estimate the LAI, FW, the pH and chlorophyll for spring- wheat. Furthermore, the correlation of the spectral index and the biochemical properties of vegetation are affected by the different cultivars.

Zhang *et al*, (2009) noticed that, chlorophyll concentration had significant correlations ($P < 0.01$) to these indices than single leaf spectral absorption in the 2nd experiment. The liner regression models with single leaf spectral absorption $y = -2.271 A 480.188 + 5.574 A 651.232 - 2.899 A 753.552 - 0.269$, $y = -4.079 A 480.188 - 2.233 A 753.552 + 5.892 A 663.239 + 0.547$ and $y = 4.217 A 651.232 - 0.718 A 753.552 - 2.897 A 663.239 - 0.399$ had higher power prediction total chlorophyll, chlorophyll a and chlorophyll b concentrations, respectively. Compared with BEACI and REACI, stepwise regression analysis showed that YEACI 630.610, YEACI 570.169 and YEACI 651.232 were good predictive power for predicting chlorophyll total concentration, chlorophyll a concentration and chlorophyll b concentration, respectively.

Abbasi *et al*, (2010) concluded that, increased efficiency in rice production is possible through varietal technology, advances in yield enhancement, and the successful development of hybrid technology. Nondestructive methods such as study the spectral reflectance of rice fields is a reliable way in remote sensing study. In this study we tested the possibility to predict high-yielding rice varieties based on the spectral reflectance data in the red edge position (REP). Spectral reflectance of rice canopies from 350 to 2500 nm were acquired under clear sky in rice filed. The obtained results indicate that REP of Hybrid. Tarom, Neda and Khazar varieties are at longer wavelength, so they are predicted as more productive rice varieties.

Shwetank *et al*, (2010) noticed that, the MIPS system provides limited information due to the small number of spectral channels. Over the past two decades, advances in satellite imaginary system have made it possible for the collection of several hundred spectral bands for processing. This is commonly referred to as hyper spectral image processing system (HIPS). This study details the differences between MISP and HISP; and focuses on the application of HIS for Rice crop classification, plant growth, plant biophysical, biochemical, physiology properties in different spectral regions and their mapping.

Zhang *et al*, (2011) concluded that, principal component analysis (PCA) method was used to select the key spectral ranges of leaf chlorophyll fluorescence. Based on the PCA, 7 key spectral indices (SI) were selected to monitor leaf CF. In these SI (R680-R935)/ (R680-R935) and R680/r935 has higher R and lower RMSE could be used for monitoring chlorophyll fluorescence. The chlorophyll fluorescence of rice response to root oxygen stress could be detected by remote sensing.

Darvishsefat *et al*, (2011) noticed that, a set of important vegetation indices sensitive to canopy chlorophyll content, photosynthesis intensity, nitrogen and water content were employed to enhance probable differences in spectral reflectance among various rice varieties. This promises the possibility of accurate mapping of rice varieties cultivated areas based on hyper spectral remotely sensed data.

Yusuf and Young (2011) reported that, spectral parameter of reflectance sensitivity was used to find the optimal wavelengths for determining and evaluating the level of damage by the black-shank fungus. The result of this research shows that, the spectral reflectance decreases significantly with the increasing severity level in both the visible and near-infrared wavelength ranges. Also the wavelength of 730 and 790 nm with corresponding bands of 283 and 330 was the most useful for discriminating black-shank disease severity level. This research indicates clearly the relationship between spectral properties and plant response.

Lee *et al*, (2011) noticed that, plants with higher N content not only had higher chlorophyll content but also had thicker, flatter and more turgid leaves, which enhances visible light absorption while stimulating near- infrared reflection. Derivative type predictors, using the transition region from red and near-infrared wavebands, not only accounted for the changes in leaf chlorophyll content and structures induced by varied N content, but helped cruminate background soil interferences. Therefore, derivative type predictors may be more appropriate than reflectance values at specific band (s) and band ratios in establishing a robust model for plant N status assessment.

Zhang *et al*, (2011) revealed that, non destructive and rapid monitoring methods for crude protein content (CPC) in rice grain are of significance in nitrogen diagnosis and grain quality monitoring and in enhancing nutrition management and use efficiency. There is a significant correlation between CPC content and key

spectral bands. The results of prediction for three models were PLSR>ANN>MLRR with correlation values of 0.96, 0.92 and 0.90, respectively for the validation data. It is implied that CPC in rice (grain quality) could be estimated by canopy spectral data.

Zhang *et al*, (2012) concluded that, peak- valley characteristic parameters such as RVAI, kg/kr, GPA2 and Kb are significantly correlated with chlorophyll content, and among them, the regression coefficient (R²) of RVAI was the highest (R²=0.705). Finally, an inverse model ($y=1.282x - 0.143$) of chlorophyll content was constructed using RVAI. The R² value of the validated model of chlorophyll content was 0.640, and the corresponding root mean square error was 0.3039. These results indicate that estimating chlorophyll content is feasible using peak-valley characteristic parameters extracted from hyper spectral imaging data.

Michio *et al*, (2012) found that, we developed a leaf greenness index (LGI), the ratio of DA-NDVI to DARF-NIR, and a simple calculation method for area means to reduce the background effect. The modified area means of LGI followed the seasonal trend in SPAD value well its pattern was inherently different from the patterns of any of the original three parameters: DARF-RED, DARF-NIR or DA-NDVI. Throughout the paddy seasons in the two years, a regression equation for estimating SPAD values using the LGI, daily solar radiation, the cosine of angle between the view and the meridian directions and the cosine of culmination solar zenith angle performed favorably (R₂=0.815). The nitrogen concentration per dry plant hill (g kg⁻¹) had a close relation to the SPAD values estimated using the equation.

Patil *et al*, (2013) noticed that, growth attributes like leaf area total bio mass and chlorophyll content and spectral indices RVI (Relative Vegetation Index) and NDVI (Normalized Difference Vegetation Index) were calculated from the reflectance measured in IR and NIR bands of Multiband Ground Truth Radiometer. The study revealed that the highest leaf area index, total biomass and chlorophyll content and P concentration in leaf and grain yield of soybean was obtained with the treatment including irrigation level (I₂), plant protection level (D₂) and fertilizer level (F₂) at all the stages of observations. Interactions between IXD, DXF and IXDXF were additive to increase the leaf area index, total biomass and chlorophyll content of soybean crop. The irrigation, plant protection measures and application of N and P fertilizers had relatively high RVI and NDVI than no irrigation, no plant protection

measures and unfertilized treatments. Total chlorophyll and N concentration in soybean leaf established significant and positive relationship with RVI where as NDVI positively correlated with LAI and total biomass.

Ghosh *et al*, (2013) indicated that, use of hyper spectral remote sensing for vegetation monitoring through biochemical and biophysical parameter estimation, discussing the potential for detecting water stress. Central to this objective is our primary research question. Can remote sensing play a key role to monitor agric-crop health to enhance the agribusiness efficiency.

Levent *et al*, (2013) noticed that, the results demonstrated that reflectance in the red portion (600-700 nm) of the electromagnetic spectrum decreased and increased in the near infrared (NIR) region (700-900 nm) with the increasing field capacity of water level. Reflectance measured before the irrigation was generally higher than after irrigation in the NIR region and lower in the red region. However, when the four levels of PC and before or after irrigation only were compared, reflectance spectra indicated that water stressed corn plants absorbed less light in the visible and more light in the NIR regions of the spectrum than the less water stressed and unstressed plants. There was a similar trend to reflectance behavior of water stress levels using chlorophyll readings that decreased over time. The CT analysis revealed that water stress can be assessed and differentiated using chlorophyll readings and reflectance data when transformed into spectral vegetation indices.

Schlemmer *et al*, (2013) indicated that, at the canopy level, Chl. and N contents can be accurately retrieved using green and red-edge Chl. indices using near infrared (780-800 nm) and either green (540-560 nm) or red-edge (730-750 nm) spectral bands. Spectral bands that were found optimal for Chl. and N estimations coincide well with the red-edge band of the MSI sensor onboard the near future Sentinel-2 satellite. The co-efficient of determination for the relationships between the red-edge chlorophyll index, simulated in Sentinel-2 bands, and Chl. and N content was 0.90 and 0.87, respectively.

Ozyigit and Bilgen (2013) reported that, according to the result, significant relationships existed between predicted and measured nutrients, with R_2 values of 0.85, 0.43 and 0.84 for nitrogen, phosphorus and potassium, respectively. while 11 wavelengths (R609, R647, R651, R654, R669, R675, R676, R680, R7211, R727,

R760) were used in the equation for estimating nitrogen level, 2 wavelengths (R675, R680) and fifteen wavelength (R410, R411, R417, R422, R460, R463, R468, R646, R651, R658, R669, R670, R674, R676, R682) were determined for phosphorus and potassium levels, respectively. The results indicated that the changes in nitrogen, phosphorus, and potassium content affected reflectance values of the visible region of spectrum (especially in the red regions) and, therefore, spectral reflectance data could be used to estimate the nitrogen, phosphorus and potassium contents in rangeland plants.

Singh *et al*, (2014) concluded that, the buildup of sulphur in surface soils was greater than in deeper soils. Application of sulphur showed the positive sulphur balance and it increased with increase in sulphur level, while it was negative under control.

Raghuveer *et al*, (2014) indicated that, the LAI was significantly higher (0.32, 1.66, 4.61 and 2.56) at 30, 60, 90 and 120 DAT with 60 kg P₂O₅ ha⁻¹ dose than other levels of P. Interaction effect was found significant on LAI (0.41 and 5.40) at 30 and 90 DAT stage with the application of 60 kg P₂O₅ ha⁻¹ when associated with *Pseudomonas* sp. Normalized Difference Vegetation Index in the hyper spectral region (NDVI_h) showed significant results at 60 DAT and harvesting stage with the application of 60 kg P₂O₅ ha⁻¹ and P control treatments (0.88 and 0.58), respectively. Chlorophyll Index at green region (CI_g) showed significant results at 60 DAT and 120 DAT stage with the application of 60 kg P₂O₅ ha⁻¹ and P control treatments (4.25 and 4.01, respectively). Grain yield was found significant with the application of P levels and maximum (3.50 t ha⁻¹) was recorded with the application of 60 kg P₂O₅ ha⁻¹. The inoculation of PSB strains did not show any significant influence on LAI, NDVI_h, CI_g and grain yield of rice. Thus, it can be concluded that the application of 60 kg P₂O₅ ha⁻¹ and inoculation of *Pseudomonas* sp. are better to increase LAI and grain yield in the field and spectral indices may be utilized for phosphorus recommendation for decision support system.

Khalid *et al*, (2014) found that, the middle infrared based vegetation index (MIVI) showed a significant response to the irrigation levels for both sampling dates. Among the tested spectral indices, Normalized difference infrared index (NDII) and normalized Difference Nitrogen Index (NDNI) exhibited the highest correlation to crop Leaf Area Index (LAI). Five indices showed the most response to wheat grain

yield. These indices included near infrared band (NIR), Water Band Index (WBI), Normalized Water Index-1 (NWI-1), Normalized Water Index-3 (NWI-3) and Normalized Water Index-4 (NWI-4).

Jagadeeswaran *et al*, (2015) noticed that, normalized difference vegetation index (NDVI), chlorophyll index (CI red edge) and red edge position (REP) for different crop growth stages. The results indicated that NDVI values correlate well with chlorophyll a, b ($r^2=0.4586$ to 0.7765) and nitrogen ($r^2=0.5449$ to 0.7635) at different stages of crop growth. The REP for no-nitrogen treatment varied from 707 to 713 nm as compared to 721 to 724 nm for sufficiently NPK treated plants and the low values for no nitrogen treatment indicates the crop is under stress.

Wang *et al*, (2015) noticed that, characteristic spectral parameters of T940/T560, T940/T650 and $\log(T940/T560)$ among the nine sets of parameters were highly correlated to the estimated contents of chlorophyll a, chlorophyll b and total chlorophyll of tomato leaves. The relative errors of total chlorophyll and chlorophyll a/b ratio were (5.1+3.7%) and (4.9+4.3%), respectively. Therefore, the above three characteristic spectral parameters could be applied in the rapid non-destructive estimating of the contents of chlorophyll a, chlorophyll b and total chlorophyll as well as chlorophyll a/b ratio of tomato leaves.

Patil *et al*, (2015) noted that, the hyper spectral measurements showed decrease in red and increase in NIR reflectance by maize up to 82 DAS and reversed thereafter. Amongst all treatments, higher absorbance of red wavelength and reflectance of NIR by maize canopy was observed in growth media received 100 kg N, 50 kg P₂O₅, 30 kg S, 20 kg ZnSO₄ and two sprays 2 percent Fe at silking and cob development stage. It was noticed that hyper spectral observations should be centralized between 550 to 670 nm and 750 to 1050 nm wavelength bands during 51 to 82 days after sowing in maize, for getting discrimination due to various nutrient applications. Chlorophyll was found to be most influencing factor contributing to total spectral reflectance. Further, it was concluded that even with the hyper spectral data it was difficult to identify/discriminate the specific nutrient deficiency in crop plant.

Jagadeeswaran *et al*, (2015) concluded that, the spectral measurements were analyzed to derive spectral indices *viz*, normalized difference vegetation index (NDVI), chlorophyll index (CI red edge) and red edge position (REP) for different

crop growth stages. The results indicated that NDVI values correlate well with chlorophyll a, b ($R^2= 0.4586$ to 0.7765) and nitrogen ($R^2=0.5449$ to 0.7635) at different stages of crop growth. The REP for no-nitrogen treatment varied from 707 to 713 nm as compared to 721 to 724 nm for sufficiently NPK treated plants and the low values for no nitrogen treatment indicates the crop is under stress.

Kaur *et al*, (2015) noticed that, the spectral indices selected for the study recorded at booting stage were correlated better with all the crop parameters having 'R²' values varied between 0.68 and 0.83. All the spectral indices were having good correlation (R^2) ranging between 0.58 and 0.82 for grain yield and 0.63-0.80 for 1000 grain weight, But best correlation were noticed between NDVI and grain yield having R^2 value 0.78, NDVI and 11000 grain wt having R^2 value 0.80, LCI and grain yield having R^2 value 0.82, LCI and 1000 grain weight having R^2 value 0.79. The LCI and NDVI were having best correlation with grain yield and 1000 grain wt. It was concluded that amongst the various indices selected, Leaf color index (LCI) was the only index which was correlated better, with all the plant growth parameters and yield at booting stage of the wheat crop.

Jianfeng *et al*, (2015) indicated that the above three characteristic spectral parameters could be applied in the rapid non destructive estimation of the contents of chlorophyll a, chlorophyll b and total chlorophyll as well as chlorophyll a/b ratio of tomato leaves.

Kalaimannan *et al*, (2016) reported that, there was a linear relationship between the leaf N and spectral bands and coefficient of determination (R) was 0.805. Hence, it can be stated that hyper spectral will serve as an alternative and reliable technique of estimating the nitrogen content in cotton canopy.

Omar *et al*, (2016) noticed that, grain yield and leaf N concentration across N fertilization levels were strongly predicted by most of these RGB indices (with $R^2\sim 0.7$), outperforming the prediction power of the NDVI and LCC. RGB indices also outperformed the NDVI when assessing genotypic differences in grain yield and leaf N concentration within a given level of N fertilization. The best predictor of leaf N concentration across the five N regimes was LCC but its performance within N treatments was inefficient. The leaf traits evaluated also seemed inefficient as phenotyping parameters. It is concluded that the adoption of RGB based phenotyping

techniques may significantly contribute to the progress of plant breeding and the appropriate management of fertilization.

Josep *et al*, (2017) indicated that, new, narrow-bandwidth indices and reflectance indices calculated from first and second derivative spectra were strongly correlated with the ratio of secondary and protective pigments to chlorophyll a and with exoxidation state of the xanthophylls cycle pigments, and therefore, with photosynthetic efficiency. These new indices may be useful in the remote sensing of plant physiological status.

Arunkumar *et al*, (2017) concluded that, among different nutrient management practices, M₃ recorded significantly higher grain yield (93.0 q ha⁻¹) Stover yield (1184.25 q ha⁻¹), growth and yield attributing parameters compared to M₁, and was found to be on par with M₂. Two per cent deviation (88.78 q ha⁻¹) was observed in M₂ when compared M₂. Among gypsum and borax treatments, S₄ recorded significantly higher grain yield (89.86 q ha⁻¹). Stover yield (160.78 q ha⁻¹). growth and yield attributing parameters, over S₁ and S₂ and was on par with S₃, S₅ and S₆.

4 Work out the soil nutrient balance and economics.

Thenua *et al*, (2014) revealed that, the available status of sulphur and zinc in soil after harvest of soybean crop was found non significant.

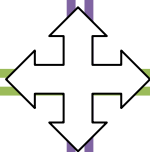
Nadaf and Chidanandappa (2015) concluded that, an application of zinc sulphate at all the three levels (5, 10 and 20 kg ha⁻¹) significantly increased the water soluble zinc (WS) from 0.36 to 0.52 mg kg⁻¹ and sorbed zinc (SORB) (r=0.96**), EMnR (r=0.89**), OM (r=0.85**) and Fe & Al-ox (r=0.96**). But, it had a negative and significant relationship with RES (r=-0.69**). Path coefficient results revealed that all fractions except residual zinc significantly and positively correlated with total uptake of zinc by groundnut.

Chaithra and Hebsur (2018) noted that, slightly higher benefit cost ratio of soybean crop (2.97) was observed with foliar application of solubor (@ 0.5%).

Krishna and Kaleeswari (2018) recorded that, availability of N, P, K, Fe, Mn, Zn, Cu and B contents in soil at different stages of pulse (redgram) were significantly influenced by the various foliar applications. The chlorophyll a, b and total chlorophyll contents were found to be highest in the treatment that receiving 100% RD NPK + foliar spray of 0.5% KNO₃ + 2% DAP + micronutrients.



MATERIAL AND METHODS



CHAPTER III

MATERIAL AND METHODS

The research project entitled “Studies on yield maximization of soybean through soil and foliar feeding of nutrients, growth regulators and monitoring the growth profile by spectral reflectance” was carried out for two consecutive years 2016-17 and 2017-18 on experimental farm of Department of Soil Science and Agricultural Chemistry, Vasantrya Naik Marathwada Krishi Vidyapeeth, Parbhani.

The material used and methods adopted for planning and conduct of field experiments soil and plants chemical analysis, statistical analysis and spectral observations are presented in this chapter under following heads.

3.1 Site and location

3.2 Soil and their mineralogy

3.3 Weather data and climatic conditions

3.4 Experimental soils

3.5 Collection and preparation of initial soil sample

3.6 Soil nutrients status of initial soil sample

3.7 Field experimental details

3.8 Growth and yield attributes

3.9 Instruments used for collection of spectral data

3.10 Spectral observations

3.11 Collection of soil and plant samples and their analysis

3.12 Spectral indices and statistical analysis

3.1 Site and location

The field experiments were conducted at the research farm of Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vasantrya Naik Marathwada Krishi Vidyapeeth, Parbhani during two consecutive years 2016-17 and 2017-18 in monsoon season.

Geographically, Parbhani district is situated in the Godavari drainage basin in the central part of India between 76°46', east longitude and 19°16' North latitude, having elevation of 423.46 m above the mean sea level in Marathwada division of Maharashtra State. The region has a semi-arid climate. It is under assured monsoon rainfall agro climatic zone with an average annual precipitation between 800 to 850 mm. The major portion of precipitation (75 per cent) being received through south-west monsoon from June to September. The mean maximum temperature varies from 26.9°C in winter to 42.4°C in summer and means minimum temperature varies from 5.8°C to 25.6°C. The climate is suitable for *Kharif* crops like Soybean, Cotton, Sorghum, Green gram, Black gram and Red gram. The soils of the region are medium to deep black (Inceptisol/Vertisol).

3.2 Soil and their mineralogy

The major black soils of the region are formed from “Deccan Trap” rock basaltic material originating through volcanic eruptions (Srinivasan *et al.*, 1989). The soils are rich in potassium, lime and magnesium (Gajbe *et al.*, 1976). The black soil used in the experiment are identical to that of typic Haplusterts of Parbhani series (Malewar, 1976).

On the basis of X-ray analysis. Malewar and Randhawa (1977 and 1978) identified clay mineral assemblage in these soils, which invariably dominant in montmorillonite followed by moderate amount of kaolinite and traces of illite. The mineralogical studies as carried out by Maniyar *et al.*, (1981), the Parbhani series constitute bulk of iron ores, along with augite, apatite, chlorite, hornblend, tourmaline, pyrite, pyroxenes, feldspar, quartz and muscovite.

3.3 Weather data and climatic conditions

The meteorological data on rainfall, maximum and minimum temperature and relative humidity recorded during the experimental period at meteorological observatory, at Vasant Rao Naik Marathwada Krishi Vidyapeeth, Parbhani are depicted in Fig. 1a and 1b

3.4 Experimental soils

The field experiments were carried out using soybean (*var.* MAUS 162) in *Monsoon* season during years 2016-17 and 2017-18 on Typic haplusterts. The soil is characterized by black colour dominated by montmorillonite clay with high

coefficient of expansion and shrinkage leads to deep cracking. The soils are formed from basaltic material. According to 7th approximation, the soils are classified as fine Smectitic Iso-hyperthermic Typic Haplusterts (Malewar, 1977) and are included in Parbhani series.

3.5 Collection and preparation of initial soil sample

In order to determine the soil properties of experimental soil before sowing, the representative surface (20 cm depth) soil sample was collected from randomly selected spots covering experimental area. A composite soil sample was prepared and analyzed for its various soil properties. The properties of experimental soil are given in Table 3.1.

Table. 3.1 Physico-chemical properties of experimental soil

SN	Soil Properties	Unit	2016-17	2017-18
1	Soil reaction (pH)		7.76	7.79
2	Electrical conductivity (EC)	dSm ⁻¹	0.29	0.31
3	Organic carbon (O.C.)	gkg ⁻¹	48.00	51.02
4	Calcium carbonate	gkg ⁻¹	58.27	56.49
5	Available nitrogen	kg ha ⁻¹	145.26	144.48
6	Available phosphorus	kg ha ⁻¹	13.60	13.68
7	Available potassium	kg ha ⁻¹	580.47	579.82
8	Available sulphur	kg ha ⁻¹	13.41	13.69
9	DTPA Zn	mg kg ⁻¹	0.52	0.53
10	HWS B	mg kg ⁻¹	0.36	0.35

3.6 Soil nutrients status of initial soil sample

The soil analysis was carried out before the establishment of soybean field experiment, during both the experimental years *i.e.* 2015-16 and 2016-17. The data presented in Table 3.1. The experimental soil was fine, Smectitic, Iso-hyperthermic Typic Haplusterts. It was slightly alkaline in reaction (7.76 and 7.79), safe in soluble salt concentration (EC 0.29 to 0.31 dSm⁻¹) and medium in organic carbon content (48.00 and 51.02 g kg⁻¹) for soybean crop during the year 2016-17 and 2017-18. The free calcium carbonate content was 58.27 and 56.49 g kg⁻¹.

The nutrient status of experimental soil before sowing of soybean during 2016-17 and 2017-18 are presented in Table 3.1. Soils are low in available N, low in P₂O₅ and high in K₂O. While, the micronutrient status likes zinc and boron content before administration of treatments were low in Zn and B content.

3.7 Field experimental details

After completion of preparatory tillage operations, the experiment was laid out in Randomized Block Design comprising seven (07) treatments replicated thrice.

3.7.1 Experimental Details

Particulars	Year 2016-17	Year 2017-18
Season	<i>Kharif</i> , 2016	<i>Kharif</i> , 2017
Crop	Soybean	Soybean
Variety	MAUS 162	MAUS 162
Spacing	45 x 5 cm ²	45 x 5 cm ²
Plot Size	5.4 x 7.0 m ²	5.4 x 7.0 m ²
Design	Randomized Block Design	Randomized Block Design
Treatments	Seven	Seven
Replications	Three	Three
Site	Research Farm, Dept. of Soil Science & Agril. Chemistry, College of Agriculture, Parbhani	Research Farm, Dept. of Soil Science & Agril. Chemistry, College of Agriculture, Parbhani
Sowing	28.06.2016	27.06.2017
Harvesting	18.10.2016	12.10.2017

3.7.2 Plan of layout

The plan of layout is depicted in fig 3.1 for *kharif* season, 2016-17 and 2017-18 on fixed layout.

3.7.3 Treatment details : 07 (Seven Treatments)

Treatments Symbols	Treatment Details
F1: Ctrl	No Fertilizers
F2: NPK	30kgN: 60kgP ₂ O ₅ : 30kgK ₂ O ha ⁻¹
F3: RDWS	30kgN: 60kgP ₂ O ₅ : 30kgK ₂ O: 20kgS ha ⁻¹ + Water Spray
F4: RDZn	30kgN: 60kgP ₂ O ₅ : 30kgK ₂ O: 20kgS + 20 kgZnSO ₄ ha ⁻¹
F5: RDZnKB	30kgN: 60kgP ₂ O ₅ : 30kgK ₂ O: 20kgS + 20kg ZnSO ₄ ha ⁻¹ + 1% KNO ₃ (40 & 60DAS)
F6: RDZnKBGR	30kgN: 60kgP ₂ O ₅ : 30kgK ₂ O: 20kgS + 20kgZnSO ₄ ha ⁻¹ + 1% KNO ₃ (40 & 60DAS) + Growth Regulators viz., (NAA20mg/l at 40DAS) + GA(20mg/l at 60DAS)
F7: RDZnGR	30kgN: 60kgP ₂ O ₅ : 30kgK ₂ O: 20kgS + 20kg ZnSO ₄ ha ⁻¹ + Growth Regulators viz., (NAA20mg/l at 40DAS) + GA (20mg/l at 60DAS)

3.7.4 Conduct of Experiment

The land of the experimental site was prepared by one ploughing and two harrowing and layout was done after the onset of monsoon.

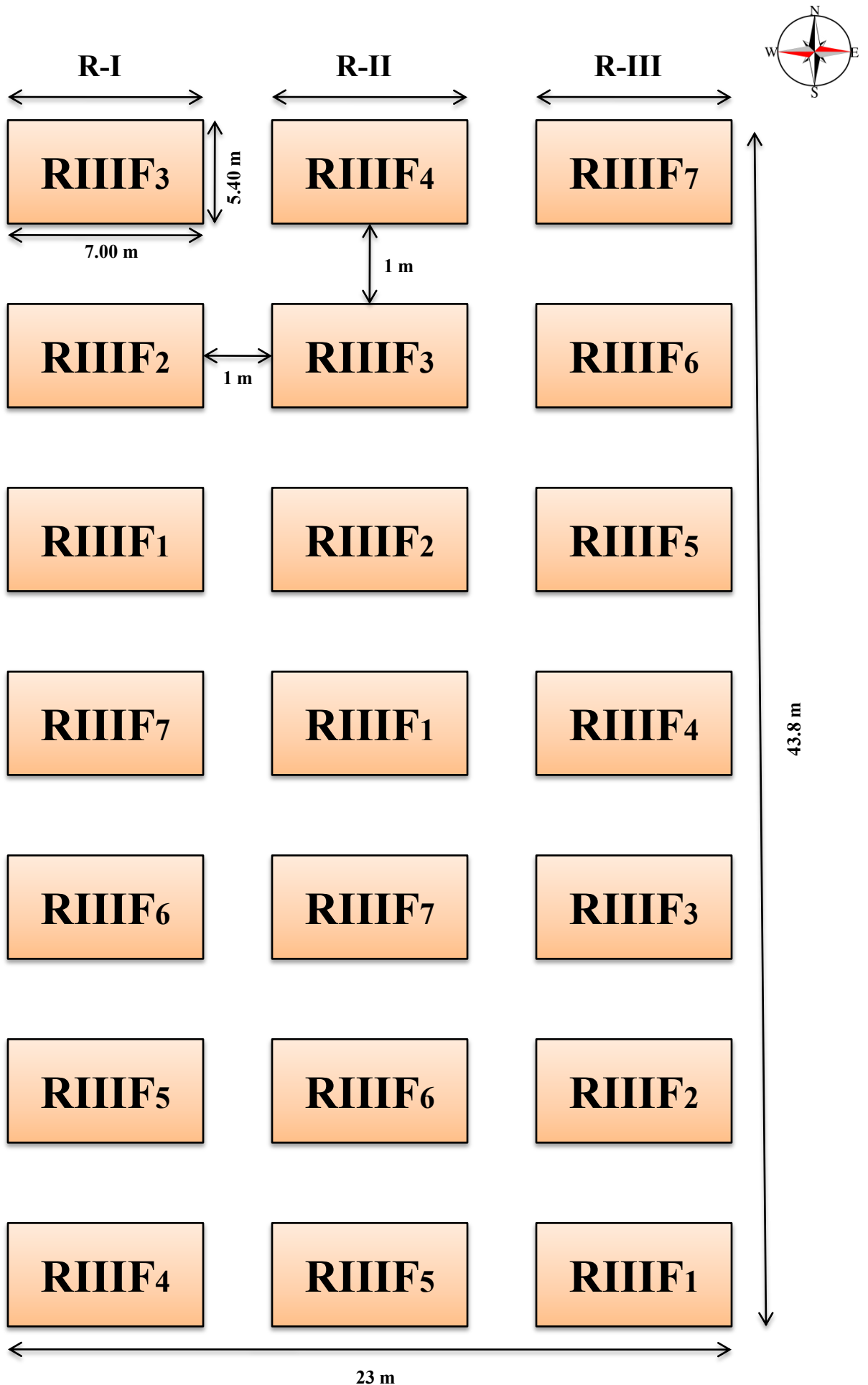


Fig.3.1. Plan of Layout (For Year 2016-17 and 2017-18)

Fig.3.2. Rainfall (mm) during the experimental years 2016-17 and 2017-18

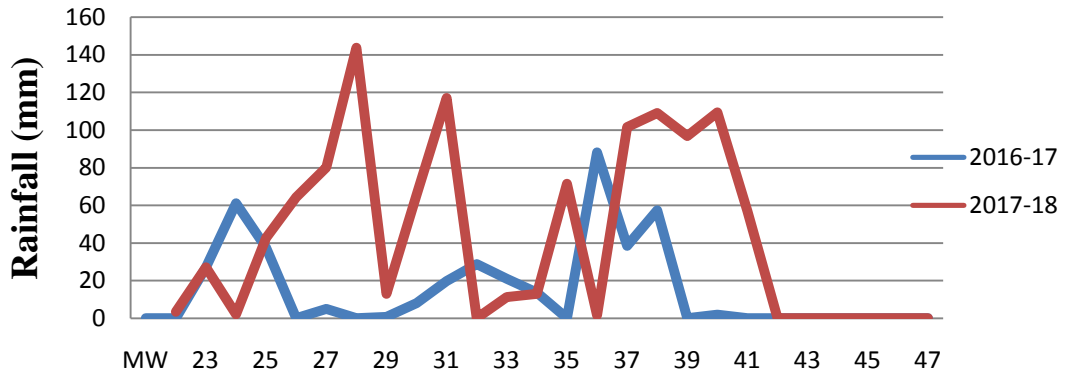


Fig.3.3 Temperature⁰ c during the experimental years 2016-17 and 2017-18

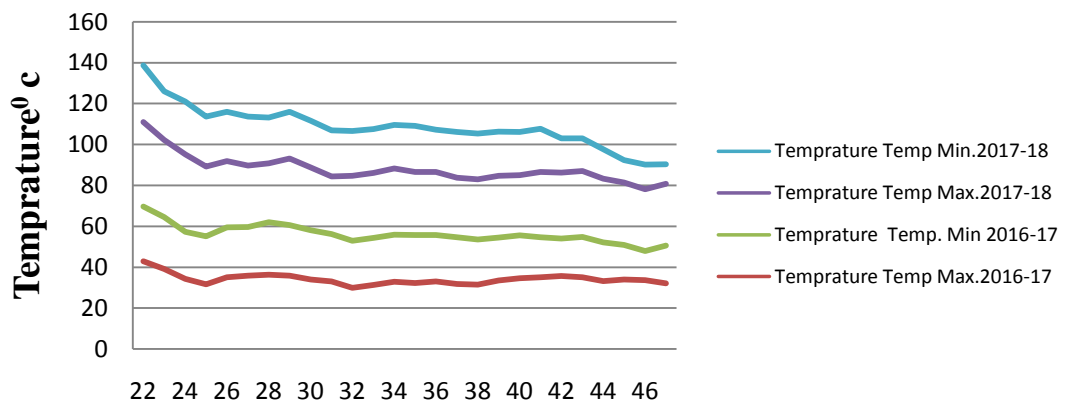


Fig.3.4 Relative humidity % during the experimental years 2016-17 and 2017-18

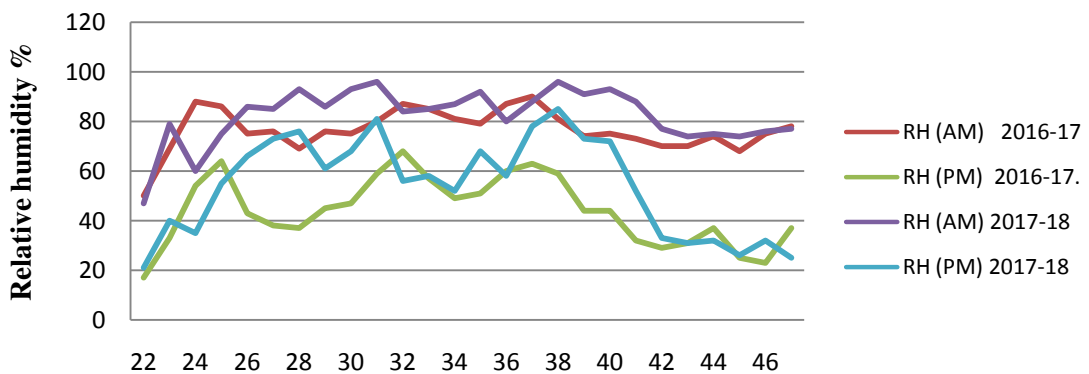




Plate.1 Soybean Biofertilizer seed treatment



Plate.2 Sowing of *kharif* Soybean

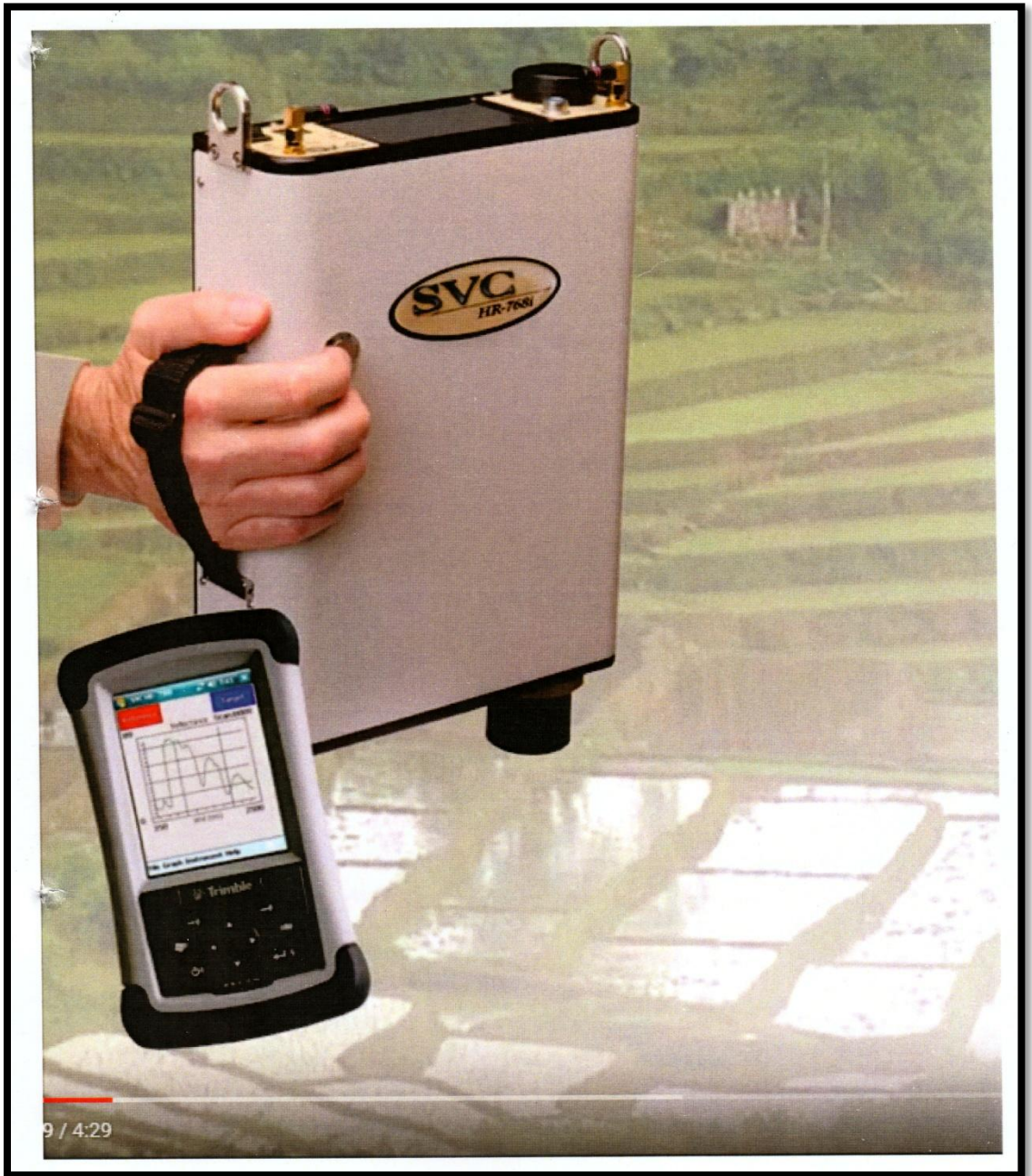


Plate.3 GER-1500 Spectrophotometer



Plate.4 Intercultural Operation & Preparation of Ridges



Plate.5 Experimental Field View

The certified seed of soybean MAUS 162 were sown in *kharif* by dibbling one seed per hill at 45 x 5 cm² distances; gap filling was done 12 days after sowing to maintain plant population. Schedule of cultural operation was carried out as per recommendations. The soybean crop was harvested and plot wise seed and straw yield per plot was recorded.

3.7.5 Seed Treatment

Seed treatment with the fungicides and biofertilizers: Soybean seeds treated with carbendazim or thiram @ 2g/kg of seed 24 hours before sowing or with the talc formulation with *Trichoderma viridae* @ 4 g/kg seed. Further the soybean seeds were treated with liquid biofertilizer i.e. *rhizophosphobacteria* @ 10ml/kg seed.

3.8 Biometric observations

3.8.1 Plant samplings

Five representative plants from each plot were being randomly selected, uprooted, washed, labeled and taking biometric observations.

3.8.2 Plant height

Height of plant was recorded from ground level to the top of shoot; Average value worked out from five plants observations and recorded as plant height.

3.8.3 Leaf area index (LAI)

Leaf area was carried out by using Systronics leaf area meter.

3.8.5 Number of nodules

Five plants selected for observations were used for nodule count. Roots of selected plants were washed then counted nodules of each plants and average number of nodules per plant was counted.

3.8.6 Fresh weight of nodules

The fresh weight of nodules was measured in g/plant on electrical balance.

3.8.7 Dry weight of nodules

The collected nodules were oven dried and dry weight of nodules recorded in g/plant.

3.8.8 Number of pods per plant

Number of pods per plant was counted for five plants and average values were recorded as number of pods per plant.

3.8.9 Pod length

Pods from five plants were selected from each plot and randomly select five pods from each plant and measure pod length.

3.8.10 Pod weight

Pods from five plants were selected from each plot and randomly select five pods from each plant and measure weight.

3.8.11 Grain and straw yield

Plot wise crop was harvested from net plot and pods will be separated and separate weight of seeds and straw were recorded in kg and calculated on the basis of ha. Basis using formula given below,

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield kg plot}^{-1}}{\text{Net plot area (m}^2\text{)}} \times 10,000$$

$$\text{Straw yield (kg ha}^{-1}\text{)} = \frac{\text{Straw yield kg plot}^{-1}}{\text{Net plot area (m}^2\text{)}} \times 10,000$$

3.8.12 Post-harvest studies

3.8.13 Grain yield

The crop was harvested plot wise and grain yield were obtained and expressed on hectare basis kg ha⁻¹.

3.8.14 Dry matter yield

The crop was harvested plot wise and dry matter yield were obtained and expressed on hectare basis kg ha⁻¹.

3.9 Instruments used for collection of spectral data

About SVC GER 1500 Spectro-radiometer

SVC, GER 1500 Spectro-radiometer was used for collecting the data on canopy reflectance in visible and near infra red (NIR) regions of electromagnetic

radiations. EMR span starts from 220 μm to 1500 μm . The screen protector of this device is highly reflective.

3.10 Spectral Observations

SVC, GER 1500 Spectro-radiometer will be used for collecting the data on canopy reflectance in visible and near infra red region (NIR) of electromagnetic radiation (EMR). EMR span start from very short wavelength gamma rays to long radio waves. The radiometric observations were carried out throughout the growing season keeping approximately 10 to 15 days interval in two observations as per weather conditions on cloud free days. The radiometer was kept one foot above the canopy. All spectral data will be collected in between 10.30 to 13.30 hrs. Indian standard time in direct sunlight on cloud free days or nearly cloud free day. Irradiance from barium sulphate standard will be measured after each radiance measurements and readings were used to calculate the corrected canopy reflectance.

The spectral bands selected,

1. Visible (blue green): 0.45-0.52 μm
2. Visible (green) : 0.52-0.59 μm
3. Visible (red) : 0.62-0.68 μm
4. NIR : 0.77-0.86 μm

3.11 Collection of soil and plant samples and their analysis

3.11.1 Soil Analysis

Preparation of soil sample

Before sowing of soybean, soil samples were collected from 0-20 depth. These soils samples were dried in shade followed by oven drying and will be sieved through 2 mm sieve. These samples were stored in cloth bags with proper labeling and finally used for nutrient analysis. The following laboratory methods were used for the analysis of initial physico-chemical properties and available nutrient status of soil as well as the soil after harvest of crop.

3.11.2 Plant Analysis

Preparation of plant samples

The treatment wise plant samples of soybean were collected at various growth stages. Plants were uprooted and the roots were cleaned with distilled water. The plant

samples will be oven dried and ground to be maximum fineness for chemical analysis. The soil and plant samples analyzed for N, P, K, S, Zn, B content. For each observation two soybean plants will be uprooted to record biomass, LAI and chlorophyll content. Same plant samples were oven dried and processed for chemical constituent analysis.

Table 3.2 Methods of Soil and Plant Analysis

Soil Property/ Nutrients	Methods	References
SOIL ANALYSIS		
pH	1: 2.5 (soil : water)	Jackson, 1973
EC	1:2.5 (soil: water)	Jackson, 1973
Organic carbon	Wet digestion	Walkley and Black, 1934
Calcium carbonate	Rapid titration	Piper, 1966
Available nitrogen	Alkaline potassium permanganate	Subbiah & Asija, 1956
Available phosphorus	0.5 M Sodium bicarbonate	Olsen <i>et al</i> , 1954
Available potassium	Neutral normal ammonium acetate	Jackson, 1973
Available sulphur	Turbidimetric method	Chopra & Kanwar, 1976
DTPA-Zn	DTPA-extraction using AAS	Lindsay & Norvell, 1978
Available B	HWS-B	
PLANT ANALYSIS (Total nutrients)		
Nitrogen	Microkjeldahl's apparatus	AOAC, 1975
Phosphorus	Vanadomolybdate phosphoric acid yellow colour method	Jackson, 1967
Potassium	Flame photometer	Jackson, 1967
Sulphur	Turbidimetric method	Tabatai & Bremner, 1970
Zinc	Acid digestion using AAS	Lindsay & Norvell, 1978
Boron	Dry ashing by Azomethine -H	Gupta, 1967
Leaf Reflectance	SVC GER 1500 Spectro-radiometer	
Chlorophyll content (Chl. a, b and total)	DMSO	Hiscox and Israelstan, 1979.
Carotenoids	DMSO	Hiscox and Israelstan, 1979.
GRAIN ANALYSIS		
Oil content	Soxhlet method	Sadasivan and Manikam, 1992
Crude protein	Microkjeldahl's Apparatus (N x 6.25)	AOAC, 1975

3.12 Spectral indices and statistical analysis

3.12.1 Calculation for spectral indices

Four spectral indices *viz.*, relative vegetation index (RVI), Normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI) and infra-



Plate.6 Selection of Plants for Spectral Observations



Plate.7 Labeling of Experimental Plots



Plate.8 Foliar Spray Formulations



Plate.9 Foliar Sprays



Plate.10 Plant Canopy before and After Spray



Plate.11 Soybean Spectral Reflectance Study



Plate.12 LAI Measurement and Nodule Count in Laboratory



Plate.13 Fertility Level- F6 (A View)



Plate.14 Soybean with F1 and F6 Fertility Levels

red percentage vegetation index (IPVI) can be computed from the spectral reflectance data. The red and near infra red spectral reflectance for each treatment will be transferred to RVI, NDVI, SAVI, and IPVI ratios.

Calculation of corrected NIR and R reflectance

$$NIR = NIRc/NIRb$$

Where,

NIRc = Canopy radiance in NIR band

NIRb = Irradiance on barium plate

Where,

Rc = Canopy radiance in R band

Rb = Irradiance on barium plate in R band

Relative/ Ratio Vegetation Index (RVI)

Relative vegetation index is the ratio vegetation index, which was first described by Jordan (1669). Relative vegetation index is a corrected ratio of canopy reflectance in NIR (Band 4) over canopy reflectance in Red (Band 3) radiation.

$$RVI = NIR/R$$

Normalized Difference Vegetation Index (NDVI)

Normalized difference vegetation index is described by Rouse *et al*, (1973) but the concept of NDVI was first presented by Kriegler *et al*, (1969).

$$NDVI = NIR-R/NIR+R$$

Soil Adjusted Vegetation Index (SAVI)

SAVI is the soil adjusted vegetation index which was introduced by (Huete, 1988).

$$SAVI = \frac{NIR-R}{NIR + R + L} \times (1 + L)$$

Where, L is a correction factor which ranges from 0: For very high vegetation cover to 1: For very low vegetation cover. The most typically used value is 0.5: For intermediate vegetation cover.


Infrared Percentage Vegetation Index (IPVI)

Infrared percentage vegetation index is first introduced by Crippen, (1990).

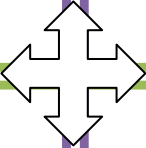

$$IPVI = NIR/ NIR + Red$$

3.12.2 Statistical Analysis

In the statistical analysis these data obtained from field experiment and the ground truth of the crop soybean on spectral reflectance, available soil nutrients, plant nutrient concentrations and various spectral ratios should be computed and correlation regression technique to be followed (Panse and Sukhatme, 1985). The biomass and economic yield data should also be derived and exposed for design analysis and critical difference is to be calculated for the treatments comparison.



**RESULTS
AND
DISCUSSION**



CHAPTER IV

RESULTS AND DISCUSSION

In order to assess “Studies on yield maximization of soybean through soil and foliar feeding of nutrients, growth regulators and monitoring growth profile by spectral reflectance” field experiments were conducted at research farm of Soil Science and Agricultural Chemistry, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani with seven treatments and three replications in randomized block design for two consecutive years 2016-17 and 2017-18. The results emerged out of the experimentation were statistically analyzed, organized, appropriately tabulated, interpreted and discussed in this chapter under the following sub-heads.

4.1 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on biometric parameters of soybean.

4.1.1 Initial and final plant population

4.1.2 Plant height

4.1.3 Number of leaves

4.1.4 Leaf area and leaf area index

4.1.5 Dry weight per plant

4.1.6 Number of nodules, fresh and dry weight of nodules

4.2 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on yield attributes of soybean.

4.2.1 Number of pods and pod weight per plant

4.2.2 Seed yield per hectare

4.2.3 Straw yield per hectare

4.2.4 Biological yield per hectare

4.2.5 Harvest index

4.3 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on chlorophyll and carotenoid pigments in leaves of soybean.

4.3.1 Chlorophyll a content

4.3.2 Chlorophyll b content

4.3.3 Total chlorophyll content

4.3.4 Carotenoid content

4.4 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on quality parameters (oil and protein content) in soybean seed

4.5 Effect of soil application of sulphur and zinc and foliar KNO₃, Borax, NAA and GA on spectral reflectance of soybean.

4.5.1 Spectral reflectance by soybean canopy

4.5.2 Canopy reflectance of soybean in Red and NIR band

4.5.3 Spectral Ratios: viz., RVI, NDVI, SAVI and IPVI of soybean

4.6 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on nutrient concentrations and uptake by soybean at harvest

4.6.1 Total N content in seed and straw of soybean

4.6.2 Total P content in seed and straw of soybean

4.6.3 Total K content in seed and straw of soybean

4.6.4 Total S content in seed and straw of soybean

4.6.5 Total Zn content in seed and straw of soybean

4.6.6 Total B content in seed and straw of soybean

4.6.7 N Uptake

4.6.8 P uptake

4.6.9 K uptake

4.6.10 S Uptake

4.6.11 Zn Uptake

4.6.12 B Uptake

4.7 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on soil properties after harvest of soybean.

4.7.1 Soil physico-chemical properties before sowing and after harvest of soybean

4.7.2 Soil nutrient status of soil before sowing and after harvest of soybean

4.8 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on nutrient balance and economics of soybean production.

4.8.1 Nutrient balance in soil

4.8.2 B: C ratio

4.1 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on biometric parameters of soybean.

Observations were recorded on initial and final plant population, height, number of leaves; leaf area index, total biomass production and economic yield were statistically analyzed.

4.1.1 Initial and final plant population

Initial and final plant population of soybean (Table 4.2) recorded non significant effect due to various fertility levels administered during both the experimental years. The average initial and final plant stand was 1667 (99.22%) and 1657 (98.63%) during the year 2016-17 and 2017-18, respectively. This explains good conduct of experimentation and no biasness in plant population that is going to affect treatment behavior. Due to non significant plant population, treatments expressed their full potential. Panse and Sukhatme (1985) reported that plant population of the field experiment must be non significant to get clear effects or treatments administrated.

4.1.2 Plant height

The periodical observations recorded on various dates under varied fertility levels are presented in Table 4.2. The height of soybean was monitored at critical growth stages of crop during both the experimental years. The critical growth stages of soybean *viz.*, vegetative, grand growth, flowering, pod formation stages falls at nearly 30,60,75 and 90 days after sowing of soybean MAUS-162 late variety specially developed for high yielding and mechanical harvesting purpose. It was observed that height of soybean crop increased from 24.55 to 74.77 cm and 29.47 to 70.17 cm during year 2016-17 and 2017-18, respectively. The average heights recorded were

Table 4.1 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on initial and final plant population of soybean

Treatments	Initial Plant Stand			Final Plant Stand		
	2016-17	2017-18	Mean	2016-17	2017-18	Mean
F1: Ctrl	1665	1657	1661	1648	1652	1650
F2: NPK	1664	1660	1662	1650	1647	1648
F3: RDWS	1666	1662	1664	1656	1658	1657
F4: RDZn	1670	1665	1667	1662	1660	1661
F5: RDZnKB	1674	1670	1672	1652	1662	1657
F6: RDZnKBGR	1676	1675	1675	1662	1668	1665
F7: RDZnGR	1674	1664	1669	1665	1660	1662
Mean	1670	1665	1667	1656	1658	1657
SE_±	5.06	6.37	--	6.49	5.74	--
CD at 5%	NS	NS	--	NS	NS	--

Table 4.2 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on plant height of soybean

Treatments	Plant height										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	17.46	25.63	29.55	33.45	26.52	18.21	23.62	27.62	30.26	24.67	25.59
F2: NPK	22.22	42.60	56.38	70.40	47.90	26.80	48.80	61.28	65.30	50.54	49.22
F3: RDWS	24.52	47.26	67.63	74.70	53.52	30.76	55.46	68.61	72.44	56.81	55.16
F4: RDZn	25.59	50.49	73.49	80.54	57.52	31.26	59.47	72.67	77.21	60.15	58.83
F5: RDZnKB	28.37	58.41	81.35	87.45	63.89	33.12	62.26	75.22	80.47	62.76	63.32
F6: RDZnKBGR	30.59	62.57	84.47	92.32	67.48	34.71	65.28	78.78	84.30	65.76	66.62
F7: RDZnGR	23.10	55.56	78.56	84.58	60.45	31.46	60.81	76.26	81.22	62.43	61.44
Mean	24.55	48.93	67.34	74.77	53.89	29.47	53.67	65.77	70.17	54.73	54.31
SE_±	1.62	0.40	0.77	0.66	--	0.56	0.81	0.70	0.84	--	--
CD at 5%	5.00	1.25	2.37	1.31	--	1.75	2.52	2.16	2.59	--	--

Table 4.3 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on number of leaves of soybean

Treatments	Number of leaves										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	12.12	18.00	22.00	16.00	17.03	12.00	21.00	24.00	12.00	17.25	17.14
F2: NPK	22.32	32.00	62.00	45.00	40.33	19.00	35.00	45.00	33.00	33.00	36.66
F3: RDWS	26.00	37.00	65.00	48.00	44.00	24.00	38.00	48.00	40.00	37.50	40.75
F4: RDZn	27.20	40.00	68.00	50.00	46.30	26.00	42.00	64.00	48.00	45.00	45.65
F5: RDZnKB	30.00	43.00	78.00	54.00	51.25	31.00	60.00	78.00	64.00	58.25	54.75
F6: RDZnKBGR	32.70	46.00	82.33	60.00	55.25	34.00	64.00	81.00	67.00	61.50	58.37
F7: RDZnGR	29.40	42.00	75.00	56.00	50.60	30.00	57.00	75.00	62.00	56.00	53.30
Mean	25.67	36.85	64.61	47.00	43.53	25.14	45.28	59.28	46.57	44.06	43.79
SE_±	0.45	1.52	0.63	0.73	--	0.65	0.90	1.38	1.10	--	--
CD at 5%	1.39	4.68	1.95	2.26	--	2.01	2.79	4.26	3.40	--	--

53.89 and 54.73 cm during the year 2016-17 and 2017-18, respectively. Further, it was also noticed that during year 2016-17 and 2017-18 growth rate was very high in vegetative stage till flowering stage. There after the growth rate was relatively low after flowering to pod formation stage (75 to 90 DAS). The effect of soil and foliar application of nutrients and growth regulators recorded significant impact on height of plant in both the years of experiments. There was significant increase in height in both the years of experiments. There was significant increase in height of plant with every addition of nutrients through soil and foliar applications. Further data revealed that application of sulphur and zinc with foliar spray of 1% KNO₃ at 40 and 60 DAS, 0.2 percent borax at 40 DAS, NAA 20 PPM at 40 DAS and GA 20 PPM at 60 DAS significantly increased plant height in both the experimental years and pooled of two years, followed by the treatment F4 (RDZnKB). It shows that addition of N, P, K and S micronutrients like Zn, and foliar sprays of K and B with growth regulators play a vital role in increasing height of soyabean crop.

4.1.3 Number of leaves

Numbers of leaves of soybean were recorded at critical growth stages of soybean during both the years of experiment. The data on number of leaves per plant are presented in Table 4.3. The maximum numbers of leaves were found at flowering stage of soybean in both the years. The average numbers of leaves recorded were 43.53 and 44.06 in 2016-17 and 2017-18, respectively. Further, it was also observed that during 2016-17 and 2017-18 application of each additional nutrient through soil and foliar application increased number of leaves per plant significantly. Treatments F₆ significantly showed more number of leaves per plant at all growth stages over control and other treatments. The mean number of leaves during 2016-17 and 2017-18 were 25.67, 36.85, 64.61 and 47.00 and 25.14, 45.25, 59.28 and 46.57 at 30, 60, 75 and 90 DAS. The numbers of leaves were maximum at 75 days after sowing *i.e.* at flowering stage. Thereafter due to leaves shedding at pod formation stage soybean leaf count reduced due to physiological shedding of older leaves to maturity of soybean leaf count becomes less.

4.1.4 Leaf area index

The data on leaf area and leaf area index as influenced by different fertility levels are presented in Table 4.4 and 4.5. The crop leaf area is one of the important

Table 4.4 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on leaf area (cm²/plant) of soybean

Treatments	Leaf area										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	248.43	512.54	532.42	232.26	381.41	312.71	536.28	556.59	334.59	435.04	408.22
F2: NPK	487.00	721.66	866.38	487.36	640.60	534.25	780.32	982.31	604.60	725.37	682.98
F3: RDWS	524.63	812.55	900.95	542.46	695.14	560.33	852.55	1115.60	681.34	802.45	748.79
F4: RDZn	582.44	860.47	956.45	581.33	745.17	617.77	961.23	1182.40	720.32	870.43	807.80
F5: RDZnKB	634.50	940.50	1182.30	670.67	857.00	602.49	1049.00	1300.00	822.70	943.54	900.27
F6: RDZnKBGR	661.46	1020.50	1238.30	710.34	907.65	639.31	1090.30	1360.12	868.31	989.51	948.58
F7: RDZnGR	620.78	904.39	1142.50	656.48	831.03	582.19	957.43	1260.40	765.72	891.43	861.23
Mean	537.03	824.65	974.18	554.41	722.56	749.86	889.55	1108.20	685.36	808.24	765.40
SE_±	12.85	28.50	26.04	20.31	--	24.32	14.35	26.90	21.37	--	--
CD at 5%	39.55	87.69	80.12	62.49	--	74.83	44.17	82.79	65.77	--	--

Table 4.5 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on LAI/plant of soybean

Treatments	LAI										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	1.10	2.27	2.36	1.47	1.80	1.38	2.37	2.46	1.48	1.92	1.86
F2: NPK	2.16	3.20	3.84	2.60	2.95	2.37	3.46	4.36	2.68	3.21	3.08
F3: RDWS	2.32	3.60	3.99	2.77	3.17	2.48	3.78	4.95	3.02	3.55	3.36
F4: RDZn	2.58	3.81	4.24	3.02	3.41	2.59	4.27	5.25	3.19	3.82	3.61
F5: RDZnKB	2.81	4.17	5.25	3.42	3.91	2.67	4.65	5.77	3.65	4.18	4.04
F6: RDZnKBGR	2.93	4.52	5.49	3.60	4.13	2.83	4.84	6.04	3.85	4.39	4.26
F7: RDZnGR	2.75	4.01	5.07	3.36	3.79	2.58	4.24	5.59	3.39	3.95	3.87
Mean	2.37	3.65	4.32	2.89	3.30	2.41	3.94	4.91	3.03	3.57	3.43
SE_±	0.05	0.12	0.11	0.09	--	0.095	0.06	0.11	0.09	--	--
CD at 5%	0.17	0.38	0.35	0.28	--	0.290	0.19	0.36	0.29	--	--

attributes that influence the growth, development and spectral parameters. Hence the measurement of leaf area was carried out at all growth stages. The data pertaining to these observations revealed that leaf area and leaf area index were influenced by various fertility levels. Leaf area was increased from 537.03 to 974.18 cm with a mean of 722.56 cm during 2016-17 and during 2017-18 leaf area increased from 749.86 to 1108.20 cm with mean value of 808.24 cm whereas, leaf area index per plant increased from 2.37 to 4.32 with a mean value of 3.30 during year 2016-17 and during year 2017-18, it was increased from 2.41 to 4.91 with mean value of 3.57. In both the years of experimentation, leaf area & leaf area index were increased progressively up to flowering stage of soybean there after there was decrease in leaf area index due to falling of leaves towards maturity of soybean.

Shruthi (2013) reported that the leaf area and leaf area index of soybean were also higher at 45 DAS and at the time of harvest in the treatment of ZnSO₄ (0.3%) + Boron (0.2%) + KNO₃ (0.5%) and NAA and GA spray. It is also observed that days to 50 per cent flowering and days to maturity were influenced significantly due to foliar application of micronutrients. However, lesser number of days (37.40 days) to 50 per cent flowering and days to maturity (82 days) were noticed due to foliar application of ZnSO₄ (0.3%) + Boron (0.2%) + KNO₃ (0.5%) imposed at 30 and 45 DAS as compared to other treatments. This might be due to efficient translocation of sugar within the plants and also production of growth promoting substances, carbohydrates and synthesis of nucleic acids in turn helped in early flowering. Similar observations were noticed in cotton by Silva *et al*, (1982).

The foliar application of different micronutrients and their combined effect on growth parameters like plant height, number of leaves, leaf area index showed significant differences in all the treatments as compared to the control. the foliar application of ZnSO₄ (0.3%) + Boron (0.2%) + KNO₃ (0.5%) at 30 and 45 DAS recorded higher plant height, more number of leaves per plant and took lesser number of days to 50 per cent flowering and days to maturity Shruthi (2013). The improvement in above growth parameters might be due to the foliar feeding of micronutrients which is more effective when roots are unable to absorb sufficient nutrients from this soil due to higher degree of fixation, loss due to leaching, low soil temperature and lack of soil moisture. The results of the present investigation are in

line with the findings of Krishnaveni *et al.*, (2004) and Restrepos (1987) in soybean and Padma *et al.*, (1989) in French bean.

Shruthi (2013) observed that foliar application of ZnSO₄ (0.3%) + Boron (0.2%) + KNO₃ (0.5%) at 30 and 45 DAS recorded significantly maximum plant height (58.70 cm) over control (52.60 cm) which might be due to the involvement of zinc in chlorophyll formation, which have helped to favor cell division, meristematic activity in apical tissue, expansion of cell and formation of new cell wall. The supply of such important micronutrients in the early crop growth phase, which in turn encouraged early vigorous growth. The growth of soybean significantly influenced with application of RDF and two sprayings of KNO₃ (30 & 45 DAS) and RDF and two sprayings of ZnSO₄ (30 & 45 DAS). Similar beneficial effect of micronutrients on plant height was reported by Krishnaveni *et al.*, (2004) in green gram and (Upadhyay, 1994) in cotton and Jadhav *et al.*, 2019 on soybean crop.

4.1.5 Dry weight

The data on dry weight per plant (biomass) of soybean under various fertility levels are presented in table 4.7 and depicted in fig 4.1. The data indicated periodical increase in dry weight of soybean. It was found to be increased with the advancement of crop growth stages up to maturity of soybean. The average increase in dry weight of plant recovery was from 14.67 to 30.78 g plant⁻¹ in 2016-17 and 16.39 to 35.89 g plant⁻¹ in 2017-18. The average mean of individual year was 24.72 and 28.62 g plant⁻¹. At all growth observations, application of RDF + Zn + foliar applications of potash, borax, NAA and GA produced maximum dry weight of soybean. The said treatment was followed by F₅ (RDF+Zn+K+B).

4.1.6 Number of nodules, fresh and dry weight of nodules

The data on nodules per plant, fresh weight of nodules and dry weight of nodules per plant are presented in Table 4.6. The number of nodules varied from 24.47 to 30.18 and 25.33 to 32.00 during year 2016-17 and 2017-18, respectively. There were no significant differences observed in both the years of experimentation due to various and treatments. Maximum numbers of nodules were observed in control treatment. Fresh weight of nodules varied from 1.22 to 1.34 and 1.12 to 1.30 g/ plant during year 2016-17 and 2017-18. Whereas, dry weight of nodules varied

Table 4.6 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on number of nodules, dry and fresh weight of nodules of soybean

Treatments	Nodules/plant			Fresh weight of nodules (g/plant)			Dry weight of nodules (g/plant)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
F1: Ctrl	30.18	32.00	31.09	1.34	1.30	1.32	0.78	0.71	0.74
F2: NPK	23.31	25.00	24.15	1.22	1.12	1.17	0.47	0.62	0.54
F3: RDWS	24.47	25.33	24.90	1.24	1.20	1.22	0.58	0.68	0.63
F4: RDZn	25.22	30.00	27.61	1.27	1.25	1.26	0.65	0.74	0.69
F5: RDZnKB	27.30	28.00	27.65	1.30	1.22	1.26	0.72	0.71	0.71
F6: RDZnKBGR	28.28	31.00	29.64	1.32	1.28	1.30	0.76	0.74	0.75
F7: RDZnGR	26.17	27.00	26.58	1.28	1.20	1.24	0.68	0.68	0.68
Mean	26.41	28.33	27.37	1.28	1.22	1.25	0.66	0.69	0.67
SE_±	2.28	2.51	--	0.043	0.023	--	0.022	0.012	--
CD at 5%	NS	NS	--	0.132	0.070	--	0.070	0.037	--

Table 4.7 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on dry weight (g/plant) of soybean

Treatments	Dry weight										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	10.48	18.31	19.40	15.48	15.91	11.23	18.55	23.32	20.58	18.42	17.16
F2: NPK	12.39	22.34	23.51	18.38	19.15	14.47	24.62	28.59	25.61	23.32	21.23
F3: RDWS	14.47	23.47	26.48	22.69	21.77	15.52	26.73	34.40	31.30	26.98	24.28
F4: RDZn	14.70	24.71	28.52	24.39	23.08	16.21	27.38	35.46	32.31	27.84	25.46
F5: RDZnKB	16.54	26.57	35.23	29.47	26.95	18.82	32.69	38.46	35.58	31.38	29.16
F6: RDZnKBGR	18.65	28.74	36.50	31.47	28.84	20.86	34.61	41.69	38.35	33.87	31.35
F7: RDZnGR	15.46	25.78	34.57	28.62	26.10	17.67	31.63	37.40	34.53	30.30	28.20
Mean	14.67	24.27	29.17	24.35	23.11	16.39	28.03	34.18	31.18	27.44	25.27
SE_±	0.31	0.59	0.78	0.73	--	0.42	0.74	0.72	0.67	--	--
CD at 5%	0.95	1.82	2.42	2.26	--	1.31	2.29	2.24	2.07	--	--

from 0.47 to 0.78 and 0.62 to 0.74 g plant⁻¹ during year 2017-18. No significant trend was observed for fresh and dry weight of nodules. Comparably maximum fresh and dry weight recorded in control treatment.

4.2 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on yield attributes of soybean.

4.2.1 Number of pods and pod weight

The data on yield attributing characters of soybean as affected by various fertility levels presented in table 4.8 and depicted in fig.4.2. The number pods per plant varied from 42.2 to 74.94 and 41.00 to 80.00 during 2016-17 and 2017-18, respectively. There was significant increase in number of pods per plant with all the treatments (Fertility levels) over control. In pooled analysis, the maximum number of pods (77.47) recorded with treatment F₆ *i.e.* soybean crop fertilized with RD+ Zn+ K, B and GR followed by treatment (F₅) soybean crop with RDF + Zn+ foliar K, B. In general numbers of pods were found maximum in year 2017-18 as compared to 2016-17. The pooled data indicated superiority of F₆ over all other treatments. The influence of different treatments on numbers of pods by the order; F₆ > F₅ > F₇ > F₄ > F₃ > F₂ > F₁.

Pod weight varied from 9.42 to 14.82 g/ plant in year 2016-17 with mean of 12.53 g / plant in year 2016-17 (Fig. 4.3 to 4.5). Similarly in year 2017-18 seed weight varied from 7.72 to 14.50 g/ plant with mean of 12.44 g/ plant in year 2017-2018. The pooled mean data also indicated the superiority of treatment F₆ over all other treatments with respect to pod weight g/ plant of soybean. In pooled analysis, treatment F₆ recorded maximum 100 seed weight (15.06 g), which was found significantly superior over rest of treatments. In general test weights of soybean were higher in 2016-17 as compared to 2017-18. The influence of different treatments on test weight followed by the order; F₆ > F₅ > F₇ > F₄ > F₃ > F₂ > F₁. The test weight was relatively lower in (F₁) control treatment.

4.2.2 Seed yield

The seed yield of *kharif* soybean significantly affected due to soil and foliar applications of nutrients and growth regulators (Table 4.9 depicted in fig.4.6). In pooled analysis, application of RD + Zn + foliar K, B and GR significantly recorded highest seed yield 26.66 qha⁻¹, which was found at par with treatment F₅ and F₇ and

Table 4.8 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on yield attributing characteristics of soybean

Treatments	No. of pods/plant			Seed wt. (g/plant)			Pod wt. (g/pod)			100 Seed wt. (g)		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
F1: Ctrl	42.12	41.00	41.56	9.42	7.72	8.57	0.28	0.31	0.29	10.47	11.60	11.03
F2: NPK	61.47	64.00	62.73	11.22	11.41	11.31	0.33	0.34	0.33	12.82	12.42	12.62
F3: RDWS	65.16	67.00	66.08	11.82	12.46	12.14	0.34	0.35	0.34	13.61	13.37	13.49
F4: RDZn	67.31	70.00	68.65	12.46	13.54	13.00	0.36	0.40	0.38	14.12	13.84	13.98
F5: RDZnKB	71.20	76.00	73.60	14.20	13.57	13.88	0.38	0.44	0.41	14.74	14.66	14.70
F6: RDZnKBGR	74.94	80.00	77.47	14.82	14.50	14.66	0.41	0.46	0.43	14.82	15.30	15.06
F7: RDZnGR	68.40	74.00	71.20	13.78	13.88	13.83	0.37	0.42	0.39	14.56	14.33	14.44
Mean	64.37	67.42	65.89	12.53	12.44	12.48	0.35	0.38	0.36	13.59	13.64	13.61
SE_±	0.86	1.14	0.39	0.42	0.34	0.15	0.006	0.006	0.005	0.40	0.28	0.05
CD at 5%	2.66	3.51	1.34	1.29	1.05	0.52	0.019	0.021	0.015	1.25	0.87	0.17

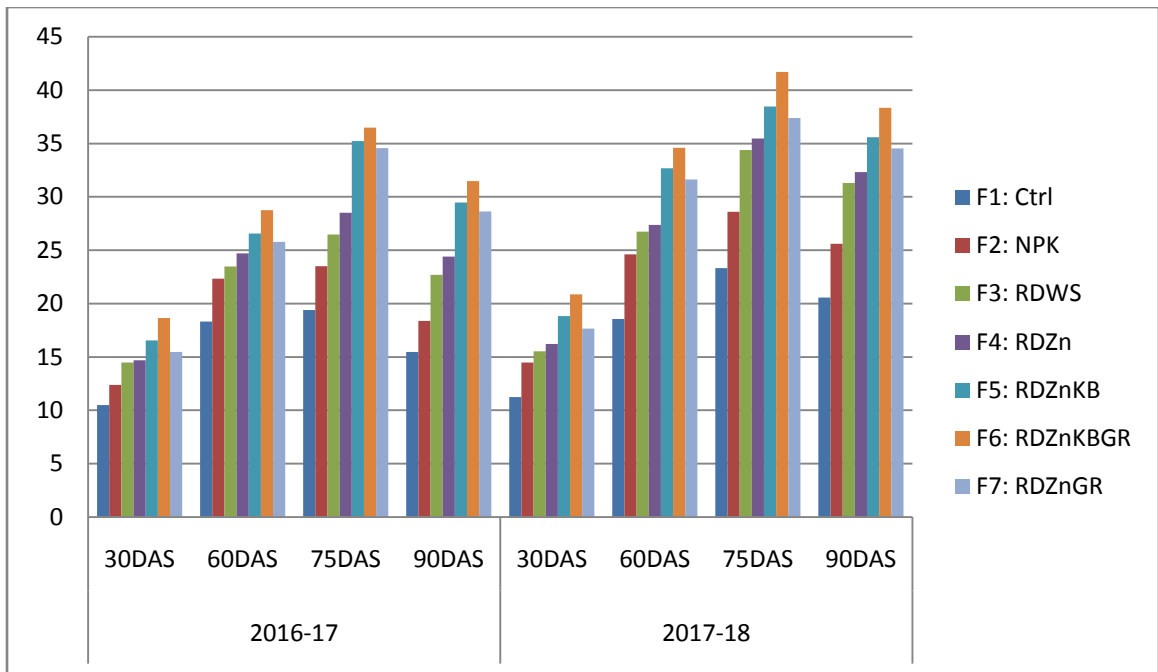


Fig. 4.1 Biomass (Dry weight) (g/plant) as influenced by fertility levels

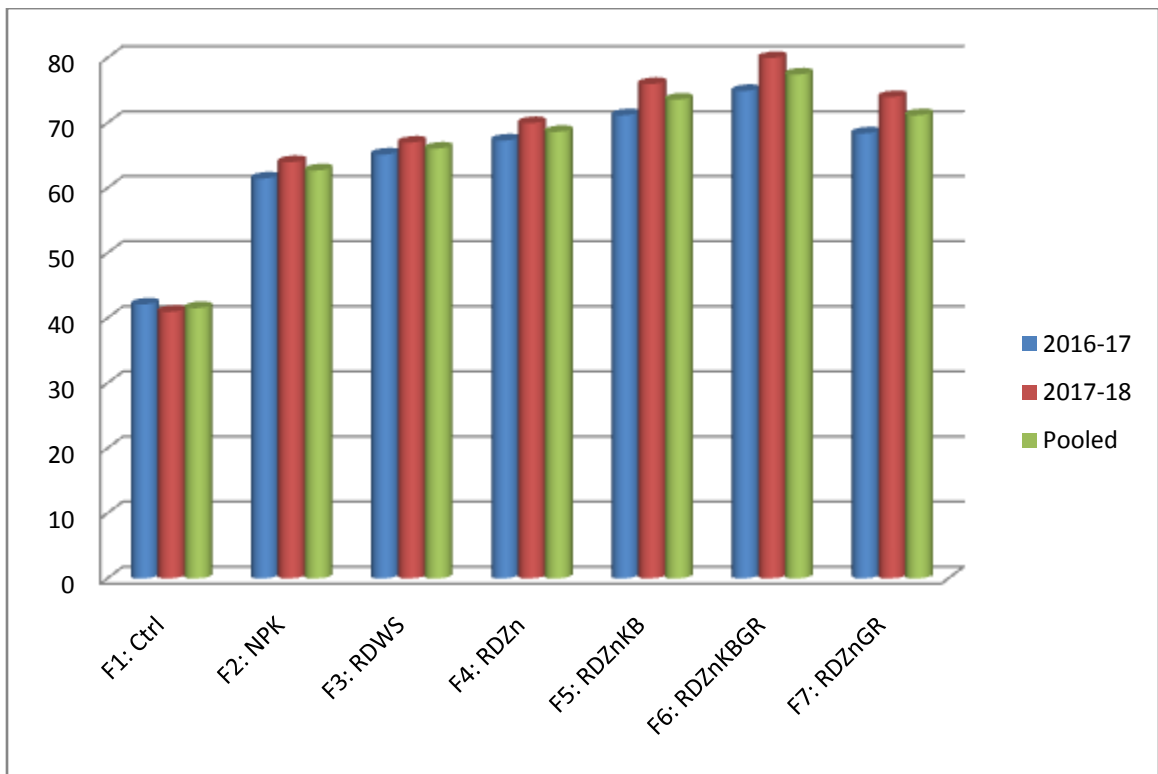


Fig. 4.2 Pods/plant as influenced by fertility levels

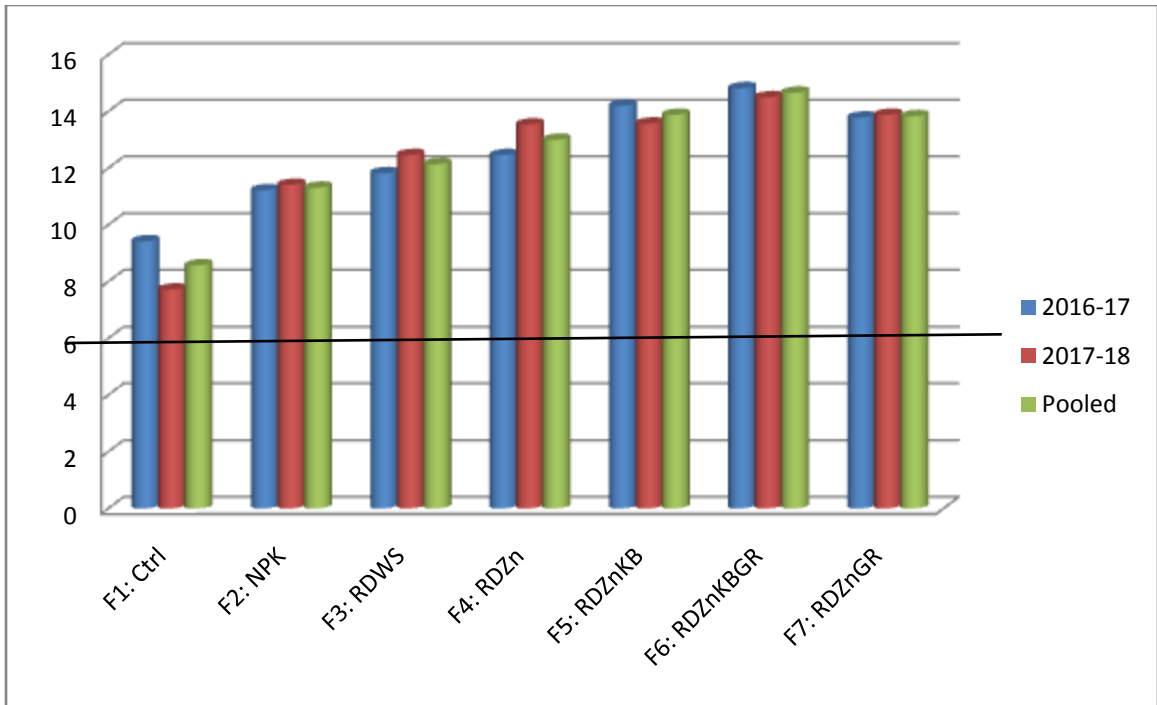


Fig. 4.3 Soybean seed weight (g/plant) as influenced by fertility levels

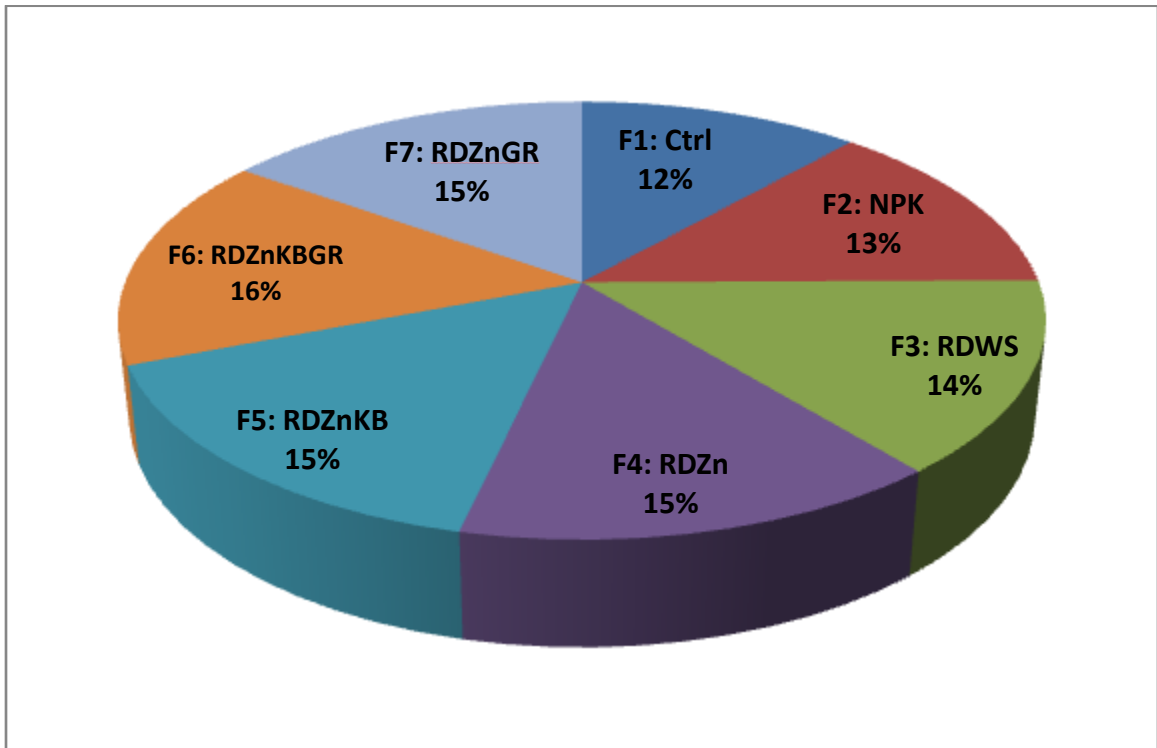


Fig. 4.4 Soybean 100 seed weight (g/100 seeds) as influenced by fertility levels

significantly superior over rest of treatments. Treatment F₁ recorded lowest seed yield 11.34 qha⁻¹. During year 2016-17 application of RD + Zn+ foliar K, B & GR recorded highest seed yield 27.90 qha⁻¹, which were found at par with F₅ and F₇. During year 2017-18 significantly highest seed yield (25.42 qha⁻¹) recorded with treatment F₆ which was found at par with F₅ and F₇.

During year 2016-17 seed yield varied from 12.42 to 27.90 qha⁻¹ with a mean of 22.67qha⁻¹. During year 2017-18 seed yield of soybean varied from 10.26 to 25.42 qha⁻¹ with a mean of 19.98 qha⁻¹. The treatments F₆, F₅, and F₇ were found on par with each other in pooled analysis as well as in both the years of experimentation.

Comparably highest seed yield was recorded in year 2016-17 compared to 2017-18. The seed yield was highest (27.90 and 25.42) with treatment F₆ during 2016-17 and 2017-18, respectively.

4.2.3 Straw yield

As regards the straw yield of soybean more over similar trend was observed as that of seed yield.(Table 4.9 and depicted in fig 4.7).

4.2.4 Biological yield

Soil and foliar application of nutrients and growth regulators significantly influenced on biological yield of soybean. Biological yield varied from 37.45 to 76.15 qha⁻¹ during year 2016-17 and 29.46 to 71.54 qha⁻¹ during year 2017-18. The biological yield was highest (76.15 and 66.93 qha⁻¹) with treatment F₆ during year 2016-17 and 2017-18, respectively. The treatment F₅ and F₇ was found at par with each other. Lowest biological yield (37.45 and 29.46 qha⁻¹) recorded in control treatment.

The pooled mean data on biological yield was in the range of 29.95 to 71.54 qha⁻¹ and further indicated the superiority of F₆ over all other treatments. The effect of different treatments followed the sequence; F₆ > F₅ > F₇ > F₄ > F₃ > F₂ > F₁.

4.2.5 Harvest index

Harvest index of soybean varied from 33.16 to 36.63 and 34.82 to 37.97 during year 2016-17 and 2017.18. The lowest harvest index observed is 33.16 and 34.82 during year 2016-17 and 2017-18. Comparably maximum harvest index was recorded during year 2017-18 compared to 2016-17.

Table 4.9 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on seed, straw, biological yield (q/ha.) and HI of soybean

Treatments	Seed yield			Straw yield			Biological yield			Harvest Index		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
F1: Ctrl	12.42	10.26	11.34	25.03	19.20	18.61	37.45	29.46	29.95	33.16	34.82	33.99
F2: NPK	20.57	17.30	18.57	37.63	31.44	34.53	58.20	48.00	53.10	35.34	36.04	35.69
F3: RDWS	21.72	18.62	19.84	39.48	32.24	35.86	61.20	50.86	56.03	35.49	36.61	36.05
F4: RDZn	23.60	20.47	22.04	42.56	33.90	38.23	66.16	54.37	60.26	35.67	37.64	36.65
F5: RDZnKB	26.82	24.00	25.41	47.44	39.40	43.42	74.26	63.40	68.83	36.11	37.85	36.98
F6: RDZnKBGR	27.90	25.42	26.66	48.25	41.51	44.88	76.15	66.93	71.54	36.63	37.97	37.70
F7: RDZnGR	25.70	23.81	24.71	46.71	39.33	43.02	72.41	64.04	67.72	35.49	37.76	36.62
Mean	22.67	19.98	21.22	41.01	33.88	36.93	63.69	53.43	58.20	35.41	36.95	36.18
SE_±	1.00	0.90	0.67	2.20	1.88	1.45	2.14	2.46	1.63	--	--	--
CD at 5%	3.08	2.78	1.97	6.78	5.80	4.23	6.62	7.59	4.77	--	--	--
CV	7.87	8.05	7.96	8.24	9.22	8.45	5.85	7.90	6.83	--	--	--

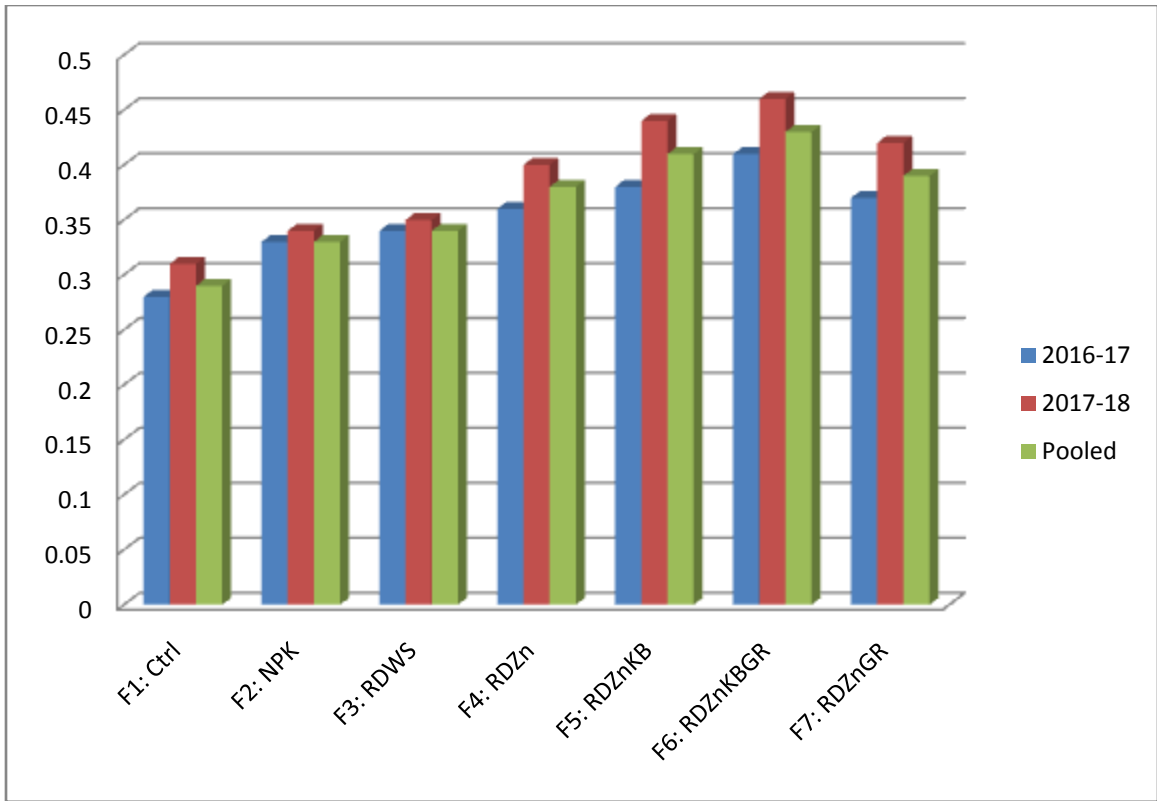


Fig. 4.5 Soybean Pod Weight (g/pod) as influenced by fertility levels

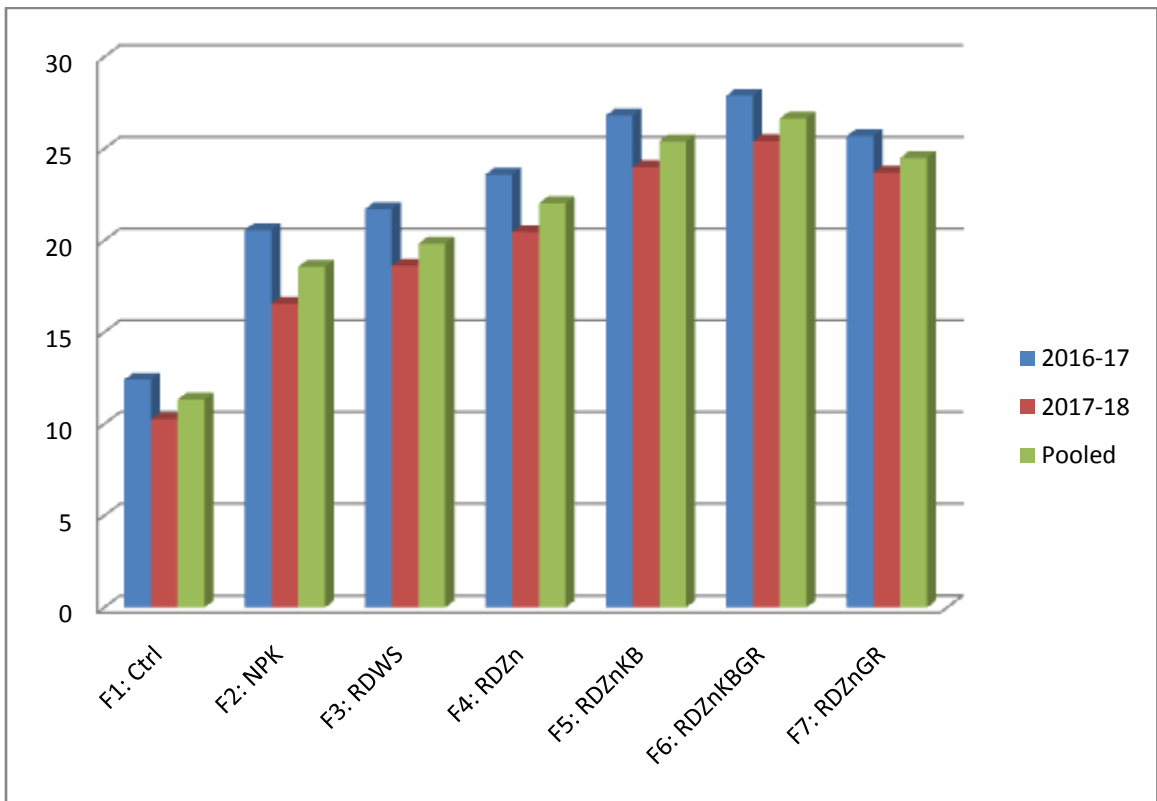


Fig. 4.6 Soybean Seed yield (q/ha.) as influenced by fertility levels

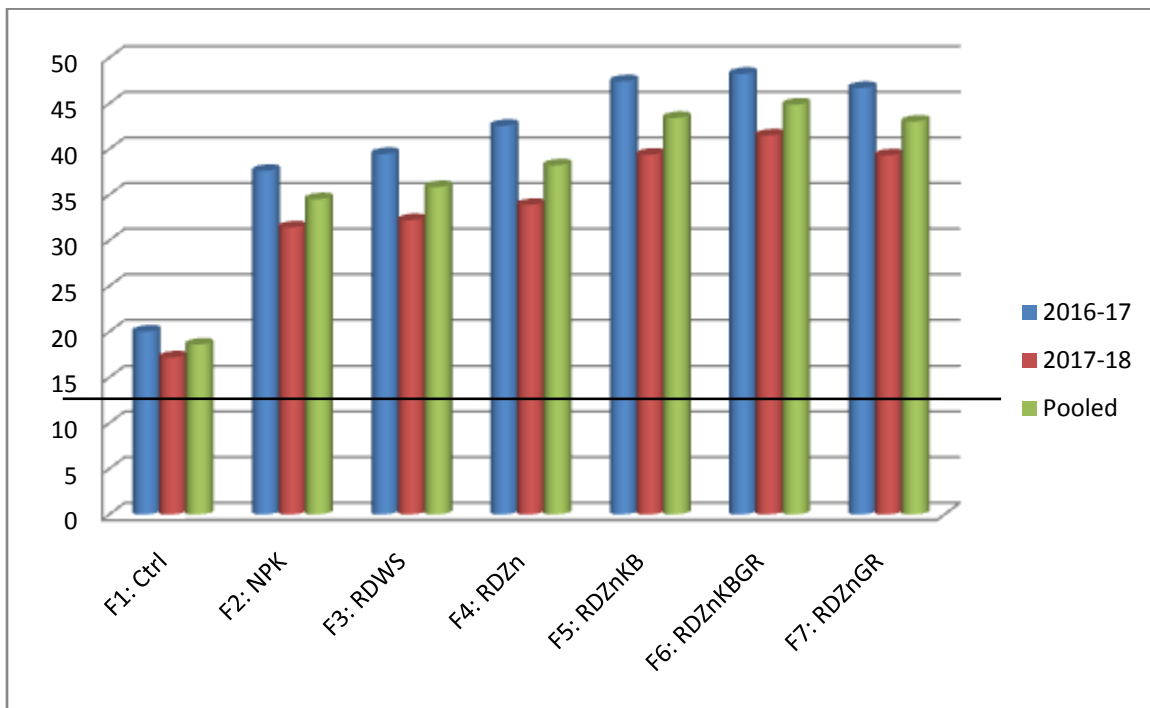


Fig. 4.7 Soybean Straw yield (q/ha.) as influenced by fertility levels

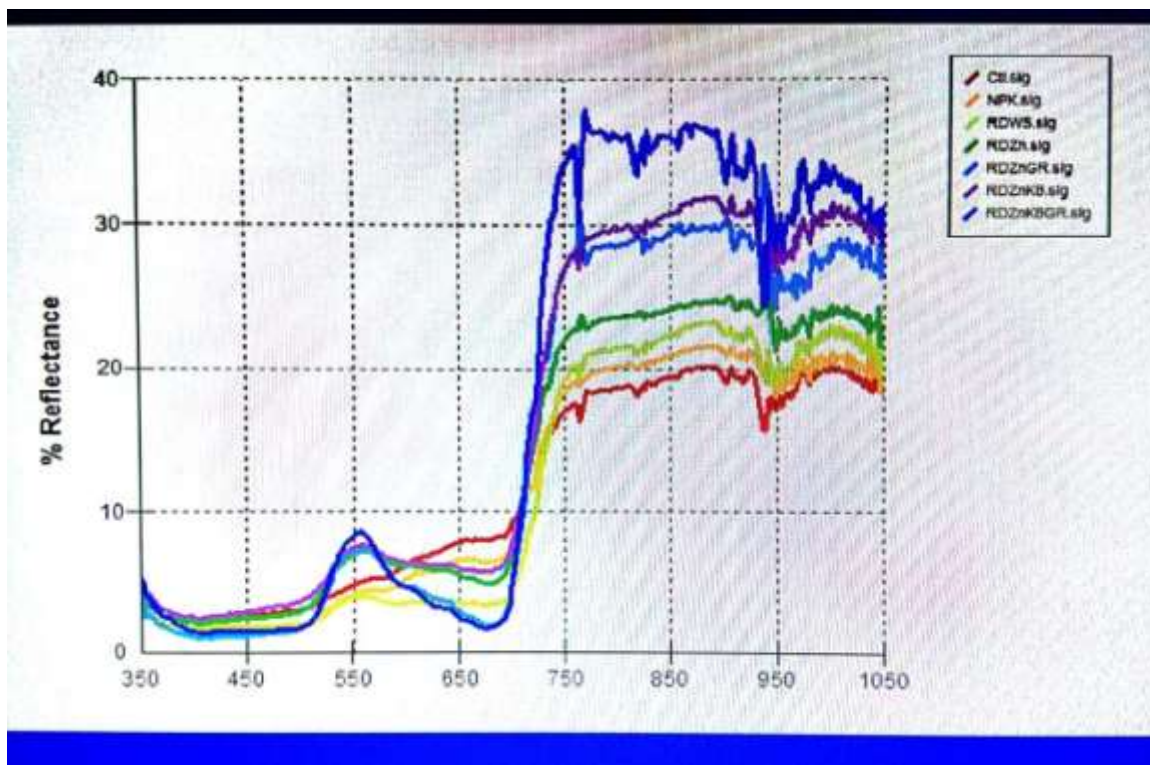


Fig. 4.8 Spectral reflectance of soybean 45 DAS under various treatments (2016)

A balanced fertilization with macro and micronutrients in plant nutrition is very important in the production of high yield with high quality seeds (Sawan *et al.*, 2001). For adequate plant growth and production, micronutrients are needed in small quantities; however, their deficiencies cause a great disturbance in the physiological and metabolic processes in the plant (Bacha *et al.*, 1997). Foliar feeding is a relatively new technique of feeding plants by applying liquid fertilizer directly to their leaves (Bernal *et al.*, 2007 and Baloch *et al.*, 2008). Throughout the world microelements such as Fe, Zn, Mn and Cu are added to foliar fertilizers, in order to compensate their deficiency especially in arid and semi arid regions (Kaya *et al.*, 2005). Micronutrients, especially Fe and Zn, act either as metal components of various enzymes or as functional, structural, or regulatory cofactors. Thus, they are associated with saccharide metabolism, photo-synthesis and protein synthesis (Marschner, 1995). In recent years, the role of micronutrients is gaining much importance particularly in soybean to boost up the productivity and also to improve the seed quality. The application of nutrients like zinc sulphate, boron and potassium nitrate brings about profound changes in various metabolic processes within the plant system and thereby, influence the seed yield potential (Tripathy *et al.*, 1999). Soybean is a pulse cum oil seed crop, its productivity relies greatly on external factors which include weather condition prevailing during critical phases of crop growth and the nutrient supply which influence the internal physiological process that results in yield.

The micronutrients are capable of redistributing dry matter in the plant system there by bringing about an improvement in the yield and its attributes as it was reported by Wankhade *et al.*, (1994) hybrid seeds. Anonymous (1995) and Raja Rajeshwari (1996) in cotton. The soybean seed yield directly depends on number of pods per plant, number of seeds per pod, seed weight per plant, seed weight per plot. Hundred seed weight is also one of the yield contributing components however, which did not differ significantly due to higher number of seeds per plant. Shruthi (2013) recorded numerically higher 100 seed weight (14.93 g) in T₇ (ZnSO₄ @ 0.3% +Boron @ 0.2% + KNO₃ @ 0.5%) compared to T₀ (control) (10.77 g)

The differences in the seed yield per hectare due to the influence of different application of micronutrient could be related to their seed yield per plant. The application of ZnSO₄ @ 0.3% + Boron@ 0.2% + KNO₃ @ 0.5% recorded significantly higher seed yield per plant (7.89 g), over ZnSO₄ @ 0.3%+ KNO₃@

0.5% (7.37 g) followed by ZnSO₄ @ 0.3%+ Boron @ 0.2% and Boron @ 0.2 % +KNO₃ @ 0.5% (7.29 and 7.02g, respectively) compared to T₀ (control). However, higher seed yield (2655 kg ha⁻¹) in the treatment of T₇ (ZnSO₄ @ 0.3% + Boron @ 0.2% + KNO₃ @ 0.5%) was recorded while significantly lower seed yield (2281 kg ha⁻¹) was noticed in T₀ (control) Shruthi (2013) in soybean. Similar results were reported by Tiwari and Yadava (1990) in Siratro plant, Sarkar and Mukhopadhyay (1990) in rice and Sudarshan and Ramaswami, (1993) in groundnut and blackgram cropping system. The marked rise in seed yield parameters recorded by application of micronutrients may be ascribed to higher translocation of metabolites from source to sink (seed) and carbohydrate metabolism and synthesis of nucleic acids. These results are in agreement with the findings of Gowda, Gopal *et al*, (1994) and Kiss, (1997) in groundnut and Balusumani *et al*, (1996) in soybean.

Seed yield and quality is more important than total biological yield which results from different combination of many physiological processes based on the environment under which the crop is grown. Seed yield and quality depends upon production of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as source to sink relation and also on plant growth and development during early stage of crop growth. Since, production as well as translocation of photosynthesis directly or indirectly dependent on seed production practices.

Shruthi (2013) reported that foliar application of ZnSO₄ (0.3%) + Boron (0.2%) + KNO₃ (0.5%) imposed at 30 and 45 DAS recorded higher seed yield and yield attributes like number of pods per plant, seed weight per plant (g), Seed weight per plot (kg), and seed yield kg per ha. Improvement in seed yield directly depends on number of pods per plant, pod weight per plant and seed weight per plant (g). In soybean, the seed yield depends on the accumulation of photo assimilates and partitioning in different parts of the plant. The yield is strongly influenced by the application of micronutrients indicating the role of these micronutrients in increasing the yield through their effect on various morpho-physiological traits. Micronutrients like zinc, boron and KNO₃ involved in the biochemical synthesis of phyto-hormone, which improved the yield and its attributes. The application of nutrients like zinc sulphate, Boron and Potassium nitrate brings about profound changes in various

metabolic processes within the plant system and thereby, influence the seed yield potential (Kumar *et al.*, 1999 and Tripathy *et al.*, 1999).

4.3 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on chlorophyll and carotenoid pigments in leaves of soybean.

Among the various pigments that influence the spectral signature of vegetation, chlorophyll contributes more than 70% of spectral reflectance and hence in the present investigation efforts were made to find out the effect of soil and foliar applications of nutrients and growth regulators on chlorophyll a chlorophyll b, total chlorophyll and caretenoid pigments concentrations and the relevant data are presented in Table 8 to 10.

4.3.1 Chlorophyll a

The periodical observations on chlorophyll a concentration recorded at various dates under varied fertility levels during year 2016-17 and 2017-18 are presented in table 4.10. On an average chlorophyll a concentration of soybean was found to be increased with growth of soybean up to 75 days after sowing during year 2016-17 and 2017-18. Thereafter there was decrease in chlorophyll a concentration. The increase was from 2.53 to 6.45 and 2.47 to 6.90 mgg⁻¹ fresh weight. it was further noted that the application of nitrogen over no nitrogen (Treatment F₁) enhanced the chlorophyll a content at all the growth stages. The role of nitrogen in chlorophyll synthesis is of vital importance. Further, treatments F₆, F₅ and F₇ shown significant influence in chlorophyll a synthesis over control (F₁). The highest chlorophyll a is recoded in treatment receiving (RDF + Zn + Foliar K, B + GR) in both the years of experimentation. Further, it was also noticed that, application of RD+ Zn + foliar K & B synthesized more chlorophyll than other treatment combinations. Spraying of potash and boron with growth regulators significantly increased the chlorophyll concentration in leaves. The pooled mean showed lowest chlorophyll a content 2.75 mg g⁻¹ fresh weight in control treatment. Whereas highest chlorophyll a content 5.68 mgg⁻¹ fresh weight was observed in treatment receiving RD+ Zn + K, B with growth regulators (F₆).

Table 4.10 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on chlorophyll a (mg/g fresh wt) content of soybean

Treatments	Chlorophyll 'a'										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	1.42	3.60	4.00	3.14	3.04	0.97	2.82	3.70	2.42	2.47	2.75
F2: NPK	2.54	6.00	6.38	4.42	4.83	2.60	6.00	6.82	5.00	5.10	4.96
F3: RDWS	2.68	6.31	6.52	4.61	5.03	2.64	6.30	7.12	5.22	5.32	5.17
F4: RDZn	2.72	6.54	6.81	4.87	5.23	2.70	6.65	7.54	5.58	5.61	5.42
F5: RDZnKB	2.80	6.72	7.22	5.12	5.46	2.81	6.73	7.70	5.62	5.71	5.58
F6: RDZnKBGR	2.84	6.80	7.28	5.42	5.58	2.87	6.76	7.78	5.71	5.78	5.68
F7: RDZnGR	2.76	6.68	7.00	4.92	5.34	2.75	6.70	7.66	5.52	5.65	5.49
Mean	2.53	6.09	6.45	4.64	4.93	2.47	5.99	6.90	5.01	5.09	5.01
SE_±	0.10	0.50	0.28	0.22	--	0.078	0.19	0.37	0.23	--	--
CD at 5%	3.11	1.56	0.86	0.68	--	0.24	0.61	1.16	0.71	--	--

4.3.2 Chlorophyll-b

On an average chlorophyll b content of soybean was found to be increased with growth of soybean crop up to 75 DAS in 2016-17 and 2017-18 (Table 4.11). There after there was decrease in chlorophyll b content up to the harvesting stage of soybean during 2016-17 and 2017-18. The increase was from 1.87 to 4.14 and 2.0 to 4.88 mg g⁻¹ fresh weight of soybean. At various growth stages and under various fertility levels, chlorophyll b showed a similar pattern as that of chlorophyll a. However chlorophyll b concentration was relatively lower than chlorophyll a concentration. Chlorophyll b concentration was highest in treatment receiving RDF + Zn + K, B and GR at 75 DAS.

4.3.3 Total chlorophyll

The data on total chlorophyll content in soybean leaves are presented in (Table 4.12). The data indicated that the total chlorophyll concentration in soybean leaves ranged from 4.41 to 10.60 mg g⁻¹ (fresh weight) with an average 8.23 mg g⁻¹ fresh weight in 2016-17. Similarly, in the year 2017-18, it was ranged from 4.48 to 11.78 mg g⁻¹ (fresh weight) with an average of 8.46 mg g⁻¹ fresh weight of soybean. Further, N, P, K, S, Zn and B fertilization contributed significantly to total chlorophyll content, which can be seen from the treatments administered. Each additional soil and foliar application of nutrient from F₁ to F₆ improved the chlorophyll content of soybean. The maximum total chlorophyll content of soybean was observed at 75 DAS in both the years of experimentation. The behavior of various treatments in respect of total chlorophyll synthesis adopted a similar pattern as that of synthesis of chlorophyll a and b. The higher chlorophyll synthesis in treatment F₆ followed by F₅ due to additional foliar sprays of potash and boron.

Chlorophyll concentrations of leaves influences the leaf biochemical properties and biochemical interactions are the result of molecular/ atomic composition of the leaf. In turn they are responsible for color changes resulting from differences in pigment concentration. In this whole chain nitrogen, sulphur, zinc and foliar applications of potash and boron play important role.

Table 4.11 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on chlorophyll b (mg/g fresh wt) content of soybean

Treatments	Chlorophyll 'b'										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	0.98	2.00	2.22	1.30	1.62	0.68	1.96	2.60	1.56	1.70	1.66
F2: NPK	1.62	4.12	4.20	2.10	3.01	1.82	3.47	4.82	3.12	3.30	3.15
F3: RDWS	1.78	4.18	4.34	2.21	3.12	2.12	3.50	5.12	3.41	3.53	3.32
F4: RDZn	2.01	4.21	4.46	2.32	3.25	2.24	3.54	5.28	3.62	3.67	3.46
F5: RDZnKB	2.24	4.45	4.50	2.48	3.41	2.40	3.58	5.42	3.71	3.77	3.59
F6: RDZnKBGR	2.30	4.60	4.76	2.76	3.60	2.47	3.82	5.56	3.77	3.90	3.75
F7: RDZnGR	2.21	4.42	4.52	2.27	3.38	2.31	3.61	5.40	3.68	3.75	3.56
Mean	1.87	3.99	4.14	2.20	3.05	2.00	3.35	4.88	3.26	3.37	3.21
SE_±	0.06	0.26	0.28	0.24	--	0.10	0.17	0.18	0.33	--	--
CD at 5%	0.21	0.83	0.86	0.75	--	0.33	0.52	0.56	1.01	--	--

4.3.4 Carotenoid

The carotenoids content ranged from 0.67 to 1.67 mg g⁻¹ fresh weights with a mean of 1.27 mgg⁻¹ fresh weights in year 2016-17 and in year 2017-18 it increases from 0.81 to 1.93 mgg⁻¹ fresh weights with a mean of 1.51 mgg⁻¹ fresh weights (Table 4.14). During the process of senescence, the chlorophyll concentration decreased and allowed the dominance of carotenoids. They showed an accumulation in carotenoid towards physiological maturity. The carotenoid concentration was lower than chlorophyll a, b and total chlorophyll and it was demonstrated inverse relationship with concentration particularly at senescence.

4.4 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on quality parameters of soybean.

The data presented in table 4.13 revealed that, the quality parameters of soybean *viz.*, protein and oil content significantly influenced by soil and foliar application of nutrients and growth regulators. In pooled protein content in soybean seed ranged from 33.72 to 34.72 with mean value of 34.24 per cent. In pooled analysis, the treatment F₆ (RDF + Zn + foliar K, B and GR) recorded numerical higher protein (34.72%) which was found at par with all other treatments.

As regards to oil content of soybean, oil content of soybean seeds ranged from 17.49 to 18.71 in pooled data of two years. The average oil content was 18.31 per cent. Maximum oil content was observed in soybean seed with treatment F₆ followed by F₅ and F₇. However, it could not reach to the level of significance.

Good seed is the basis for successful crop production. The quality seeds are ensured with uniform germination, rapid root and shoot development and resulted in increase in the yield per unit area. However realization of seed yield always depends on production of superior quality seeds as further dividends in cultivation of crops depends on utility of quality seeds without which targeted profits cannot be achieved. This beneficial effect of foliar application of micronutrient were exhibited only when it was applied in conjunction which could be due to synergistic role of micronutrient in increasing the nutrient availability and sustaining it over a period of time as compared to their individual application. Similar results were reported by Reddy (1983) in alfalfa and Ramezani and Shekafandeh (2011) in soybean. Further, Rubes (1984) have reported an enhanced in seed quality parameters in pea and soybean,

Table 4.12 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on total chlorophyll (mg/g fresh wt) content of soybean

Treatments	Total chlorophyll										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	2.40	5.60	6.22	4.44	4.66	1.65	4.78	6.30	3.98	4.17	4.41
F2: NPK	4.15	10.12	10.58	6.52	7.84	4.42	9.47	11.63	8.12	8.41	7.97
F3: RDWS	4.46	10.49	10.86	6.82	8.15	4.76	9.80	12.24	8.63	8.85	8.31
F4: RDZn	4.73	11.75	11.27	7.19	8.48	4.94	10.10	12.82	9.20	9.26	8.76
F5: RDZnKB	5.04	11.17	11.72	7.60	8.88	5.21	10.30	13.12	9.33	9.49	9.03
F6: RDZnKBGR	5.14	11.40	12.04	8.18	9.19	5.34	10.50	13.34	9.48	9.66	9.42
F7: RDZnGR	4.97	11.10	11.52	7.19	8.69	5.06	10.30	13.07	9.20	9.40	9.04
Mean	4.41	10.09	10.60	6.84	8.23	4.48	9.32	11.78	8.27	8.46	8.34
SE_±	0.36	0.36	0.37	0.26	--	0.26	0.29	0.30	0.23	--	--
CD at 5%	1.13	1.10	1.15	0.82	--	0.82	0.91	0.92	0.72	--	--

Table 4.13 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on protein and oil content (%) of soybean seeds

Treatments	Protein content			Oil content		
	2016-17	2017-18	Pooled	2016-17	2017-18	Pooled
F1: Ctrl	33.37	34.06	33.72	17.24	17.40	17.49
F2: NPK	35.18	35.75	34.01	18.12	18.24	18.18
F3: RDWS	35.31	35.87	34.20	18.24	18.28	18.26
F4: RDZn	35.37	35.93	34.21	18.30	18.34	18.32
F5: RDZnKB	36.12	36.68	34.24	19.07	18.87	18.57
F6: RDZnKBGR	36.31	36.81	34.72	19.18	19.08	18.71
F7: RDZnGR	35.50	36.06	34.60	18.31	18.37	18.70
Mean	35.30	35.88	34.24	18.19	18.26	18.31
SE_±	0.44	0.35	0.70	0.32	0.28	0.48
CD at 5%	NS	NS	NS	NS	NS	NS

Table 4.14 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on carotenoid (mg/g fresh wt) content of soybean

Treatments	Carotenoid										
	2016-17				Mean	2017-18				Mean	Pooled Mean
	30 DAS	60 DAS	75 DAS	90 DAS		30 DAS	60 DAS	75 DAS	90 DAS		
F1: Ctrl	0.68	0.84	0.80	1.70	1.05	0.70	0.87	0.84	1.82	2.86	1.95
F2: NPK	0.65	0.80	0.78	1.65	0.97	0.67	0.82	0.80	1.70	0.99	0.93
F3: RDWS	0.60	0.78	0.75	1.60	0.93	0.64	0.80	0.77	1.65	0.92	0.92
F4: RDZn	0.60	0.76	0.73	1.48	0.89	0.62	0.78	0.78	1.55	0.93	0.91
F5: RDZnKB	0.58	0.74	0.70	1.43	0.86	0.62	0.78	0.74	1.50	0.91	0.88
F6: RDZnKBGR	0.57	0.72	0.68	1.40	0.84	0.60	0.75	0.70	1.55	0.90	0.87
F7: RDZnGR	0.55	0.74	0.71	1.47	0.86	0.58	0.77	0.73	1.60	0.92	0.89
Mean	0.60	0.76	0.73	1.53		0.63	0.79	0.76	1.62		
SE_±	0.02	0.06	0.13	0.04	--	0.03	0.09	0.11	0.08	--	--
CD at 5%	0.06	0.19	0.42	0.12	--	0.09	0.28	0.35	0.25	--	--

respectively and they were of the opinion that the increased in seed quality parameters noticed in $ZnSO_4 @ 0.3\% + Boron @ 0.2 + KNO_3 @ 0.5\%$, was due to its better translocation and metabolism as a carrier of phosphate nutrients particularly into the seed as well activator of enzymes like transphosphorylase, dehydrogenase and carboxylase.

4.5 Effect of soil application of sulphur and zinc and foliar application of KNO_3 , Borax, NAA and GA on spectral reflectance of soybean.

4.5.1 Spectral reflectance by soybean canopy

The figure 4.8 to 4.17 depicts the effect of soil and foliar application of nutrients and growth regulators on spectral behavior at various growth stages.

Spectral measurements were carried out from 350 to 1050 nm with **SVC GER 1500 Spectro radiometer** were collected on 45, 60, 75, 90, 105 DAS during year 2016-17 depicted in figure 8, 9, 10, 11 and 12 and figures 13, 14, 15, 16 and 17, respectively for 30, 60, 75, 90 and 105 DAS during year 2017-18. The canopy spectral reflectance were obtained with each set of treatment are depicted in figure 4.8 to 4.17.

The results depicted in figures regarding the spectral measurements carried out with 2 nm band width covering 350 to 1050 nm wave spectrums by SVC GER 1500 Spectro-radiometer revealed that at early stage of growth. The soil reflectance dominated the spectral reflectance.

Thereafter in all the treatments there was continuous increase in. reflectance. Further detail scrutiny of figure revealed that in 2016-17 the canopy reflectance at 45, 60, 75, 90 and 105 DAS was nearly 40%, 60%, 80% and reduced thereafter to 45% to 25%. Similar pattern was noted in 2017-18. The observation values of reflectance in red region were lower than those in NIR. Whereas when crop growth precedes typical vegetation spectral curve is being obtained till the grand growth stage of soybean. Reflectance in the visible region decreased towards senescence. Increase in reflectance in visible region can be attributed to chlorophyll degradation.

The percent reflectance in red wavelength was reduced at its lowest value (0.3%) and reached the highest in NIR (80%) at 75 DAS. Further at harvesting stage of crop the average reflectance was reduced. There was increase in reflectance in red band due to reduced chlorophyll concentration in the leaves and decrease in NIR

reflectance due to wilting of leaf. The amount of radiation reflected from the vegetation canopy in the VIS was quite low, due to high absorption of radiation energy by the leaf pigments responsible of the photosynthetic process. Primarily, the chlorophylls with the sharp peak of reflectance in the green wavelengths (550 nm) and the peak of absorptions in the red wavelengths (670 nm). In the NIR domain the reflectance factor was high due to natural cellular structure and the enhancement of reflectance caused by multiple radiations scattering between the leaf layers. Variations in spectral reflectance comes in the treatment resulted from changes in leaf structure and composition including concentration which might have been various nutrient combinations. Spectral reflectance pattern due to various nutrient combinations applied to soybean through soil and foliar varied over the crop growth period season. The physiological changes resulting from nutrient fertilization produced different canopy reflectance. Separation between all six observations shows that the larger treatment differences were observed at 75 DAS. These observations indicated the usefulness of near infrared and red wavelength as treatment discriminator wavelengths.

4.5.2 Canopy reflectance by soybean in Red and NIR band.

The reflectance behavior of soybean canopy in experimental year 2017 during crop growth with respect to red band depicted in fig.4.18. It was noticed while observing the figures that the red wave length (0.62 to 0.68 μm) reflectance was more at 30 DAS and dropped down till 75 DAS and showed more reflectance after 75 DAS till 105 DAS. There was maximum absorption of red bands by crops at 75 DAS. Amongst the treatments F_6 *i.e.* RDZnKBGR showed maximum absorption of Red wavelength at 75 DAS.

Maximum absorption of red band observed at 75 DAS. There after the red wavelength absorption increased by soybean crop up to 75 DAS the red reflectance started increasing and it was maximum at 105 DAS. This graph confirm the hypothesis that red wavelength is absorbed more if chlorophyll concentration is more and as chlorophyll concentration decreases the red wavelength absorption is also decreases. In the present study, in early growth stages, crop exposed low leaf area, less chlorophyll concentration and high soil area surface, red absorption was less and reflectance was more. As leaf area and concentration of chlorophyll increased with advancement of crop growth, red reflectance was lowered down and absorption was

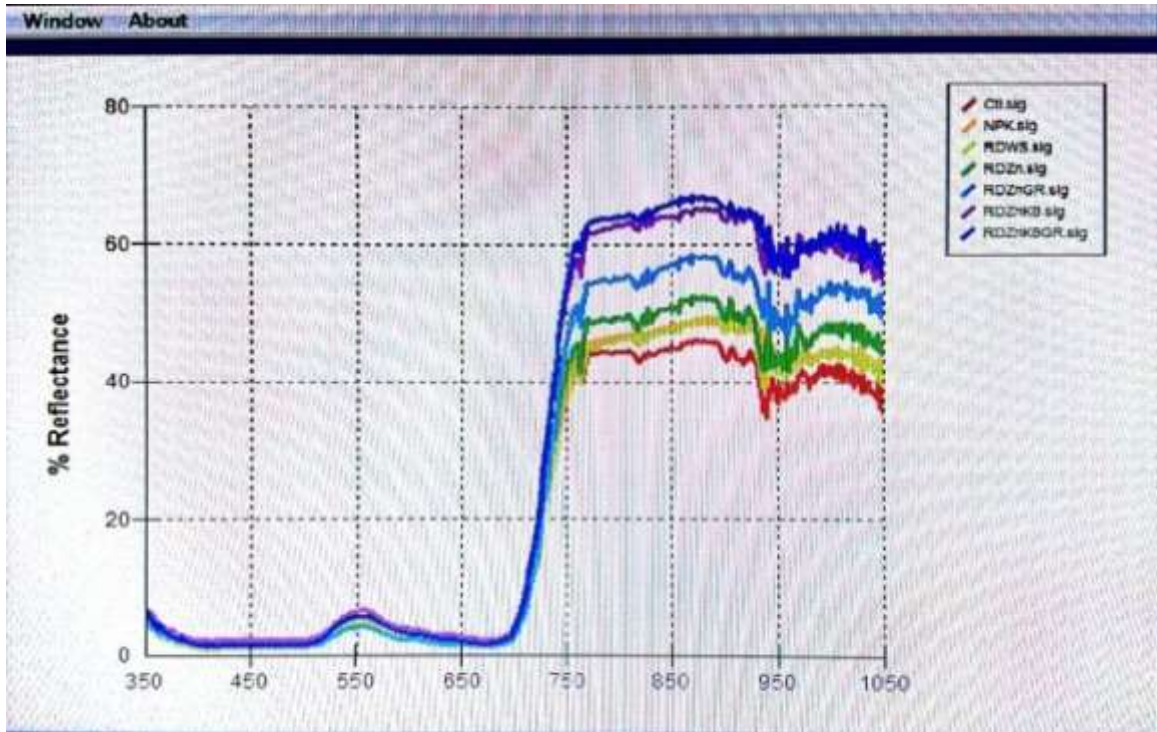


Fig. 4.9 Spectral reflectance of soybean 60 DAS under various treatments (2016)

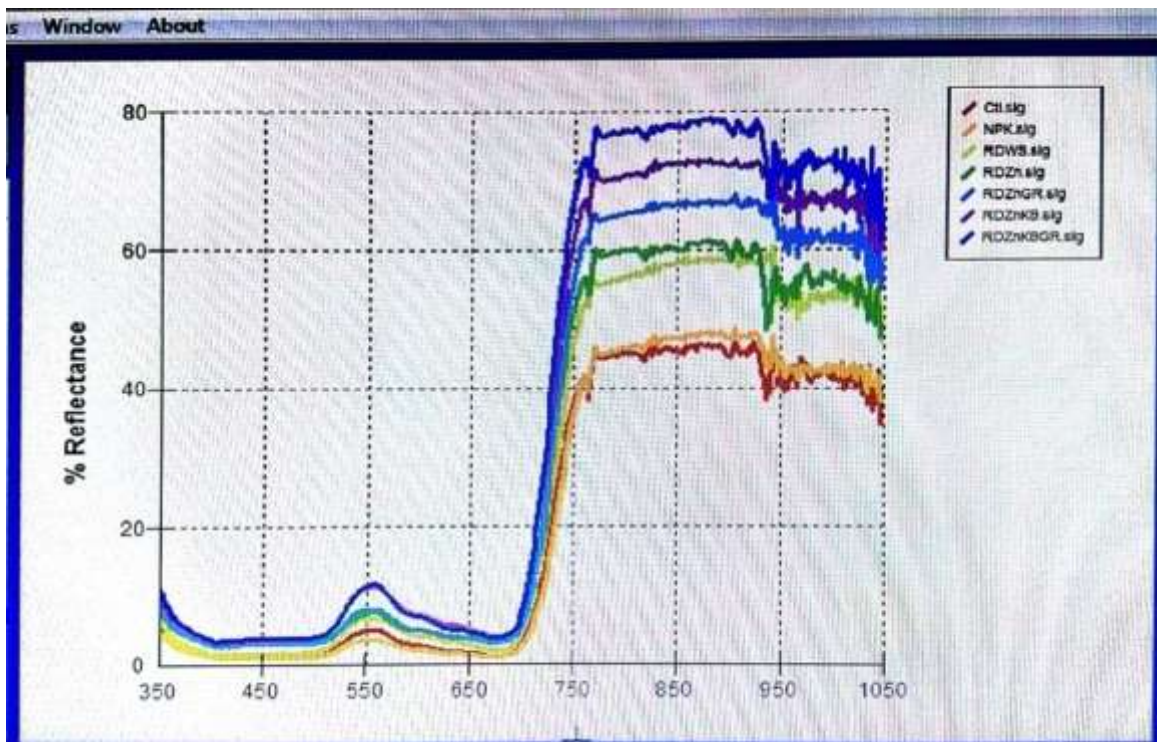


Fig. 4.10 Spectral reflectance of soybean 75 DAS under various treatments (2016)



Fig. 4.11 Spectral reflectance of soybean 90 DAS under various treatments (2016)

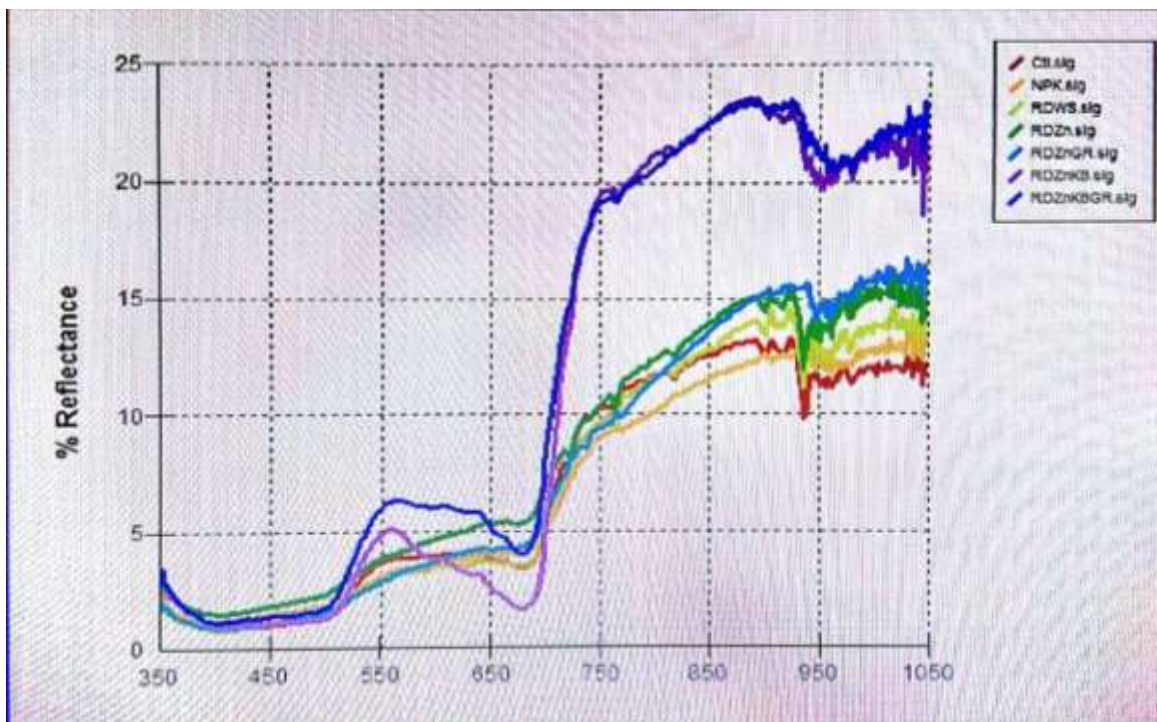


Fig. 4.12 Spectral reflectance of soybean 105 DAS under various treatments

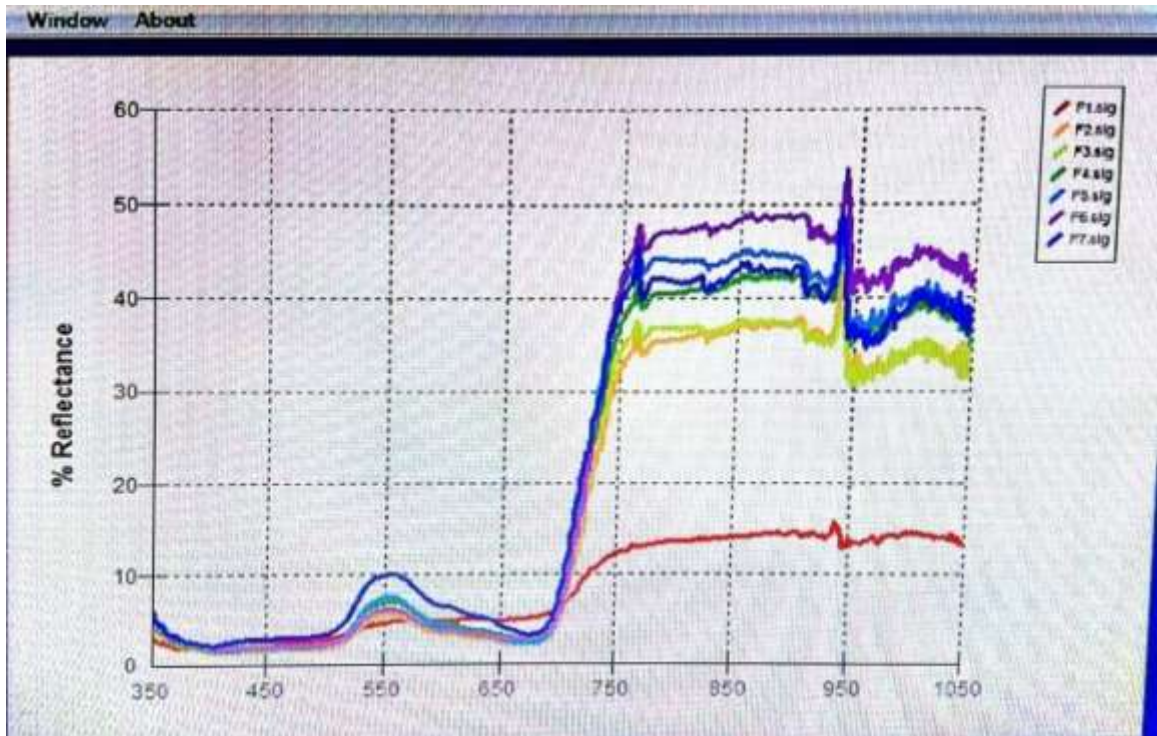


Fig. 4.13 Spectral reflectance of soybean 30 DAS under various treatments (2017)



Fig. 4.14 Spectral reflectance of soybean 45 DAS under various treatments (2017)



Fig. 4.15 Spectral reflectance of soybean 60 DAS under various treatments (2017)



Fig. 4.16 Spectral reflectance of soybean 90 DAS under various treatments (2017)



Fig. 4.17 Spectral reflectance of soybean 105 DAS under various treatments (2017)

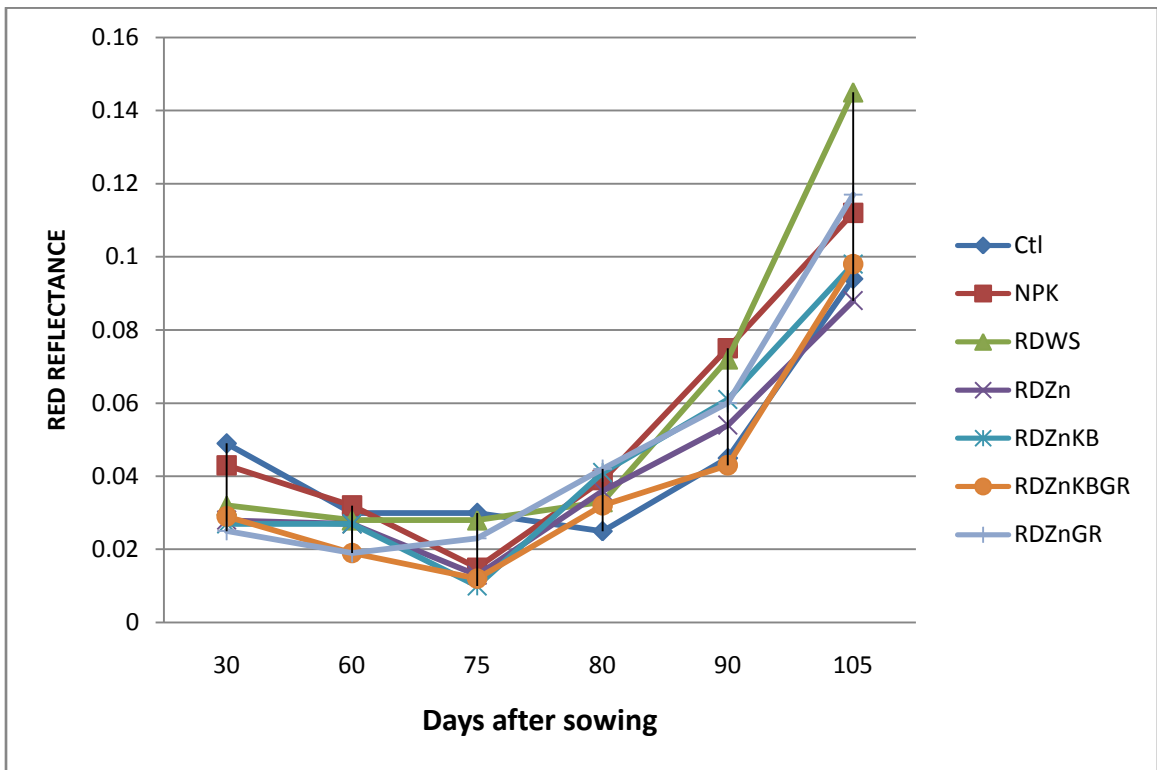


Fig. 4.18 Effect of Fertility levels on Red reflectance (2017)

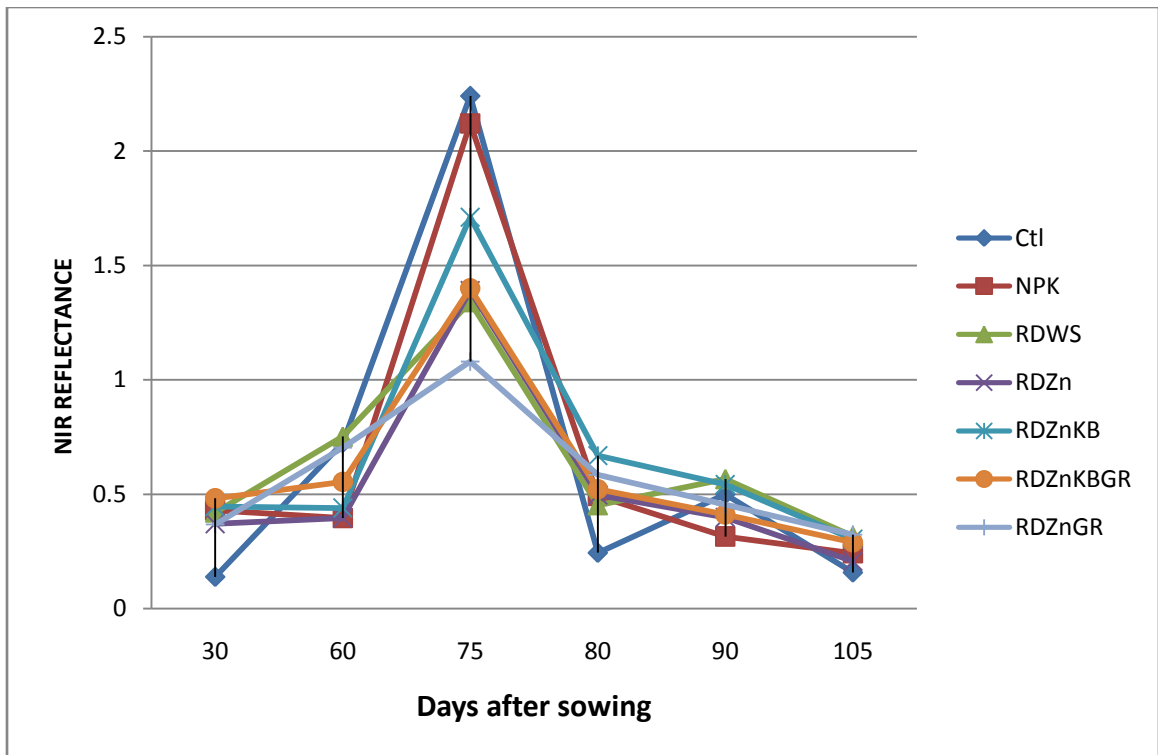


Fig. 4.19 Effect of Fertility levels on NIR reflectance (2017)

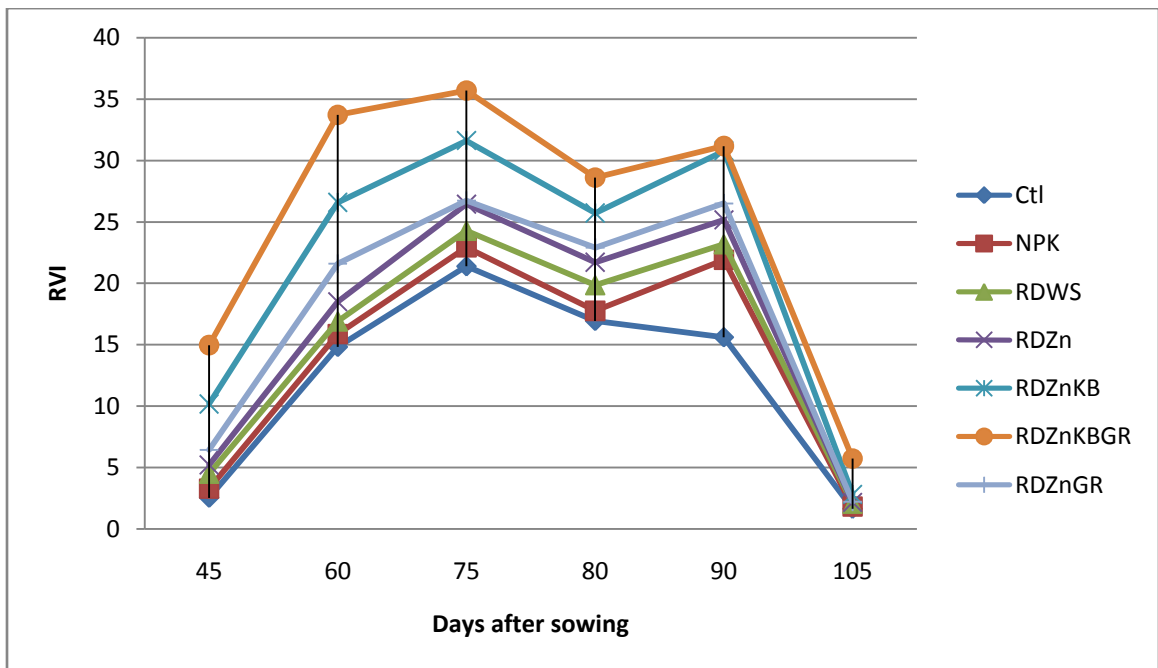


Fig. 4.20 RVI as influenced by Fertility Levels (2016)

increased. It is also noticed that, all fertility levels treatment curves behaves in a similar way. However, there was relatively more absorption of red wavelength by F₆ and less absorption of red wavelength by F₁.

This might be because of F₆ treatment provided balanced supply of nutrients and F₁ was devoid of these nutrients. The maximum absorption was between 60-90 DAS in both the years.

Fig. 4.19 showed the NIR reflectance as influenced by various fertility levels during the year 2017-18. The NIR reflectance shows almost a opposite mirror print of red reflectance. The NIR wavelength reflectance was lower up to 60 DAS. There after it increased and reached at peak between 60 to 80 DAS (at 75 DAS). Further, NIR reflectance was more in F₆ treatment followed by F₅ treatment. It was low in F₁ treatment in both the years. It reached its maximum peak value at 75 DAS.

Summerisigly, the results presented above showed that in early growth of soybean. The red reflectance was maximum and NIR reflectance was minimum. After this growth period the red reflectance was decreased because of increasing chlorophyll content while NIR reflectance was increased due to increased leaf area and vigor of crop. Further in early stage of crop the spectral reflectance was dominated by soil and during grand growth period of soybean leaf canopy dominates the soil. The results presented and discussed above are closely associated with the observation drawn by Raghuv_{ee}r *et al.*, 2014, Jagadeeswaran *et al.*, 2015, Patil *et al.*, 2015, Jainfeng *et al.*, 2015, Joseph *et al.*, 2017.

4.5.3 Spectral Ratios: viz., RVI, NDVI, SAVI and IPVI

Effect of various treatments on spectral ratios are depicted through figure number 4.20 to 4.23 during 2016-17 and figure number 4.24 to 4.27 during 2017-18.

RVI, NDVI, SAVI and IPVI spectral indices of soybean crop as influenced by varied fertility levels are depicted in Fig. 20, 21, 22 and 23 for year 2016-17 and figure 24, 25, 26 and 27 for the year 2017-18. The red and NIR reflectance of soybean canopy during the year 2016-17 and 2017-18 as influenced by various soil and foliar nutrition & growth regulators treatments were collected to calculate spectral indices.

4.5.2.1 Effect of fertility levels on RVI

As observed in a typical vegetation reflectance spectrum. Wavebands of red region were mostly absorbed by chlorophyll pigments while wavebands on NIR region were reflected significantly due to less absorption. So, the ratio of NIR/R *i.e.* RVI gives idea about vigor or healthiness of crop.

In the present research programme during 2016-17 and 2017-18 spectral index RVI showed variation between 60 to 80 days after sowing during both the years. The differences among the treatments were very clearly at 75 DAS (Fig. 5 & 9). Further soybean crop received no nutrients showed lowest RVI. While on addition of nutrients and growth regulators through soil and foliar applications resulted increase in RVI. The higher RVI values seen with fertility levels (F₆) receiving recommended dose of fertilizer + zinc sulphate + foliar application of potash, borax and growth regulators followed by F₅ treatment (RD + Zn+ foliar K, B). Further, the treatments F₀, F₁, F₂, F₃, F₄, F₅, and F₆ clearly discriminated due to RVI. However the effect due to foliar application growth regulators not recorded by RVI. This might be because of fact that the role of growth regulators in chlorophyll synthesis is indirect whereas clear discrimination due to nitrogen, sulphur, zinc & foliar K & B application in RVI was because of their direct role in chlorophyll synthesis. Role of nitrogen, sulphur, zinc, and boron in improvement of chlorophyll synthesis and increased RVI values.

Further, the soybean crop received no nutrients showed lowest RVI. The higher RVI value was seen with the fertility levels receiving RDF, and zinc through soil application with foliar KNO₃, borax, NAA and GA. This might be due to clear discrimination due to role of nitrogen; sulphur in RVI was because of their direct involvement in chlorophyll synthesis application. Role of nitrogen and sulphur in improvement of chlorophyll synthesis and increased RVI values were reported by Kolte (2005), Ashtikar (2006) and Patil *et al*, (2015).

4.5.2.2 Effect of fertility levels on NDVI

The normalized difference vegetation index shows the variation during 2016-17 and 2017-18 under various sets of treatments between 60 to 80 DAS in both the years. The soybean crop fertilized with N, P, K, S, Zn and foliar K, B and growth regulators recorded maximum NDVI followed by treatment receiving N, P, K, S, Zn

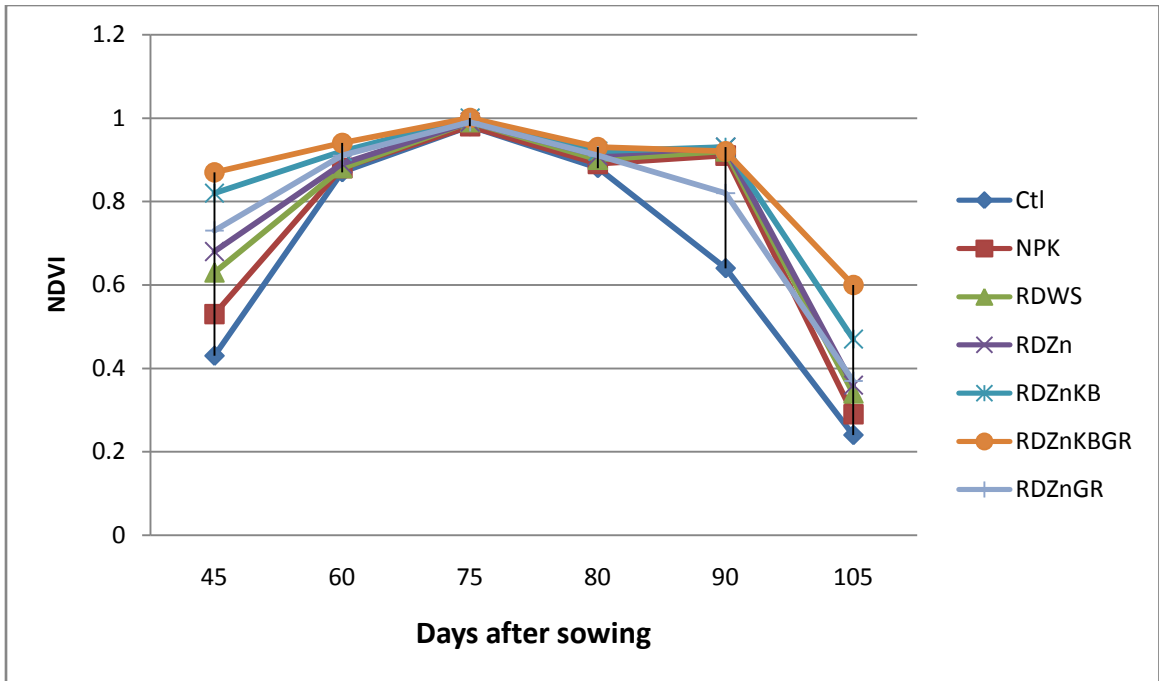


Fig. 4.21 NDVI as influenced by Fertility Levels (2016)

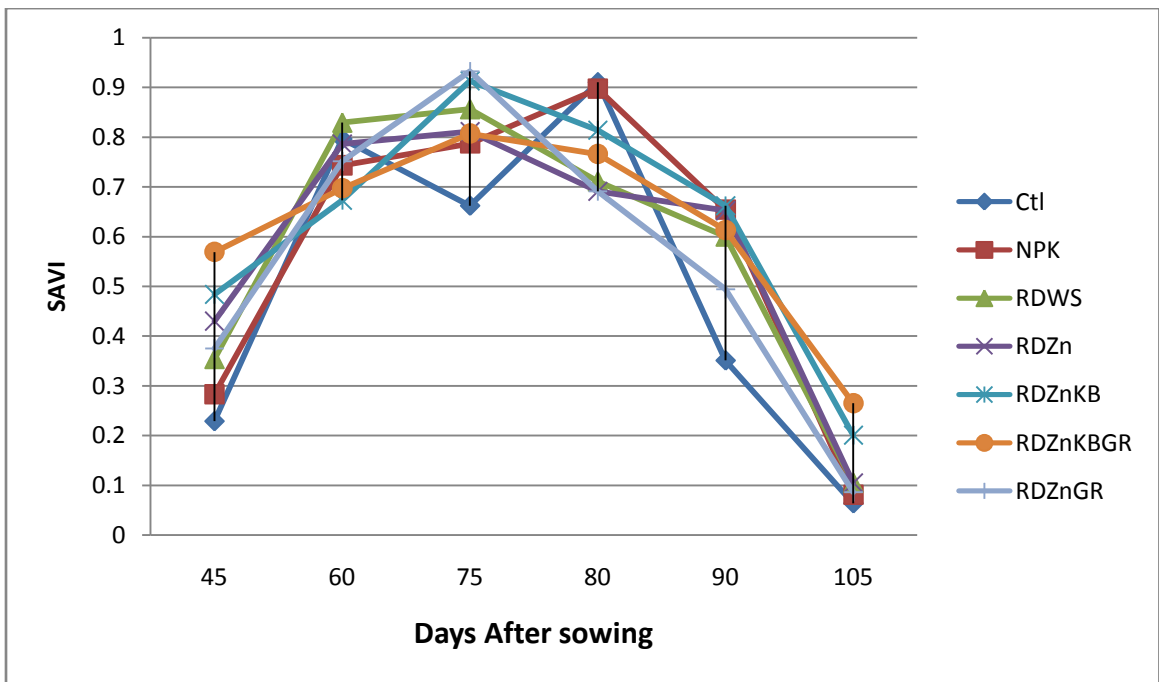


Fig. 4.22 SAVI as influenced by Fertility Levels (2016)

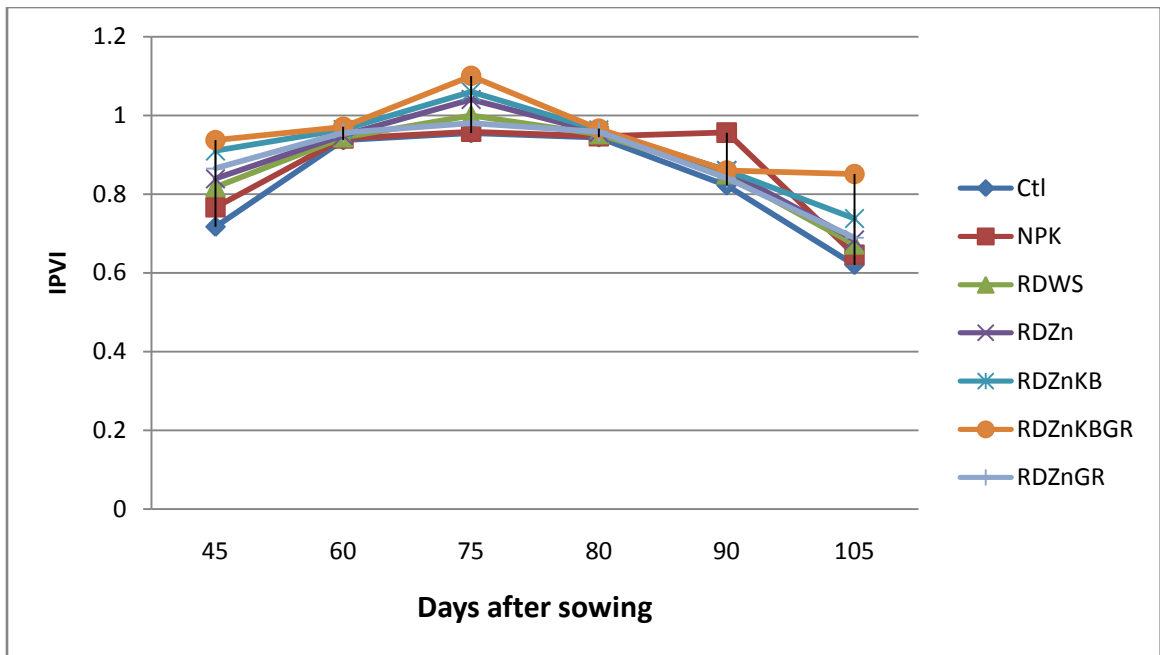


Fig. 4.23 IPVI as influenced by Fertility Levels (2016)

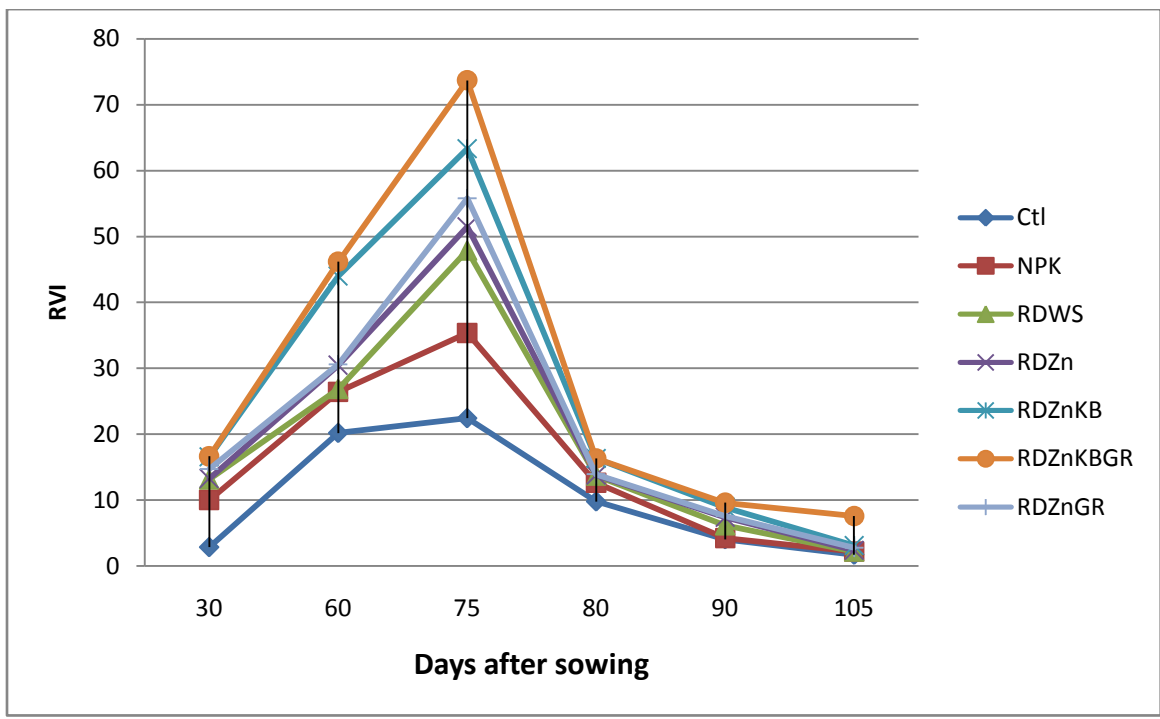


Fig. 4.24 RVI as influenced by Fertility Levels (2017)

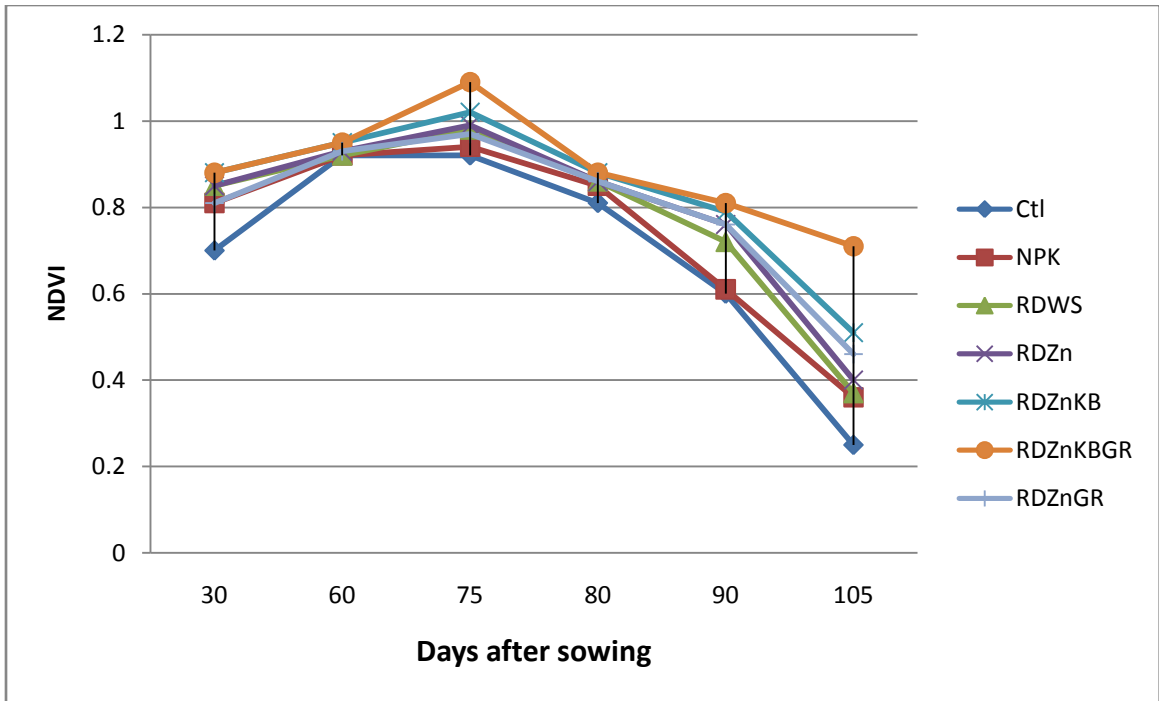


Fig. 4.25 NDVI as influenced by Fertility Levels (2017)

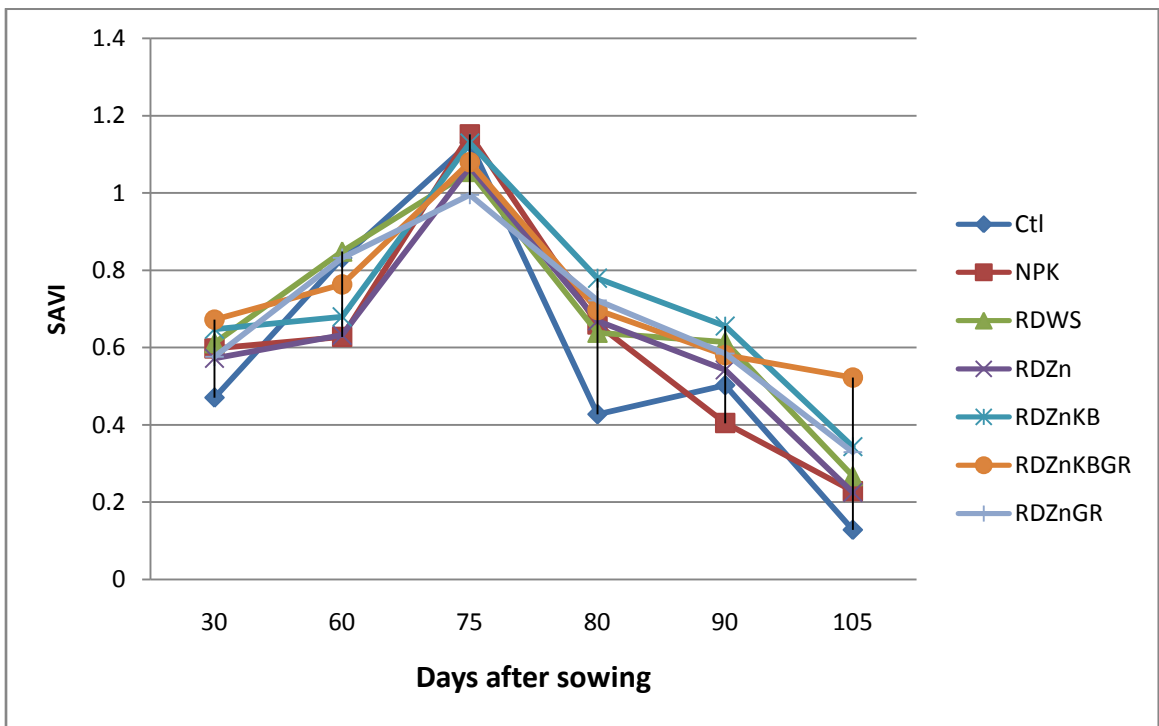


Fig. 4.26 SAVI as influenced by Fertility Levels (2017)

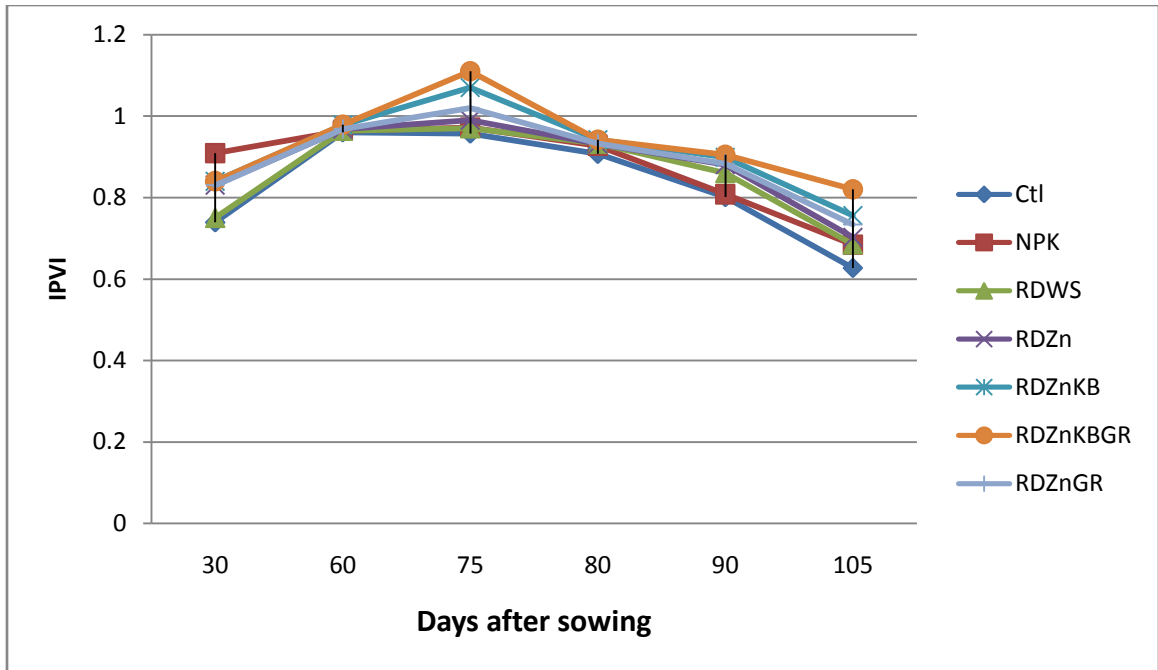


Fig. 4.27 IPVI as influenced by Fertility Levels (2017)

and foliar K, B. Similarly, both shows clear differences between control plot and fertilized plots. (figure 21 and 25)

4.5.2.3 Effect of fertility levels on SAVI

The soil adjusted vegetation index of both the years depicted in fig 22 and 26 clearly shows the growth differences created by fertility levels and were dissymmetry discriminated by the SAVI ratio. In SAVI the errors due to soil background are minimized because in SAVI determination coverage of soil by leaf area is considered through factor L (where L is a correction factor which ranged from 0 for very high vegetation cover to 1 for very low vegetation cover) Factor L minimizes interferences due to exposed soil surface. The most typically used value is 0.5 which is for intermediate vegetation cover.

In early growth stage of crop soil reflectance is more as compared to vegetation cover reflectance and hence other spectral indices were not close to the reality. But in SAVI, reflectance due to soil and leaves is considered and hence it results in to real scenario. SAVI was able to discriminate the fertilized and non fertilized crop even at early growth stage of soybean (*i.e.* 30 to 60 days after sowing as this ratio minimizes the error occurred due to soil surface exposure. SAVI is useful to predict soil and plant healthiness.

4.5.2.4 Effect of fertility levels on IPVI

The effect of fertility levels on growth of soybean was not captured by IPVI in both the years of experimentation. The relationship between the infra red percentage vegetation index and crop growth were not established properly. Indicating there by IPVI is not a suitable index for monitoring the growth and detection of chlorophyll pigment. The IPVI consider only photo synthetically active radiation and hence this might be the reason of unsuitability of IPVI under such situations. (figure 23 and 27)

The RVI, NDVI and SAVI ratio depicted in figure 20 to 23 and 24 to 27 showed that all these ratios low in F₁ treatment (no nutrient application) whereas higher in F₆ treatments. *i.e.* application of RDF + Zn + foliar K, B, NAA & GA. The capability of discrimination of nutrient stress *vs.* nutrients applied crops was centralized between 60 to 80 DAS grand growth period of soybean. The grand growth period of soybean is characterized by high chlorophyll concentration and leaf area.

These two parameters influenced the spectral reflectance. Very clear destination in spectral reflectance was notice between nutrient applied and nutrient hungry soybean. Because nutrient applications improved the chlorophyll content of leaves sand hence nutrient stressed red radiation plants found to have lower NIR reflectance. In this study RVI, NDVI, SAVI and IPVI were tested as a yardstick for assessment of growth of soybean crop.

The RVI, NDVI, SAVI and IPVI ratios depicted in fig 20 to 27 showed that all these ratios low in F₁ treatment (No Fertilizer application), whereas higher in F₆ treatment *i.e.* application of 30kgN: 60kgP₂O₅: 30kgK₂O: 20kgS + 20kg ZnSO₄ ha⁻¹ + Growth Regulators *viz.*, (NAA 20mg/l at 40 DAS) + GA (20mg/l at 60DAS) at 75 DAS. The capability of discrimination of nutrients stress *vs.* nutrients applied crops was centralized between 60 to 75 DAS (Grand growth period of soybean). The grand growth period of soybean is characterized by high chlorophyll concentration and leaf area. These two parameters influenced the spectral reflectance. Very clear destination in spectral reflectance was noticed between nutrient applied and nutrients hungry soybean. Because fertilizer nutrients applied improved the chlorophyll content of leaves and hence nutrient stressed red radiation plants found to have lower NIR reflectance. Yusuf and Yong (2011) showed the visible spectrum (400-700nm), which is the spectrum of the electromagnetic range that can be detected by human eye in three bands of red, green and blue light. Both the visible spectrum region, NIR and IR in hyper spectral imaging is used to detect the chemical composition of plants, to determine the nutrient and water status and estimate the pigment content of leaves such as chlorophyll and carotenoid quantitave determinations. (Dian *et al.*, 2008). Hyper spectral methods provide high quality spectral information of the pigment distribution within leaves; through this the healthy and infected vegetable leaves and fruits can be easily differentiated by their reflectance intensities. Hyper spectral also can be for the development and monitoring health of crops. (Bauriegel *et al.*, 2011).

4.6 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on nutrient concentrations and uptake of soybean.

4.6.1 Total Nitrogen

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant N concentration during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.15.

The pooled grand mean of total N concentration in soybean plant varied from 5.34 to 5.81, 0.22 to 0.37 and 5.45 to 5.89 and 0.30 to 0.58 per cent in seed and straw of soybean during year 2016-17 and 2017-18, respectively.

In both the experimental years and pooled results indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators proved to be superior in increasing N concentration in seed and straw of soybean.

4.6.2 Total Phosphorus

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant P concentration during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.15.

The pooled grand mean of total N concentration in soybean plant varied from 0.30 to 0.38, 0.15 to 0.31 and 0.33 to 0.42 and 0.18 to 0.34 per cent in seed and straw of soybean during year 2016-17 and 2017-18, respectively.

In both the experimental years and pooled results indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators proved to be superior in increasing P concentration in seed and straw of soybean during both the years of experimentations.

4.6.3 Total Potassium

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant K concentration during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.15.

Table 4.15 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on N, P and K concentration (%) in seed and straw of soybean

Treatments	Nitrogen				Phosphorus				Potassium			
	2016-17		2017-18		2016-17		2017-18		2016-17		2017-18	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
F1: Ctrl	5.34	0.22	5.45	0.30	0.30	0.15	0.33	0.18	1.20	0.47	1.32	0.51
F2: NPK	5.63	0.40	5.72	0.51	0.35	0.28	0.38	0.31	1.28	0.59	1.40	0.64
F3: RDWS	5.65	0.39	5.74	0.50	0.34	0.27	0.37	0.30	1.28	0.60	1.38	0.65
F4: RDZn	5.66	0.38	5.75	0.58	0.37	0.30	0.41	0.33	1.29	0.62	1.41	0.66
F5: RDZnKB	5.78	0.37	5.87	0.60	0.38	0.31	0.42	0.34	1.33	0.65	1.44	0.69
F6: RDZnKBGR	5.81	0.36	5.89	0.58	0.37	0.30	0.42	0.34	1.33	0.65	1.44	0.70
F7: RDZnGR	5.68	0.37	5.77	0.58	0.36	0.28	0.41	0.33	1.31	0.63	1.37	0.65
Mean	5.63	0.36	5.72	0.52	0.35	0.27	0.39	0.30	1.33	0.60	1.34	0.64
SE_±	0.25	0.01	0.52	0.06	0.02	0.03	0.01	0.01	0.11	0.02	0.06	0.03
CD at 5%	NS	0.03	NS	0.17	NS	NS	0.03	0.04	NS	0.06	NS	0.08

The pooled grand mean of total K concentration in soybean plant varied from 1.20 to 1.33, 0.47 to 0.65 and 1.32 to 1.44 and 0.51 to 0.70 per cent in seed and straw of soybean during year 2016-17 and 2017-18, respectively.

In both the experimental years and pooled results indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators proved to be superior in increasing K concentration in seed and straw of soybean during both the years of experimentations.

From the above interpretation data, it was clearly indicated that maximum potassium concentration was observed. It was also noted that highest K content in plant was at square formation and thereafter it declined up to boll bursting of crop. This may be due to accumulation of these nutrients in floral parts and there have been changes within the plant due to translocation of K from leaves and stem to reproductive organs.

4.6.4 Total sulphur

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant S concentration during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.16.

The pooled grand mean of total S concentration in soybean plant varied from 50.10 to 0.23, 0.15 to 0.29 and 0.12 to 0.27 and 0.16 to 0.32 per cent in seed and straw of soybean during year 2016-17 and 2017-18, respectively. In both the experimental years and pooled results indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators proved to be superior in increasing S concentration in seed and straw of soybean during both the years of experimentations.

4.6.5 Total Zinc concentration

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant Zn concentration during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.16.

The pooled grand mean of total N concentration in soybean plant varied from 0.60 to 0.75, 0.63 to 0.78 and 0.35 to 0.49 and 0.38 to 0.54 mg kg⁻¹ in seed and straw of soybean during year 2016-17 and 2017-18, respectively.

Table 4.16 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on S, Zn and B concentration in seed and straw of soybean

Treatments	Sulphur (%)				Zinc (ppm)				B (ppm)			
	2016-17		2017-18		2016-17		2017-18		2016-17		2017-18	
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw
F1: Ctrl	0.10	0.15	0.12	0.16	0.60	0.63	0.35	0.38	24	8.7	26	7.4
F2: NPK	0.12	0.16	0.14	0.18	0.62	0.65	0.38	0.42	25	9.1	27	7.7
F3: RDWS	0.24	0.29	0.27	0.32	0.64	0.66	0.40	0.43	25	8.8	27	7.8
F4: RDZn	0.23	0.28	0.26	0.31	0.74	0.77	0.45	0.45	26	8.7	28	7.6
F5: RDZnKB	0.22	0.27	0.25	0.28	0.75	0.78	0.47	0.50	31	13.00	33	10.6
F6: RDZnKBGR	0.21	0.27	0.24	0.27	0.74	0.77	0.47	0.54	30	13.00	32	10.5
F7: RDZnGR	0.19	0.24	0.23	0.26	0.73	0.75	0.49	0.48	26	9.00	28	8.0
Mean	0.19	0.24	0.22	0.25	0.69	0.72	0.43	0.46	26.71	10.04	28.71	8.51
SE_±	0.02	0.01	0.03	0.01	0.04	0.02	0.01	0.02	0.62	0.30	2.75	0.22
CD at 5%	0.05	0.04	0.10	0.02	NS	0.06	0.03	0.07	1.90	0.91	NS	0.69

In both the experimental years and pooled results indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators proved to be superior in increasing Zn concentration in seed and straw of soybean during both the years of experimentations.

4.6.6 Total boron concentration

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant B concentration during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.16.

The pooled grand mean of total B concentration in soybean plant varied from 24 to 30, 8.7 to 13 and 26 to 33 and 7.4 to 10.6 mg kg⁻¹ in seed and straw of soybean during year 2016-17 and 2017-18, respectively.

It is inferred from the results interpreted from 4.6.1 to 4.6.6 indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of KNO₃, borax with growth regulators proved to be superior in increasing total boron concentration in seed and straw of soybean during both the years of experimentations.

4.6.7 Nitrogen uptake by soybean

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant N uptake during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.17.

N uptake in soybean plant varied from 66.32 to 159.03, 5.50 to 17.37, 55.60 to 147.18 and 5.76 to 24.07 kg ha⁻¹ in seed and straw during year 2016-17 and 2017-18, respectively. Pooled mean of N uptake varied from 60.96 to 153.11, 5.63 to 20.72 kg ha⁻¹, in seed and straw, respectively. Total nitrogen uptake pooled mean varied from 66.49 to 176.62 kg ha⁻¹.

4.6.8 Phosphorus uptake by soybean

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant P uptake during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.18.

P uptake in soybean plant varied from 3.72 to 10.32, 3.75 to 16.40, 3.38 to 10.67 and 3.45 to 14.11 kg ha⁻¹ in seed and straw during year 2016-17 and 2017-18,

Table 4.17 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on N uptake (kg ha⁻¹) of soybean

Treatments	2016-17			2017-18			Pooled		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
F1: Ctrl	66.32	5.50	71.82	55.60	5.76	61.36	60.96	5.63	66.49
F2: NPK	115.80	15.05	130.85	94.72	16.03	110.75	105.22	15.54	120.80
F3: RDWS	118.93	15.30	134.23	106.87	16.12	122.00	112.74	15.69	128.27
F4: RDZn	133.57	16.17	149.74	117.70	19.66	237.36	125.64	17.92	143.49
F5: RDZnKB	153.14	17.35	172.36	138.00	23.64	164.52	145.57	20.50	168.44
F6: RDZnKBGR	159.03	17.37	179.46	147.18	24.07	173.79	153.11	20.72	176.62
F7: RDZnGR	145.97	17.28	163.25	137.38	22.81	160.19	141.68	20.05	161.72
Mean	127.48	14.86	143.10	113.92	18.29	160.00	120.70	16.58	145.20
SE_±	10.10	0.97	6.86	8.01	0.79	7.51	6.44	1.39	5.09
CD at 5%	31.12	2.98	21.14	24.67	2.44	23.15	18.81	4.81	14.85

Table 4.18 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on P uptake (kg ha⁻¹) of soybean

Treatments	2016-17			2017-18			Pooled		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
F1: Ctrl	3.72	3.75	7.47	3.38	3.45	6.83	3.55	3.60	7.15
F2: NPK	7.19	10.53	17.22	6.29	9.74	16.03	6.77	10.14	16.88
F3: RDWS	7.15	10.65	17.80	6.88	9.67	16.55	7.02	10.16	17.18
F4: RDZn	8.73	14.04	22.77	8.39	11.18	19.57	8.56	12.61	21.17
F5: RDZnKB	10.19	16.12	26.31	10.08	13.39	23.47	10.14	14.76	24.89
F6: RDZnKBGR	10.32	16.40	26.72	10.67	14.11	24.78	10.50	15.26	25.75
F7: RDZnGR	9.25	15.41	24.66	9.76	12.97	22.73	9.51	14.19	23.70
Mean	8.08	12.41	20.49	7.93	10.64	18.57	8.00	11.53	19.53
SE_±	0.52	0.94	1.05	0.40	0.44	0.62	0.33	0.52	0.61
CD at 5%	1.60	2.91	3.25	1.22	1.34	1.90	0.95	1.52	1.78

Table 4.19 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on K uptake (kg ha⁻¹) of soybean

Treatments	2016-17			2017-18			Pooled		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
F1: Ctrl	14.90	11.76	26.66	13.54	9.79	23.33	14.22	10.78	25.00
F2: NPK	26.32	22.20	48.52	23.18	20.12	43.30	23.08	21.16	45.91
F3: RDWS	26.94	23.68	50.62	25.69	20.95	46.64	27.98	22.32	48.63
F4: RDZn	30.44	26.38	56.82	28.86	22.37	51.23	29.65	24.38	54.03
F5: RDZnKB	35.67	30.83	66.50	34.56	27.18	61.74	35.12	29.01	64.12
F6: RDZnKBGR	37.10	31.36	68.46	36.60	29.05	65.65	36.85	30.21	67.06
F7: RDZnGR	33.66	29.42	63.08	32.61	25.56	58.17	33.03	27.49	60.62
Mean	29.73	25.09	54.38	27.39	22.15	50.01	28.56	23.62	52.19
SE_±	2.92	2.37	3.41	2.70	1.45	2.80	1.99	1.39	2.21
CD at 5%	8.99	7.32	10.52	8.31	4.46	8.64	5.80	4.06	6.45

respectively. Pooled mean of P uptake varied from 3.55 to 10.50, 3.60 to 15.26 kg ha⁻¹, in seed and straw, respectively. Total phosphorus uptake pooled mean varied from 7.15 to 25.75 kg ha⁻¹.

4.6.9 Potassium uptake by soybean

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant K uptake during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.19.

Scrutiny of the data revealed that, K uptake in soybean plant varied from 14.90 to 37.10, 11.76 to 31.36, 13.54 to 36.60 and 9.79 to 29.05 kg ha⁻¹ in seed and straw during year 2016-17 and 2017-18, respectively. Pooled mean of K uptake varied from 14.22 to 36.85, 10.78 to 30.21 kg ha⁻¹, in seed and straw, respectively. Total potassium uptake pooled mean varied from 25.00 to 67.06 kg ha⁻¹.

4.6.10 Sulphur uptake by soybean

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant S uptake during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.20.

S uptake in soybean plant varied from 1.24 to 5.63, 3.75 to 13.02, 1.02 to 6.10 and 3.02 to 11.20 kg ha⁻¹ in seed and straw during year 2016-17 and 2017-18, respectively. Pooled mean of S uptake varied from 1.10 to 5.98, 3.39 to 12.75 kg ha⁻¹, in seed and straw, respectively. Total sulphur uptake pooled mean varied from 4.52 to 18.09 kg ha⁻¹.

4.6.11 Zinc uptake by soybean

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant Zn uptake during two consecutive years *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.21.

Zn uptake in soybean plant varied from 0.74 to 2.14, 0.87 to 2.36, 0.64 to 1.95 and 0.67 to 2.11 g ha⁻¹ in seed and straw during year 2016-17 and 2017-18, respectively. Pooled mean of Zn uptake varied from 0.66 to 2.05, 0.77 to 2.24 g ha⁻¹, in seed and straw, respectively. Total Zn uptake pooled mean varied from 1.46 to 4.28 g ha⁻¹.

Table 4.20 Sulphur uptake (kg ha^{-1}) of soybean as influenced by various fertility levels

Treatments	2016-17			2017-18			Pooled		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
F1: Ctrl	1.24	3.75	4.99	1.02	3.02	4.04	1.10	3.39	4.52
F2: NPK	2.46	6.02	8.48	2.31	5.65	7.96	2.39	5.84	8.22
F3: RDWS	5.05	11.44	16.49	5.02	10.31	15.33	4.87	10.88	15.91
F4: RDZn	5.42	11.91	17.33	5.32	10.50	15.82	5.37	11.21	16.58
F5: RDZnKB	5.63	12.80	18.43	6.00	11.03	17.03	5.82	12.75	17.73
F6: RDZnKBGR	5.85	13.02	18.87	6.10	11.20	17.30	5.98	12.11	18.09
F7: RDZnGR	4.88	11.21	16.09	5.47	10.22	15.69	5.18	10.88	15.89
Mean	4.30	10.02	14.38	4.46	9.13	13.31	4.38	9.58	13.85
SE\pm	0.55	0.73	1.18	0.62	0.75	0.73	0.42	0.53	0.69
CD at 5%	1.71	2.26	3.62	1.93	2.32	2.26	1.22	1.54	2.02

Table 4.21 Zinc uptake (g ha^{-1}) of soybean as influenced by various fertility levels

Treatments	2016-17			2017-18			Pooled		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
F1: Ctrl	0.74	0.87	1.61	0.64	0.67	1.31	0.66	0.77	1.46
F2: NPK	1.33	1.42	2.75	1.07	1.32	2.39	1.20	1.37	2.57
F3: RDWS	1.38	1.57	2.95	1.22	1.38	2.60	1.30	1.48	2.78
F4: RDZn	1.81	1.91	3.72	1.57	1.62	3.19	1.69	1.77	3.29
F5: RDZnKB	2.09	2.22	4.31	1.87	1.97	3.84	1.98	2.10	4.08
F6: RDZnKBGR	2.14	2.36	4.50	1.95	2.11	4.06	2.05	2.24	4.28
F7: RDZnGR	1.92	2.28	4.02	1.78	1.88	3.66	1.85	2.08	3.84
Mean	1.53	1.80	3.36	1.43	1.56	3.01	1.48	1.68	3.18
SE\pm	0.21	0.16	0.28	0.17	0.11	0.14	0.14	0.10	0.16
CD at 5%	0.65	0.50	0.87	0.53	0.35	0.44	0.40	0.29	0.46

Table 4.22 Boron uptake (g ha^{-1}) of soybean as influenced by various fertility levels

Treatments	2016-17			2017-18			Pooled		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
F1: Ctrl	29.88	21.77	51.65	26.67	14.20	40.87	28.28	17.99	46.26
F2: NPK	51.42	34.24	85.66	44.71	24.20	68.91	48.07	29.22	77.29
F3: RDWS	52.62	34.74	87.36	50.27	25.14	75.41	51.45	29.94	81.39
F4: RDZn	61.36	37.02	98.38	57.31	25.76	83.07	59.34	31.39	90.73
F5: RDZnKB	83.14	61.67	144.81	79.20	41.76	120.96	81.17	51.72	132.89
F6: RDZnKBGR	83.70	62.75	146.45	81.34	43.58	124.92	82.52	53.17	135.69
F7: RDZnGR	66.82	42.03	108.85	66.68	31.46	98.14	66.75	36.75	103.50
Mean	61.28	42.00	103.31	58.03	29.44	87.47	59.65	35.74	95.39
SE\pm	5.61	4.47	8.09	4.00	2.39	3.10	3.44	2.45	4.33
CD at 5%	17.28	13.17	24.93	12.31	7.37	9.55	10.05	7.15	12.64

4.6.12 Boron uptake by soybean

Data on effect of soil and foliar feeding of nutrients and growth regulators on soybean plant B uptake during two consecutive year *i.e.* 2016-17, 2017-18 and their pooled are presented in table 4.22.

Scrutiny of the data revealed that, the B uptake in soybean plant varied from 29.88 to 83.70, 21.77 to 62.75, 26.67 to 81.34 and 14.20 to 43.58 g ha⁻¹ in seed and straw during year 2016-17 and 2017-18, respectively. Pooled mean of B uptake varied from 28.28 to 82.52, 17.99 to 53.17 g ha⁻¹, in seed and straw, respectively. Total boron uptake pooled mean varied from 46.26 to 135.69 g ha⁻¹.

Thus it can be inferred from the results presented above on nutrient uptake by soybean as influenced by soil and foliar feeding of nutrients and growth regulators increased the uptake of nitrogen, phosphorus, potassium, sulphur and zinc significantly. These results might be due to the increased uptake of nitrogen might be resulted due to increased dry matter production. Higher uptake of nutrients by soybean could be due to higher dry matter, seed and haulm yields. Chaitra and Hebsur, (2018). The increased uptake of N, P and K by soybean with boron application might be due to its synergistic effect. Synergistic effects of boron with N, P, K and sulphur were reported by Tandon (1989) and Syed *et al*, (2013). Longkumer *et al*, (2017) also reported that the total nutrient uptake of N, P, K, S and B by soybean increased with increasing levels of S and B application individually. The lowest uptake of sulphur was recorded in control. The uptake of micronutrients by soybean was favorably improved by foliar application of boron along with RDF. The application of different levels of boron resulted in a linear increase in boron in leaf tissues of soybean plant. Highest total uptake of boron might be due to higher availability of boron which was supplied through soil and foliar application. The lowest total boron uptake was noticed in control. Devi and Singh (2012) also found that application of boron significantly influenced the B uptake by soybean. The uptake of micronutrients by soybean was favorably improved by application of boron (Rathod *et al.*, 2016).

4.7 Effect of soil application of sulphur and zinc and foliar application of KNO₃, Borax, NAA and GA on soil properties after harvest of soybean.

4.7.1 Soil physico-chemical properties before sowing and after harvest of soybean

Table 4.23 shows the data of physico-chemical properties of experimental soil after harvest of *kharif* soybean. As regards the soil status after harvest of *kharif* soybean. No significant differences were observed in soil pH. Numerically the values of recommended dose of fertilizers and foliar applications of potash and boron recorded highest pH. As regards the total grand mean of pH, maximum pH was recorded in treatment 7.80 which received recommended dose of fertilizers + S @ 20 kg ha⁻¹ + 1% KNO₃ (40 & 60 DAS) + 0.2% borax (40 DAS) + NAA (20 mg/l, 40 DAS) + GA (20 mg/l, 60 DAS). The EC values of soils after harvest of *kharif* soybean were increased as compare to initial values. In pooled data, the EC values were ranged from (0.28 to 0.36 dSm⁻¹) and highest EC (0.38 dSm⁻¹) was recorded in treatment F₆ and F₄. In pooled data, the organic carbon content was varied from 49.17 to 58.03 gkg⁻¹. The maximum organic carbon (58.03 gkg⁻¹) was found in soil under treatment. The organic carbon content was increased after harvest of *kharif* soybean compared to initial status. During the both years of experimentation and in pooled data, the organic carbon content of soil increased significantly due to combined application of recommended dose of fertilizers + S @ 20 kg ha⁻¹ + 1% KNO₃ (40 & 60 DAS) + 0.2% borax (40 DAS) + NAA (20 mg/l, 40 DAS) + GA (20 mg/l, 60 DAS). Calcium carbonate content of soil in pooled data, ranged from 55.47 to 58.81 gkg⁻¹. The calcium carbonate content values were decreased after harvest stage as compared to initial content of calcium carbonate.

4.7.2 Soil nutrient status of soil before sowing and after harvest of soybean

Nutrient status of soil after harvest of *kharif* soybean presented in table 4.24 to 4.25. In pooled analysis data, available nitrogen in soil after harvest of soybean crop was found maximum (147.54 kg ha⁻¹) in treatment receiving 30 kg N: 60 kg P₂O₅:30kg K₂O ha⁻¹ to soybean crop. Minimum available nitrogen (143.86 kg ha⁻¹) was found in soil of control. (No fertilizers). These results are in confirmatory with the earliest findings of Ali *et al*, (2012).

In two years pooled analysis, the available P₂O₅ content of soil after harvest of soybean was varied from The maximum available P₂O₅ (147.54 kg ha⁻¹) was

Table 4.23 Soil properties of the experimental site before sowing and after harvest of soybean

Treatments	pH		Mean	EC (dSm ⁻¹)		Mean	Organic carbon (gkg ⁻¹)		Mean	CaCO ₃ (gkg ⁻¹)		Mean
	2016-17	2017-18		2016-17	2017-18		2016-17	2017-18		2016-17	2017-18	
F1: Ctrl	7.73	7.74	7.73	0.27	0.29	0.28	48.52	49.82	49.17	55.22	55.71	55.47
F2: NPK	7.76	7.78	7.77	0.30	0.35	0.33	53.71	54.00	53.86	57.24	59.79	58.68
F3: RDWS	7.78	7.80	7.79	0.31	0.36	0.34	53.22	53.83	53.53	57.00	58.00	57.50
F4: RDZn	7.75	7.78	7.77	0.32	0.38	0.35	54.83	55.21	55.02	56.70	60.47	58.59
F5: RDZnKB	7.77	7.78	7.78	0.33	0.36	0.35	55.02	55.82	55.51	56.62	61.00	58.81
F6: RDZnKBGR	7.79	7.79	7.80	0.34	0.38	0.36	55.23	56.02	55.63	55.80	58.56	57.18
F7: RDZnGR	7.75	7.77	7.76	0.30	0.35	0.35	57.42	58.64	58.03	56.82	59.41	58.12
Mean	7.76	7.77	7.77	0.31	0.35	0.34	54.02	54.76	54.39	56.49	58.99	57.76
Initial	7.76			0.29			48.00			58.27		
SE_±	0.02	0.01	0.01	0.01	0.02	0.01	0.78	1.37	0.79	1.02	1.05	1.02
CD at 5%	NS	0.03	0.04	0.04	NS	0.04	2.39	4.22	2.30	NS	NS	NS

recorded under F₂ treatment, which received 30 kg N: 60 kg P₂O₅: 30 kg K₂O ha⁻¹ and lowest available P₂O₅ (143.86 kg ha⁻¹) recorded under treatment control. Foliar application of macro and micronutrients was more beneficial to legumes Zayed *et al*, (2011).

In pooled data, the highest value for available K₂O in pooled data (581.95 kg ha⁻¹) was found under treatment F₃, which received 30 kg N; 60 kg P₂O₅; 30 kg K₂O; 20 kg S ha⁻¹ + water spray, minimum availability of K₂O (577.77 kg ha⁻¹) was found under control. The potassium has long been referred to as the “quality” nutrient. Potassium is a unique element had also plays a regulatory role in plant metabolism and development. It also regulates the opening and closing of stomata, which are essential for photosynthesis, water and nutrient transport. The available K status was increased with the increased levels of foliar application of fertilizers but there was a decreased trend that occurred between the stages.

In pooled analysis, application of 30kgN: 60kgP₂O₅: 30kgK₂O: 20kgS + water spray increased the availability of sulphur (14.37 kg ha⁻¹) in soil after harvest of *kharif* soybean. The maximum availability DTPA-Zn (0.58 mg kg⁻¹) was observed in treatment in which soybean fertilized with 30kgN: 60kgP₂O₅: 30kgK₂O: 20kgS + 20kgZnSO₄ ha⁻¹. Chaudhary and Goswami (2005) also confirmed these findings. Foliar application of boron doesn't play significant influence on hot water soluble boron. Whereas, numerically highest value of available boron (0.037 kg ha⁻¹) observed in soybean crop fertilized with 30kgN: 60kgP₂O₅: 30kgK₂O: 20kgS + 20kgZnSO₄ ha⁻¹ + 1% KNO₃ (40 & 60 DAS) and lowest value of available boron (0.32 mg kg⁻¹) was observed in treatment receiving 30kgN: 60kgP₂O₅: 30kgK₂O ha⁻¹.

Table 4.24 Nutrient status of the experimental soil before sowing and after harvest of crop

Treatments	Available Macro-nutrients											
	Nitrogen (kgha ⁻¹)		Mean	Phosphorus (kgha ⁻¹)		Mean	Potassium (kgha ⁻¹)		Mean	Sulphur (mgkg ⁻¹)		Mean
	2016-17	2017-18		2016-17	2017-18		2016-17	2017-18		2016-17	2017-18	
F1: Ctrl	143.00	144.72	143.86	13.00	13.22	13.11	578.24	577.31	577.77	12.42	12.40	12.41
F2: NPK	146.54	148.54	147.54	14.49	15.10	14.79	580.72	583.25	581.98	11.80	11.74	11.77
F3: RDWS	145.20	147.62	146.41	14.12	14.82	14.47	581.50	582.41	581.95	14.69	14.06	14.37
F4: RDZn	144.63	146.70	145.66	13.89	14.47	14.18	579.57	581.24	580.40	14.41	13.95	14.18
F5: RDZnKB	144.22	146.20	145.21	13.80	14.32	14.06	580.00	582.00	581.00	14.26	13.72	13.99
F6: RDZnKBGR	143.74	145.84	144.79	12.68	13.72	13.20	579.85	581.47	580.66	14.00	13.61	13.80
F7: RDZnGR	144.00	146.12	145.06	13.82	14.24	14.03	578.86	580.97	579.91	14.30	14.03	14.16
Mean	144.48	146.53	145.50	13.68	14.27	13.97	579.82	581.23	580.52	13.69	13.35	13.52
Initial	145.26			13.60			580.47			13.41		
SE_±	6.44	6.89	4.71	0.93	0.98	1.15		18.14	12.09	0.94	0.65	3.49
CD at 5%	19.83	21.22	13.76	2.85	3.01	3.96		NS	35.28	2.91	2.02	12.09

Table 4.25 Micro-nutrient status of the experimental soil before sowing and after harvest of soybean

Treatments	DTPA-Zn		Mean	HWS-B		Mean
	2016-17	2017-18		2016-17	2017-18	
F1: Ctrl	0.52	0.50	0.51	0.34	0.33	0.33
F2: NPK	0.52	0.51	0.51	0.33	0.32	0.32
F3: RDWS	0.51	0.53	0.52	0.33	0.32	0.32
F4: RDZn	0.57	0.59	0.58	0.34	0.33	0.33
F5: RDZnKB	0.55	0.57	0.56	0.38	0.37	.037
F6: RDZnKBGR	0.54	0.56	0.55	0.37	0.36	0.36
F7: RDZnGR	0.56	0.58	0.57	0.36	0.35	0.35
Mean	0.53	0.54		0.30	0.34	
Initial	0.52			0.36		
SE_±	0.02	0.01	0.03	0.01	0.01	0.02
CD at 5%	0.05	0.04	0.11	NS	0.03	0.05

4.8 Effect of soil application of sulphur, zinc and foliar KNO₃, Borax, NAA and GA on nutrient balance sheet in soil and economics of soybean production.

4.8.1 Nutrients balance in soil

As regards the nutrient balance (N, P, K, S, Zn, B) in soil presented in table number 26 to 31. It was observed that, negative nutrient balance was observed in F₁ (control) treatment for N, P and K nutrients, whereas maximum nutrient balance for N, P and K were found under treatment F₂ followed by F₃, F₄, F₅ and F₇.

As regards to sulphur, zinc and boron, negative nutrient balance of S observed under treatments F₁ and F₂. Whereas, maximum available sulphur was observed under treatment F₃ followed by F₄, F₅, F₆. Micronutrients *viz.*, DTPA Zn and HWS B, negative DTPA zinc was observed under treatments F₁ and F₂. Positive available zinc were recorded under treatment F₄ followed by F₇, F₅, F₆, F₃. Negative hot water soluble boron was recorded under treatments F₂, F₃, F₁ and F₄. Whereas, positive hot water soluble boron were observed under treatments F₅ and F₆.

Availability of N, P, K, S, Zn and B contents in soil at different stages was significantly influenced by various foliar applications. (Krishna and Kaleeswari, 2018).

Available status of S and Zn in the soil after the harvest of the soybean crop was non significantly influenced. By the different fertility levels. However, initial value of available S, there was slightly buildup in S fertilized plots. There was no clear cut effect on zinc after the soybean and lower levels of fertility during the both the years. Chaudhary and Goswami (2005) also confirmed these findings. Thenua *et al.*, (2014) reported available status of sulphur and zinc in soil after harvest of soybean crop was found non significant by the application of S and Zn to soybean crops.

4.8.2 B: C ratio

The data on mean Cost of cultivation, Gross and Net monetary returns and Benefit Cost ratio as influenced by different treatments are presented in table 4.32. The per hectare mean value for Cost of cultivation, Gross and Net monetary returns and Benefit Cost ratio are Rs. 28994 Rs. 62411, Rs. 33131 and 2.15, respectively. The maximum cost of cultivation recorded in treatment F₆. Under the RDF + 20 kg ZnSO₄ + Foliar KNO₃ @ 1% + Borax @ 0.2% + Growth regulators NAA and GA application, the working cost of cultivation was Rs. 32080 which produced the highest gross

monetary returns Rs. 80698 and net monetary returns with Rs. 46618 and B:C ratio of 2.51 which was highest to rest of the treatments under comparison. While the lowest value of working Cost of cultivation, Gross and Net monetary returns and Benefit: Cost ratio were recorded to the tune of Rs. 20500 Rs. 31752 Rs. 11252, and 1.54 with absolute control with exclusion of any fertilizer application, respectively.

Table 4.26 Balance sheet of available N (kg ha^{-1}) in soil as influenced by different fertility levels after two years cycle

Treatments	Initial available N (kg ha^{-1})	N added through fertilizer (kg ha^{-1})	Calculated available N (kg ha^{-1})	Actual N balance (kg ha^{-1})	N Net loss or Gain (kg ha^{-1})
F1: Ctrl	145.06	--	145.26	144.72	-0.54
F2: NPK	145.26	60	205.26	148.54	+3.28
F3: RDWS	145.26	60	205.26	147.62	+2.36
F4: RDZn	145.26	60	205.26	146.70	+1.44
F5: RDZnKB	145.26	60	205.26	146.20	+0.94
F6: RDZnKBGR	145.26	60	205.26	145.84	+0.58
F7: RDZnGR	145.26	60	205.26	146.12	+0.86

Table 4.27 Balance sheet of available P₂O₅ (kg ha⁻¹) in soil as influenced by different fertility levels after two years cycle

Treatments	Initial available P₂O₅ (kg ha⁻¹)	P₂O₅ added through fertilizer (kg ha⁻¹)	Calculated available P₂O₅ (kg ha⁻¹)	Actual P₂O₅ balance (kg ha⁻¹)	P₂O₅ Net loss or Gain (kg ha⁻¹)
F1: Ctrl	13.60	--	13.60	13.22	-0.38
F2: NPK	13.60	120	133.60	15.10	+1.50
F3: RDWS	13.60	120	133.60	14.82	+1.22
F4: RDZn	13.60	120	133.60	14.47	+0.87
F5: RDZnKB	13.60	120	133.60	14.32	+0.72
F6: RDZnKBGR	13.60	120	133.60	13.72	+0.12
F7: RDZnGR	13.60	120	133.60	14.24	+0.64

Table 4.28 Balance sheet of available K₂O (kg ha⁻¹) in soil as influenced by different fertility levels after two years cycle

Treatments	Initial available K₂O (kg ha⁻¹)	K₂O added through fertilizer (kg ha⁻¹)	Calculated available K₂O (kg ha⁻¹)	Actual K₂O balance (kg ha⁻¹)	K₂O Net loss or Gain (kg ha⁻¹)
F1: Ctrl	580.47	--	580.47	577.31	-3.16
F2: NPK	580.47	60	640.47	583.25	+2.78
F3: RDWS	580.47	60	640.47	582.414	+1.94
F4: RDZn	580.47	60	640.47	581.24	+0.77
F5: RDZnKB	580.47	60	640.47	582.00	+1.53
F6: RDZnKBGR	580.47	60	640.47	581.47	+1.00
F7: RDZnGR	580.47	60	640.47	580.97	+0.50

Table 4.29 Balance sheet of available S (kg ha^{-1}) in soil as influenced by different fertility levels after two years cycle

Treatments	Initial available S (kg ha^{-1})	S added through fertilizer (kg ha^{-1})	Calculated available S (kg ha^{-1})	Actual S balance (kg ha^{-1})	S Net loss or Gain (kg ha^{-1})
F1: Ctrl	30.03	--	30.03	27.77	-2.26
F2: NPK	30.03	--	30.03	26.29	-3.74
F3: RDWS	30.03	40	70.03	31.49	+1.46
F4: RDZn	30.03	40	70.03	31.24	+1.21
F5: RDZnKB	30.03	40	70.03	30.73	+0.70
F6: RDZnKBGR	30.03	40	70.03	30.48	+0.45
F7: RDZnGR	30.03	40	70.03	31.42	+1.39

Table 4.30 Balance sheet of available Zinc (kg ha^{-1}) in soil as influenced by different fertility levels after two years cycle

Treatments	Initial available Zn	Zn added through fertilizer (kg ha^{-1})	Calculated available Zn	Actual Zn balance	Zn Net loss or Gain
F1: Ctrl	1.16	--	1.16	1.11	-0.05
F2: NPK	1.16	--	1.16	1.13	-0.03
F3: RDWS	1.16	--	1.16	1.18	+0.02
F4: RDZn	1.16	9.0	10.16	1.31	+0.15
F5: RDZnKB	1.16	9.0	10.16	1.27	+0.11
F6: RDZnKBGR	1.16	9.0	10.16	1.24	+0.08
F7: RDZnGR	1.16	9.0	10.16	1.29	+0.13

Table 4.31 Balance sheet of available Boron (kg ha^{-1}) in soil as influenced by different fertility levels after two years cycle

Treatments	Initial available B	B added through fertilizer	Calculated available B	Actual B balance	B Net loss or Gain
F1: Ctrl	0.80	--	0.80	0.73	-0.07
F2: NPK	0.80	--	0.80	0.71	-0.09
F3: RDWS	0.80	--	0.80	0.71	-0.09
F4: RDZn	0.80	--	0.80	0.73	-0.07
F5: RDZnKB	0.80	--	0.80	0.82	+0.02
F6: RDZnKBGR	0.80	--	0.80	0.81	+0.01
F7: RDZnGR	0.80	--	0.80	0.78	-0.02

Table 4.32 Effect of soil and foliar feeding of nutrients and growth regulators on economics of *kharif* soybean

Treatments	Treatment Details	Cost of Cultivation* (Rs. ha ⁻¹)	Gross Monetary Returns* (Rs. ha ⁻¹)	Net monetary Returns* (Rs. ha ⁻¹)	B:C Ratio* (Rs.)
F₁	Ctrl	20500	31752	11252	1.54
F₂	NPK	28700	51996	23296	1.81
F₃	RDWS	29400	55568	26168	1.89
F₄	RDZn	28700	65712	37012	2.28
F₅	RDZnKB	31600	76148	44548	2.40
F₆	RDZnKBGR	32080	80698	46618	2.51
F₇	RDZnGR	31980	75000	43020	2.34
Mean		28994	62411	33131	2.15

(* Indicated the mean values of 2016-17 and 2017-18)



SUMMARY AND CONCLUSION



CHAPTER V

SUMMARY AND CONCLUSION

The field experiment on “Studies on yield maximization of soybean (*Glycine max* L.) through soil and foliar feeding of nutrients, growth regulators and monitoring growth profile by spectral reflectance” was conducted during *kharif* season of years 2016-17 and 2017-18 at experimental farm of Department of Soil Science and Agricultural Chemistry, Vasant Rao Naik Marathwada Agriculture university, Parbhani. An attempt was made to study the effect of various treatments on periodical growth parameters, yield attributes, content and uptake of nutrients, yield productivity, Spectral reflectance and quality parameters of soybean. The changes in soil physiochemical properties soil pH, EC, organic carbon, available macro nutrient status N, P, K, S and DTPA extractable Zn and Boron in soil. Nutrient balance sheet of available nutrients in soil was also studied. Economics of different treatments were also calculated. The important findings evolved from the present investigation are summarized below:

Initial and final plant population of soybean recorded non significant effect due to various fertility levels administered during both the experimental years. This explains good conduct of experimentation and no biasness in plant population that is going to affect treatment behavior

The height of soybean was monitored at critical growth stages of crop during both the experimental years. The effect of soil and foliar application of nutrients and growth regulators recorded significant impact on height of plant in both the years of experiments. There was significant increase in height in both the years of experiments and with every addition of nutrients through soil and foliar applications.

The maximum numbers of leaves were found at flowering stage of soybean in both the years. Application of each additional nutrient through soil and foliar application increased number of leaves per plant significantly. Thereafter leaf count reduced due to physiological shedding of older leaves to maturity of soybean leaf count becomes less.

In both the years of experimentation, leaf area & leaf area index were increased progressively up to flowering stage of soybean there after there was decrease in leaf area index due to falling of leaves towards maturity of soybean. It is

also observed that days to 50 per cent flowering and days to maturity were influenced significantly due to foliar application of micronutrients.

There was periodical increase in dry weight of soybean. It was found to be increased with the advancement of crop growth stages up to maturity of soybean. At all growth observations, application of RDF + Zn + foliar applications of KNO₃, borax, NAA and GA produced maximum dry weight of soybean.

There was significant increase in number of pods per plant with all the treatments (Fertility levels) over control. The influence of different treatments on numbers of pods by the order; F₆ > F₅ > F₇ > F₄ > F₃ > F₂ > F₁. The influence of different treatments on test weight followed by the order; F₆ > F₅ > F₇ > F₄ > F₃ > F₂ > F₁. The test weight was relatively lower in (F₁) control treatment.

The seed yield of *kharif* soybean significantly affected due to soil and foliar applications of nutrients and growth regulators. Application of RD + Zn + foliar K, B and GR significantly recorded highest seed yield, straw yield and total biological yield.

The periodical observations on chlorophyll a, chlorophyll b and total chlorophyll concentration recorded at various dates under varied fertility levels. On an average chlorophyll concentration of soybean was found to be increased with growth of soybean up to 75 days after sowing during year 2016-17 and 2017-18. Thereafter there was decrease in chlorophyll concentration. It was further noted that the application of nitrogen over no nitrogen (Treatment F₁) enhanced the chlorophyll a content at all the growth stages. However chlorophyll b concentration was relatively lower than chlorophyll a concentration. N, P, K, S, Zn and B fertilization contributed significantly to total chlorophyll content, which can be seen from the treatments administered. Each additional soil and foliar application of nutrient from F₁ to F₆ improved the chlorophyll content of soybean. The higher chlorophyll synthesis in treatment F₆ followed by F₅ due to additional foliar sprays of potash and boron.

An accumulation in carotenoid pigment observed towards physiological maturity of crop. The carotenoid concentration was lower than chlorophyll a, b and total chlorophyll and it was demonstrated inverse relationship with concentration particularly at senescence.

The quality parameters of soybean *viz.*, protein and oil content significantly influenced by soil and foliar application of nutrients and growth regulators. Treatment F₆ (RDF + Zn + foliar K, B and GR) recorded numerical higher protein which was found at par with all other treatments. Maximum oil content was observed in soybean seed with treatment F₆ followed by F₅ and F₇. However, it could not reach to the level of significance.

The observation values of reflectance in red region were lower than those in NIR. Whereas when crop growth precedes typical vegetation spectral curve is being obtained till the grand growth stage of soybean. Reflectance in the visible region decreased towards senescence. At early stage of growth the soil reflectance dominated the spectral reflectance. The observation values of reflectance in red region were lower than those in NIR. Whereas when crop growth precedes typical vegetation spectral curve is being obtained till the grand growth stage of soybean. Reflectance in the visible region decreased towards senescence. There was maximum absorption of red bands by crops at 75 DAS. Amongst the treatments F₆ *i.e.* RDZnKBGR showed maximum absorption of Red wavelength at 75 DAS. It is also noticed that, all fertility levels treatment curves behaves in a similar way. However, there was relatively more absorption of red wavelength by F₆ and less absorption of red wavelength by F₁.

Soybean crop received no nutrients showed lowest RVI, while on addition of nutrients and growth regulators through soil and foliar applications resulted increase in RVI. The higher RVI values seen with fertility levels (F₆) receiving recommended dose of fertilizer + zinc sulphate + foliar application of potash, borax and growth regulators followed by F₅ treatment (RD + Zn+ foliar K, B). The soybean crop fertilized with N, P, K, S, Zn and foliar K, B and growth regulators recorded maximum NDVI followed by treatment receiving N, P, K, S, Zn and foliar K, B. Similarly, both shows clear differences between control plot and fertilized plots.

The soil adjusted vegetation index of both the years depicted clearly shows the growth differences created by fertility levels and were dissymmetry discriminated by the SAVI ratio. In SAVI, reflectance due to soil and leaves is considered and hence it results in to real scenario. SAVI was able to discriminate the fertilized and non fertilized crop even at early growth stage of soybean. The relationship between the infra red percentage vegetation index and crop growth were not established properly. Indicating there by IPVI is not a suitable index for monitoring the growth and

detection of chlorophyll pigment. Very clear destination in spectral reflectance was notice between nutrient applied and nutrient hungry soybean.

In both the experimental years and pooled results indicated that the soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators proved to be superior in increasing N, P, K, S, Zn and total boron concentration in seed and straw of soybean. Nutrient uptake by soybean as influenced by soil and foliar feeding of nutrients and growth regulators increased the uptake of nitrogen, phosphorus, potassium, sulphur and zinc significantly.

No significant differences were observed in soil pH. The EC values of soils after harvest of *kharif* soybean were increased as compare to initial values. The organic carbon content was increased after harvest of *kharif* soybean compared to initial status. While calcium carbonate content were decreased after harvest stage as compared to initial content of calcium carbonate.

Available nitrogen, phosphorus, potassium, sulphur and DTPA Zinc in soil after harvest of soybean crop was found maximum in treatment receiving 30 kg N: 60 kg P₂O₅:30kg K₂O ha⁻¹ to soybean crop.

Negative nutrient balance was observed in F₁ (control) treatment for N, P and K nutrients, whereas positive nutrient balance for N, P and K were found under treatment F₂ followed by F₃, F₄, F₅ and F₇. As regards to sulphur, zinc and boron, negative nutrient balance of S observed under treatments F₁ and F₂. Whereas, positive available sulphur was observed under treatment F₃ followed by F₄, F₅, F₆. Micronutrients *viz.*, DTPA Zn and HWS B, negative DTPA zinc was observed under treatments F₁ and F₂. Positive available zinc were recorded under treatment F₄ followed by F₇, F₅, F₆, F₃. Whereas, positive hot water soluble boron was recorded under treatments F₅ and F₆. The maximum cost of cultivation recorded in treatment F₆. Under the RDF + 20 kg ZnSO₄ + Foliar KNO₃ @ 1% + Borax @0.2% + Growth regulators NAA and GA application, the working cost of cultivation was Rs. 32080 which produced the highest gross monetary returns Rs. 80698 and net monetary returns with Rs. 46618 and B:C ratio of 2.51 which was highest to rest of the treatments under comparison.

CONCLUSION

- ✓ Soybean crop fertilized with recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron, Growth Regulators produced maximum height, LAI, pod yield, test weight, grain yield and straw yield and at par with Recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron.
- ✓ Hyper spectral measurement showed maximum increase in NIR reflectance and R absorbance by soybean crop at 75 DAS in both the years. This stage can be considered for taking reflectance studies.
- ✓ Maximum absorbance of red wavelength and reflectance of NIR by soybean canopy was observed with treatment fertilized with recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron, Growth Regulators treatment.
- ✓ The RVI, NDVI, SAVI ratios were low in control and higher in treatment fertilized with recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron, Growth Regulators followed by treatment fertilized with recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron.
- ✓ NDVI found to be better indicator for assessment of soybean crop.
- ✓ The RVI, NDVI values progressively increased up to grand growth period of soybean, thereafter there was progressively decreased in RVI and NDVI values.
- ✓ Maximum uptake of N, P, K, S, Zn and B was observed in treatment fertilized with recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron, Growth Regulators followed by treatment fertilized with recommended dose of fertilizer + zinc + foliar application of KNO_3 and Boron.
- ✓ The soil and foliar application of nutrients and growth regulators does not influenced significantly on physico – chemical properties of soil.
- ✓ There are gradual buildup of organic carbon content in treatment receiving recommended does fertilizer, zinc sulphate and foliar application of potash and boron.

- ✓ Negative nutrient balance was recorded under no fertilizer application where as there was positive nutrient balance in the treatment with recommended dose of fertilizer to soybean crop.
- ✓ The maximum cost of cultivation recorded in treatment F₆. Under the RDF + 20 kg ZnSO₄ + Foliar KNO₃ @ 1% + Borax @0.2% + Growth regulators NAA and GA application, the working cost of cultivation was Rs. 32080 which produced the highest gross monetary returns Rs. 80698 and net monetary returns with Rs. 46618 and B:C ratio of 2.51 which was highest to rest of the treatments under comparison.



**LITERATURE
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APPENDICES



APPENDIX I

**Weekly weather data recorded at Agro-meteorological Observatory, Vasantrya
Naik Marathwada Krishi Vidyapeeth, Parbhani during the year, 2016-17.**

WK	Period	Rainfall (mm)	R.D.	Temperature °C		Humidity (%)		EVP	BSS (Hrs)	W. V. (Kmp)
				Max.	Min	AM	PM			
22	28-03June	0.0	0.0	42.8	26.9	50	17	14.0	8.7	7.9
23	04-10June	27.0	2.0	39.0	25.5	69	33	9.5	7.1	6.3
24	11-17June	61.1	3.0	34.2	23.1	88	54	5.3	6.5	6.6
25	18-24June	37.5	2.0	31.6	23.5	86	64	4.5	2.5	5.8
26	25-01July	0.0	0.0	35.1	24.3	75	43	7.3	7.5	6.6
27	02-08July	5.0	1.0	35.8	23.8	76	38	8.1	9.4	9.4
28	09-15July	0.0	0.0	36.2	25.8	69	37	6.0	9.4	9.4
29	16-22July	0.6	0.0	35.8	24.8	76	45	5.5	8.9	8.9
30	23-29July	8.0	1.0	34.0	24.0	75	47	4.9	8.5	8.5
31	30-05Aug	19.8	1.0	33.0	23.1	80	59	6.0	8.4	8.4
32	06-12Aug	28.8	4.0	29.9	23.0	87	68	2.4	5.6	5.6
33	13-19Aug	21.0	2.0	31.3	23.0	85	57	4.1	5.7	5.7
34	20-26Aug	13.6	1.0	32.9	22.9	81	49	10.0	6.0	6.0
35	27-02Sept	0.0	0.0	32.3	23.3	79	51	5.0	6.1	6.1
36	03-09 Sep	88.1	4.0	33.0	22.6	87	60	7.0	4.2	4.2
37	10-16 Sep	38.4	4.0	31.7	22.8	90	63	6.2	3.1	3.4
38	17-23 Sep	57.4	1.0	31.4	22.0	81	59	4.0	5.8	4.7
39	24-30 Sep	0.0	0.0	33.5	20.9	74	44	6.5	8.4	3.7
40	01-07Oct.	1.8	0.0	34.6	20.9	75	44	7.1	7.3	3.6
41	08-14Oct.	0.0	0.0	35.1	19.4	73	32	7.8	9.0	2.1
42	15-21Oct.	0.0	0.0	35.7	18.3	70	29	7.8	9.2	3.6
43	22-28Oct.	0.0	0.0	35.1	19.6	70	31	5.9	8.3	3.0
44	29-04 Nov.	0.0	0.0	33.2	18.9	74	37	5.6	8.1	4.5
45	05-11 Nov.	0.0	0.0	33.9	16.9	68	25	6.3	7.6	4.5
46	12-18 Nov.	0.0	0.0	33.6	14.2	75	23	6.2	8.9	5.3
47	19-25 Nov.	0.0	0.0	32.1	18.4	78	37	6.6	6.4	6.2
48	26-02 Dec.	0.0	0.0	32.9	17.0	79	33	5.5	7.6	2.8
49	03-09 Dec.	0.0	0.0	32.6	13.8	71	26	5.3	9.2	3.1
50	10-16 Dec.	0.0	0.0	33.8	17.7	72	31	5.6	8.9	3.4
51	17-23 Dec.	0.0	0.0	32.9	16.1	71	31	5.9	8.5	4.0
52	24-31 Dec.	0.0	0.0	30.3	8.5	74	23	5.2	9.6	3.9

APPENDIX II

**Weekly weather data recorded at Agro-meteorological Observatory, Vasantrya
Naik Marathwada Krishi Vidyapeeth, Parbhani during the year, 2017-18.**

MW	Period	RF (mm)	Rainy Days	Temp °C		Humidity %		EVP (mm)	BSS (Hrs.)	W.S. (K/h)
				Max.	Min.	AM	PM			
22	28-03 June	3.4	1	41.2	27.8	47	21	16.3	10.3	9.3
23	04-10 June	27.0	4	37.7	23.9	79	40	8.8	6.4	6.7
24	11-17 June	2.0	0	37.8	25.9	60	35	10.2	7.5	9.1
25	18-24 June	42.7	3	34.1	24.4	75	55	7.0	4.6	6.4
26	25-01 July	64.3	3	32.5	24.1	86	66	4.9	4.2	6.6
27	02-08 July	80.2	5	30.1	23.9	85	73	3.8	1.0	5.9
28	09-15 July	143.8	3	28.8	22.4	93	76	3.0	2.9	5.9
29	16-22 July	12.9	2	32.5	22.9	86	61	4.7	5.1	5.0
30	23-29 July	65.6	3	30.7	22.9	93	68	3.7	4.1	4.4
31	30-05 Aug	117.0	4	28.2	22.6	96	81	2.5	2.4	5.1
32	06-12 Aug	0.0	0	31.7	22.1	84	56	5.2	5.9	6.2
33	13-19 Aug	11.2	1	31.8	21.4	85	58	5.0	6.6	5.4
34	20-26 Aug	13.0	2	32.4	21.4	87	52	5.2	8.0	4.4
35	27-02 Sept	71.5	5	31.0	22.5	92	68	4.2	4.2	3.6
36	03-09 Sep	1.5	0	30.9	20.7	80	58	5.3	8.8	5.0
37	10-16 Sep	101.6	3	29.3	22.4	88	78	3.6	1.7	4.6
38	17-23 Sep	109.1	4	29.6	22.3	96	85	2.9	2.5	3.4
39	24-30 Sep	96.9	4	30.2	21.7	91	73	3.3	3.7	4.7
40	01-07 Oct.	109.5	3	29.4	21.3	93	72	3.4	5.3	3.9
41	08-14 Oct.	56.9	2	32.0	21.2	88	52	4.7	7.5	2.9
42	15-21 Oct.	0.0	0	32.2	16.9	77	33	5.5	9.6	2.2
43	22-28 Oct.	0.0	0	32.3	16.1	74	31	5.9	9.0	2.7
44	29-04 Nov.	0.0	0	31.2	14.4	75	32	5.1	9.5	3.8
45	05-11 Nov.	0.0	0	30.6	11.0	74	26	4.3	9.5	1.9
46	12-18 Nov.	0.0	0	30.3	12.1	76	32	4.1	8.2	2.5
47	19-25 Nov.	0.0	0	30.3	9.6	77	25	4.7	9.6	2.8
48	26-02 Dec.	0.0	0	31.5	10.1	77	25	4.7	9.1	2.2
49	03-09 Dec.	0.0	0	30.0	11.9	74	36	4.6	9.1	3.3
50	10-16 Dec.	0.0	0	29.7	12.7	74	30	4.7	8.5	3.9
51	17-23 Dec.	0.0	0	29.6	8.8	75	24	4.6	9.8	2.3
52	24-31 Dec.	0.0	0	29.5	8.0	75	29	4.2	9.8	2.4

APPENDIX III

Nitrogen, phosphorus and potassium concentration (%) in soybean at different growth stages (2016-17)

Treatments	Nutrient concentrations								
	Nitrogen			Phosphorus			Potassium		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	3.24	2.10	1.90	0.42	0.30	0.26	1.4	1.00	0.85
F2: NPK	3.82	3.12	2.80	0.70	0.61	0.55	2.0	1.70	1.30
F3: RDWS	3.90	3.27	3.00	0.73	0.62	0.57	2.5	1.74	1.34
F4: RDZn	4.12	3.41	3.15	0.76	0.64	0.59	2.7	1.80	1.38
F5: RDZnKB	4.45	3.50	3.24	0.77	0.65	0.60	2.9	1.84	1.40
F6: RDZnKBGR	4.40	3.80	3.40	0.75	0.67	0.62	2.8	1.78	1.48
F7: RDZnGR	4.47	3.62	3.52	0.78	0.69	0.64	2.7	1.80	1.50
Mean	4.06	3.31	3.00	0.70	0.60	0.55	2.43	1.67	1.32
SE_±	0.11	0.23	0.29	0.03	0.02	0.05	0.25	0.15	0.07
CD at 5%	0.34	0.71	0.91	0.09	0.07	0.17	0.78	0.45	0.22

APPENDIX IV

Nitrogen, phosphorus and potassium concentration (%) in soybean at different growth stages (2017-18)

Treatments	Nutrient concentrations								
	Nitrogen			Phosphorus			Potassium		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	3.40	2.20	1.95	0.45	0.32	0.28	1.52	1.14	0.90
F2: NPK	4.00	3.27	2.30	0.74	0.64	0.51	2.20	1.85	1.34
F3: RDWS	4.10	3.38	2.27	0.78	0.65	0.53	2.64	1.88	1.38
F4: RDZn	4.22	3.10	2.40	0.80	0.67	0.55	2.85	2.00	1.42
F5: RDZnKB	4.38	3.12	2.46	0.78	0.67	0.56	3.00	2.26	1.47
F6: RDZnKBGR	4.35	3.18	2.47	0.76	0.65	0.54	2.94	2.24	1.52
F7: RDZnGR	4.40	3.22	2.50	0.78	0.66	0.55	2.97	2.28	1.55
Mean	4.12	3.08	2.34	0.73	0.61	0.50	2.59	1.95	1.37
SE_±	0.23	0.30	0.22	0.03	0.02	0.03	0.19	0.27	0.09
CD at 5%	NS	NS	NS	0.10	0.07	0.11	0.58	NS	0.26

APPENDIX V

Sulphur, Zinc and Boron concentration in soybean at different growth stages (2016-17)

Treatments	Nutrient concentrations								
	Sulphur (%)			Zinc (mgkg ⁻¹)			Boron (mgkg ⁻¹)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	0.32	0.24	0.19	0.82	0.64	0.48	31	25	20
F2: NPK	0.45	0.35	0.30	1.04	0.81	0.70	52	40	34
F3: RDWS	0.48	0.38	0.31	1.08	0.83	0.72	54	42	36
F4: RDZn	0.50	0.42	0.33	1.12	0.85	0.75	56	44	38
F5: RDZnKB	0.56	0.47	0.35	1.14	0.84	0.76	57	45	40
F6: RDZnKBGR	0.55	0.46	0.34	1.15	0.83	0.74	55	46	39
F7: RDZnGR	0.57	0.49	0.36	1.17	0.85	0.73	60	48	42
Mean	0.49	0.40	0.31	1.07	0.81	0.70	52.14	41.43	35.57
SE_±	0.03	0.02	0.02	0.08	0.01	0.02	2.45	1.05	0.73
CD at 5%	0.10	0.07	0.06	NS	0.02	0.07	7.55	3.25	2.26

APPENDIX VI

Sulphur, Zinc and Boron concentration in soybean at different growth stages (2017-18)

Treatments	Nutrient concentrations (mgkg ⁻¹)								
	Sulphur (%)			Zinc (mgkg ⁻¹)			Boron (mgkg ⁻¹)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	0.34	0.26	0.21	0.87	0.66	0.48	34	27	22
F2: NPK	0.47	0.37	0.32	1.12	0.84	0.70	55	43	36
F3: RDWS	0.52	0.40	0.35	1.18	0.87	0.72	57	45	38
F4: RDZn	0.54	0.44	0.37	1.20	0.88	0.75	58	47	40
F5: RDZnKB	0.58	0.50	0.36	1.16	0.90	0.76	60	46	38
F6: RDZnKBGR	0.56	0.48	0.35	1.17	0.88	0.74	59	48	39
F7: RDZnGR	0.59	0.52	0.38	1.19	0.91	0.77	63	50	28
Mean	0.53	0.42	0.33	1.13	0.85	0.70	55.14	43.71	34.38
SE_±	0.05	0.02	0.02	0.08	0.04	0.04	3.11	2.60	0.94
CD at 5%	NS	0.05	0.05	NS	0.12	0.11	9.58	8.00	2.91

APPENDIX VII

Available N, P and K (kg ha⁻¹) status of soil at different growth stages of soybean (2016-17)

Treatments	Nutrients status								
	Nitrogen			Phosphorus			Potassium		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	141.26	140.22	142.48	12.94	14.42	13.70	580.27	579.67	580.47
F2: NPK	145.57	144.27	145.26	13.68	15.87	14.81	582.89	581.60	580.00
F3: RDWS	143.26	142.58	144.32	14.10	15.84	14.70	583.00	581.74	580.40
F4: RDZn	143.00	142.00	143.26	13.82	14.26	13.74	582.47	580.90	581.68
F5: RDZnKB	142.48	141.46	144.00	14.00	14.70	13.44	583.40	581.67	580.94
F6: RDZnKBGR	142.80	140.57	142.40	13.24	13.44	13.00	582.67	580.62	580.00
F7: RDZnGR	143.22	142.26	144.04	13.47	14.94	13.24	581.52	579.68	580.70
Mean	143.08	141.90	143.68	13.60	14.78	13.80	582.31	580.84	580.59
SE_±	10.53	8.33	5.98	2.03	1.71	0.81	20.66	14.20	13.10
CD at 5%	NS	NS	18.42	6.24	5.28	2.49	NS	NS	NS

APPENDIX VIII

Available N, P and K status (kg ha⁻¹) of soil at different growth stages of soybean (2017-18)

Treatments	Nutrient status								
	Nitrogen			Phosphorus			Potassium		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	143.89	142.89	143.00	12.68	13.00	13.47	580.62	579.26	578.48
F2: NPK	144.52	145.27	147.36	14.67	15.00	15.40	585.89	584.68	584.00
F3: RDWS	145.26	144.78	146.00	13.42	14.11	14.87	584.67	583.46	583.32
F4: RDZn	146.00	143.22	145.68	13.20	13.85	14.68	583.64	582.62	582.70
F5: RDZnKB	145.35	144.56	145.60	13.42	14.42	14.82	584.00	583.00	582.47
F6: RDZnKBGR	144.67	142.68	144.69	12.42	12.78	13.85	583.42	582.31	581.90
F7: RDZnGR	144.26	143.67	145.62	13.04	13.68	14.72	582.46	581.40	581.00
Mean	144.85	143.86	145.42	13.26	13.83	14.54	583.52	582.39	581.98
SE_±	18.32	21.34	13.49	1.43	2.41	2.27	15.97	9.23	13.01
CD at 5%	NS	NS	41.56	4.42	7.43	7.00	49.21	28.44	40.11

APPENDIX IX

Available S, Zn and B status of soil at different growth stages of soybean (2016-17)

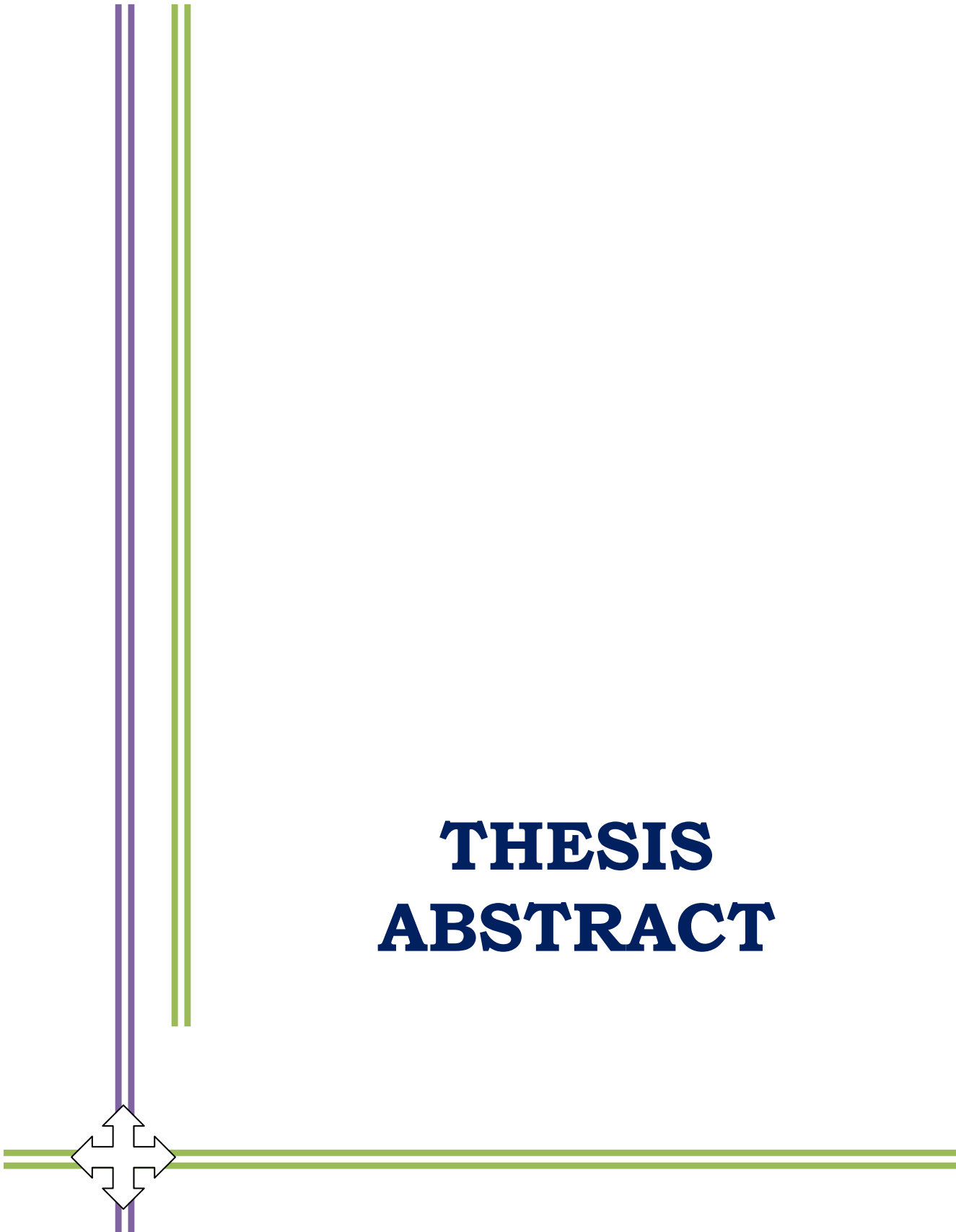
Treatments	Nutrient status								
	Sulphur (kg ha ⁻¹)			DTPA-Zn (mg kg ⁻¹)			HWS-B (mg kg ⁻¹)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	13.47	13.14	12.82	0.47	0.45	0.47	0.35	0.34	0.33
F2: NPK	12.69	12.22	11.80	0.49	0.47	0.48	0.34	0.34	0.35
F3: RDWS	15.00	14.80	14.74	0.49	0.48	0.48	0.35	0.33	0.34
F4: RDZn	15.21	14.47	14.45	0.57	0.55	0.56	0.35	0.35	0.34
F5: RDZnKB	14.90	14.48	14.32	0.54	0.52	0.54	0.39	0.38	0.39
F6: RDZnKBGR	15.00	14.89	14.24	0.55	0.53	0.54	0.40	0.38	0.38
F7: RDZnGR	15.12	14.42	14.47	0.57	0.54	0.55	0.37	0.36	0.35
Mean	14.48	14.06	13.83	0.52	0.50	0.51	0.36	0.35	0.35
SE_±	1.53	1.39	1.20	0.04	0.02	0.03	0.02	0.01	0.02
CD at 5%	4.73	4.29	3.70	0.13	0.05	0.10	NS	0.02	NS

APPENDIX X

Available S, Zn and B status of soil at different growth stages of soybean (2017-18)

Treatments	Nutrient status (mgkg ⁻¹)								
	Sulphur (kg ha ⁻¹)			DTPA-Zn (mgkg ⁻¹)			HWS-B (mgkg ⁻¹)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
F1: Ctrl	13.34	13.00	12.67	0.48	0.46	0.47	0.34	0.33	0.34
F2: NPK	12.26	13.17	12.42	0.49	0.47	0.48	0.33	0.32	0.31
F3: RDWS	15.12	14.22	13.77	0.51	0.48	0.50	0.34	0.33	0.31
F4: RDZn	14.24	13.69	13.84	0.53	0.55	0.58	0.34	0.32	0.32
F5: RDZnKB	14.00	13.22	13.47	0.52	0.54	0.55	0.37	0.35	0.36
F6: RDZnKBGR	14.47	13.39	13.52	0.55	0.53	0.54	0.39	0.37	0.35
F7: RDZnGR	14.22	13.47	13.95	0.58	0.56	0.57	0.37	0.36	0.34
Mean	13.95	12.02	13.37	0.52	0.51	0.52	0.35	0.34	0.33
SE_±	1.41	1.49	3.20	0.04	0.03	0.01	0.02	0.01	0.02
CD at 5%	4.35	4.59	9.87	0.12	0.09	0.03	NS	0.02	NS

**THESIS
ABSTRACT**



ABSTRACT

**STUDIES ON YIELD MAXIMIZATION OF SOYBEAN (*Glycine max* L.)
THROUGH SOIL AND FOLIAR FEEDING OF NUTRIENTS, GROWTH
REGULATORS AND MONITORING GROWTH PROFILE BY SPECTRAL
REFLECTANCE**

By

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2020

Research Guide	:	Dr. V. D. Patil
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A field experiment was conducted to find out the effect of soil and foliar feeding of nutrients and growth regulators on yield and quality of *kharif* soybean during year 2015-2016 and 2016-17 at Research farm, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out in randomized block design with seven treatments *viz.*, F₁-Control, F₂-NPK (30:60:30 kg ha⁻¹), F₃-RDF (NPKS 30:60:30:20 kg ha⁻¹), F₄-RDF + 20 kg ZnSO₄ ha⁻¹, F₅- RDF + 20 kg ZnSO₄ ha⁻¹+ 1% KNO₃ foliar (40 & 60 DAS), F₆- RDF + 20 kg ZnSO₄ ha⁻¹+ 1% KNO₃ foliar (40 & 60 DAS) + 0.2% borax (40 DAS)+ NAA (20mg/l) 40 DAS+ GA (20 mg/l) 60DAS, F₇- RDF + 20 kg ZnSO₄ ha⁻¹+ NAA (20mg/l) 40 DAS+ GA (20 mg/l) 60 DAS with three replications. The yield and quality of soybean significantly influenced due to application of F₆- RDF + 20 kg ZnSO₄ ha⁻¹+ 1% KNO₃ foliar (40 & 60 DAS)+ 0.2% borax (40 DAS) + NAA (20 mg/l) 40 DAS+ GA (20mg/l) 60 DAS. Yield attributing characters *viz.*, maximum number of pods (77.47), seed weight (14.66 g./plant), pod weight (0.43 g./pod), 100 seed weight (15.06 g.) seed yield (26.66 q./ha.), straw yield (44.88 qha⁻¹), biological yield (71.54 qha⁻¹) and harvest index (37.70) was recorded in pooled data of both the years of experimentation. Maximum protein content (35.56%) and oil content (19.13%) were observed in F₆- RDF + 20 kg ZnSO₄

ha⁻¹+ 1% KNO₃ foliar (40&60DAS)+ 0.2% borax (40DAS)+ NAA (20mg/l) 40 DAS+ GA (20mg/l) 60 DAS in pooled data of both the years of experimentation. The RVI, NDVI, SAVI ratios were low in control and higher in treatment fertilized with recommended dose of fertilizer + Zinc + foliar application of KNO₃ and Boron, Growth Regulators followed by treatment fertilized with recommended dose of fertilizer + Zinc + foliar application of KNO₃ and Boron. NDVI found to be better indicator for assessment of soybean crop. Maximum uptake of N, P, K, S, Zn and B was observed in treatment fertilized with recommended dose of fertilizer + Zinc + foliar application of foliar application of KNO₃ and Boron, Growth Regulators.

Zn and B was observed in soybean crop fertilized with F₆ treatment *i.e.* recommended dose of fertilizer with foliar sprays of potash, borax with growth regulators. Nutrient uptake by soybean as influenced by soil and foliar feeding of nutrients and growth regulators increased the uptake of nitrogen, phosphorus, potassium, sulphur and zinc significantly. No significant differences were observed in soil pH. The EC values of soils after harvest of *kharif* soybean were increased as compare to initial values. The organic carbon content was increased after harvest of *kharif* soybean compared to initial status. While calcium carbonate content were decreased after harvest stage as compared to initial content of calcium carbonate.

Available nitrogen, phosphorus, potassium, sulphur and DTPA Zinc in soil after harvest of soybean crop was found maximum in treatment receiving 30 kg N: 60 kg P₂O₅:30kg K₂O ha⁻¹ to soybean crop. Negative nutrient balance was observed in F₁ (control) treatment for N, P and K nutrients, whereas positive nutrient balance for N, P and K were found under treatment F₂ followed by F₃, F₄, F₅ and F₇. As regards to sulphur, zinc and boron, negative nutrient balance of S observed under treatments F₁ and F₂. Whereas, positive available sulphur was observed under treatment F₃ followed by F₄, F₅, F₆. Micronutrients *viz.*, DTPA Zn and HWS B, negative DTPA zinc was observed under treatments F₁ and F₂. Positive available zinc were recorded under treatment F₄ followed by F₇, F₅, F₆, F₃. Whereas, positive hot water soluble boron was recorded under treatments F₅ and F₆.

Keywords : Soybean, Yield, Maximization, Spectral reflectance, RVI, NDVI, SAVI, IPVI.

VITAE



VITAE

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4	S.S.C.	MSBSE, Divisional Board Aurangabad	1987	66	First