

**PRODUCTIVITY AND QUALITY
OF GREENGRAM [*Vigna radiata* (L.)]
AS INFLUENCED BY POTASSIUM AND
ZINC NUTRITION**

BY
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B.Sc. (Ag.)

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DECLARATION

I, **Mr. MOHAMMAD JAVID RAHIMI** hereby declare that the thesis entitled “**PRODUCTIVITY AND QUALITY OF GREENGRAM [*Vigna radiata* (L.)] AS INFLUENCED BY POTASSIUM AND ZINC NUTRITION**” submitted to the Acharya N.G. Ranga Agricultural University for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

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No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

₹	: Rupee
%	: Per cent
@	: At the rate of
°C	: Degree Celsius
AAS	: Atomic Absorption Spectrophotometer
B:C ratio	: Benefit-Cost ratio
C mol. (P ⁺) kg ⁻¹	: Centi mol per kilogram
Ca	: Calcium
CaNO ₃	: Calcium Nitrate
CD (P=0.05)	: Critical difference at 5 per cent level of significance
DAS	: Days after sowing
DTPA	: Diethylene Triamine Penta Acidic Acid
dS m ⁻¹	: Deci Siemen per metre
EC	: Electrical conductivity
EDTA	: Ethylene Diamine Tetra Acetic Acid
<i>et al.</i> ,	: and other people
Fed	: Feddan (one feddan = 0.42 hectares)
fed ⁻¹	: Per feddan
Fig.	: Figure
GA	: Gibberellic Acid
g ha ⁻¹	: Grams per hectare
g kg ⁻¹	: Gram per kilogram
g l ⁻¹	: Gram per litre
g plant ⁻¹	: Grams per plant
ha ⁻¹	: Per hectare
HI	: Harvest index
IAA	: Indole Acetic Acid
<i>i.e.</i>	: That is

kg ha ⁻¹	: Kilogram per hectare
l	: Litre
LAI	: Leaf area index
M ha	: Million hectare
Mg	: Magnesium
MgNO ₃	: Magnesium nitrate
ml l ⁻¹	: Milliliter per litre
M t	: Million tones
mM	: Milli mole
mm day ⁻¹	: Millimeter per day
NS	: Not significant
pH	: Potential of Hydrogen ion concentration
Plant ⁻¹	: Per plant
ppm (mg kg ⁻¹)	: Parts per million or milligram per kilogram
q ha ⁻¹	: Quintal per hectare
RBD	: Randomized block design
RH	: Relative humidity
SAT	: Semi Arid Tropics
SEm±	: Standard error of mean
t ha ⁻¹	: Tonne per hectare
USWB	: United States Weather Bureau
T _{max}	: Maximum temperature
T _{min}	: Minimum temperature
<i>viz.</i> ,	: Namely

ABSTRACT

Author of the thesis : **MOHAMMAD JAVID RAHIMI**

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A field experiment entitled “**Productivity and quality of greengram as influenced by potassium and zinc nutrition**” was carried out during *kharif*, 2018 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University.

The experiment was laid out in a randomized block design with eight treatments and replicated thrice. The treatments consisted of eight nutrient management practices *viz.*, control (T₁), application of Recommended Dose of Fertilizers (RDF) (20-50-0 kg N, P₂O₅ and K₂O ha⁻¹) (T₂), soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), foliar application of KNO₃ @ 1 % at flower bud initiation stage along with RDF (T₆), foliar application of ZnSO₄ @ 0.2 % at flower bud initiation stage along with RDF (T₇), foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈). The test variety of greengram used in the present investigation was IPM 2-14.

At 15 and 30 DAS, the highest stature of growth parameters *viz.*, plant height, leaf area index, dry matter production and highest number of branches plant⁻¹ were recorded with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), whereas at harvest, foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded the tallest plants with largest LAI and highest dry matter production, which was however comparable with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹

along with RDF and significantly superior over the rest of the nutrient management practices. All these growth parameters were the lowest with control (T₁) at all the stages.

The yield attributes *viz.*, number of pods branch⁻¹, seeds pod⁻¹ and test weight were registered the highest with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅) and significantly superior over the rest of the treatments tried. The lowest values of above said yield attributes were recorded with control (T₁).

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded the highest seed and haulm yield as well as harvest index, which was however comparable with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅) and superior over rest of the nutrient management practices. T₈ and T₅ increased the seed yield to the tune of 31.38 and 29.28 per cent, respectively, compared to application of RDF alone (T₂). The lowest seed and haulm yield including harvest index were recorded with control (T₁).

The highest nutrient uptake (N, P, K and Zn) of greengram at harvest was registered with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however on par with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), but were in turn comparable with foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) in zinc uptake and significantly higher over the rest of the nutrient management practices, while it was the lowest with control (T₁).

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded significantly the highest protein and zinc content in the seed, which was comparable with foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇). The lowest values of protein and zinc contents were registered with control (T₁).

The highest gross returns were obtained with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) which was however comparable with soil application of 40 kg of K₂O ha⁻¹ + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅). Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded significantly the highest net returns and benefit-cost ratio over the rest of the nutrient management practices tried. The lowest economic returns were recorded with non application of fertilizers control (T₁).

The highest post-harvest soil available nitrogen and phosphorus status were recorded with application of recommended dose of fertilizers (T₂), while soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃) recorded higher soil

available potassium after harvest. The highest post-harvest soil available zinc was registered with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅). The lowest post-harvest soil available nitrogen, phosphorus, potassium and zinc were observed with non application of fertilizers control (T₁).

From the above experimentation, it may be concluded that higher seed yield, protein and zinc content in the seed and monetary returns would be obtained with application of 20 kg N, 50 kg P₂O₅ along with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage in greengram on sandy loam soils during *khariif*. Foliar application of potassium and zinc is an effective approach, which not only enhances the yield but also achieve nutritional quality, better monetary returns in greengram.

Chapter - I

Introduction

Chapter – I

INTRODUCTION

Pulse crops play a significant role in food production of India, which accounts for one third of global area under pulses (29.4 M ha) and one fourth of production (23.1 M t) with a productivity of 786 kg ha⁻¹ during the year 2016-17. Even though India has the largest area under pulses in the world, the average productivity is very low and the production is insufficient to meet the population requirement.

Greengram is the third most important pulse crop of India accounting for 12 per cent of total pulse production in the country next to bengalgram and pigeonpea. India is the world's largest producer and consumer of greengram, which is cultivated over an area of 4.30 million hectares with an annual production of 2.2 million tonnes with an average productivity of 500 kg ha⁻¹. In Andhra Pradesh, greengram is cultivated over an area of 1.34 lakh ha with annual production of 0.66 lakh tonnes with a productivity of 493 kg ha⁻¹ (Ministry of Agriculture and Co - operation, 2017). The lower yield of greengram in India is mainly attributed to its cultivation on poor soils with inadequate and imbalanced nutrient application. Application of plant nutrients in balanced proportion and appropriate quantities is absolutely essential for improving the productivity of pulses (Sarkar, 1995).

Under intensive cropping systems, a large amount of potassium is removed, leading to serious depletion of potassium reserves from soils. Pulses have long been sidelined in the crop nutrition especially in leguminous crops where biological nitrogen fixation is shown to be improved with potassium application (Jones *et al.*, 1997). Pulses such as chickpea and pigeonpea remove about 60 and 52 kg K₂O t⁻¹ of grain, respectively (Srinivasarao *et al.*, 2003).

Factors which can lead to potassium deficiency are through leaching in sandy soils, irrigation water with high sodium content and where high rates of Ca and Mg are added through the irrigation water or through fertilization. Besides, the current N P K use ratio (6.8 : 2.8 : 1) when viewed from a generally proclaimed ideal ratio of 4 : 2 : 1 was unfavourable to potassium availability (Katyal, 2012).

As potassium is a structural component of soil minerals, hence may not be readily available for growth and development of plant, moreover peak absorption of potassium occurs from flowering to early pod development and any deficiency of potassium during this period can result in yield loss without obvious foliar symptoms. Potassium is one of the major nutrients associated with movement of water, nutrients and carbohydrates within the plant. It not only enhances the biological nitrogen fixation but also improves the protein content, water use efficiency and resistance to pests and diseases and it is also vital for sustaining the productivity of modern high input agriculture. Foliar application of macro nutrients particularly potassium can help the plants to recover from temporary stress caused by biotic and abiotic factors (Nasri *et al.*, 2011).

Among the micronutrients, zinc deficiency is the most common deficiency prevalent in the world (Alloway, 2004). Zinc deficiency in Indian soils is expected to increase from 42 per cent in 1970 to 63 per cent by 2025 due to continuous depletion of soil fertility. The soil factors responsible for zinc deficiency include lower content of total zinc (sandy soils with low organic matter), saline, alkaline and calcareous soils particularly in arid and semi arid areas (Jat *et al.*, 2012). Zinc plays an important role in chlorophyll formation, carbohydrate metabolism and protein biosynthesis. It is now being considered as the 3rd most important limiting nutrient in crop production after nitrogen and phosphorous. Supplementation of nutrients through foliar spray resulted in better nutrient balance in plants (Patra *et al.*, 1995).

Significance of nitrogen and phosphorus fertilization on pulses is well known, but the need for potassium and zinc nutrition and their combination at different stages is not well documented. However, the available literature pertaining the necessity on the need for potassium and zinc nutrition and their combination at different stages in greengram is very meager.

Taking into consideration of the above facts and deficiency in the current state of information, the present experiment was taken up to study **“Productivity and quality of greengram as influenced by potassium and zinc nutrition”** with the following objectives:

1. To find the effect of potassium and zinc on growth and yield of greengram.
2. To study the response of greengram to potassium and zinc along with nitrogen and phosphorus.
3. To identify economically viable combination of potassium and zinc application for enhancing the productivity and quality of greengram.

Chapter - II

Review of Literature

Chapter – II

REVIEW OF LITERATURE

The literature available pertinent to the present study entitled “Productivity and quality of greengram as influenced by potassium and zinc nutrition” is reviewed in this chapter. As the available literature on greengram is meagre, the information on other legume pulse crops was also included under this chapter.

2.1 EFFECT OF POTASSIUM

2.1.1 Growth Parameters

Patra *et al.* (1995) observed larger leaf area index (LAI) and higher crop growth rate (CGR) in groundnut with post flowering foliar application of potassium nitrate @ 0.5 per cent on sandy loam soils of Kalyani, West Bengal.

Mathan *et al.* (1996) reported that application of 20 kg N + 50 kg P₂O₅ + 50 kg K₂O ha⁻¹ along with 6.25 tonnes of FYM ha⁻¹ and *Rhizobium* inoculation significantly increased the plant height, branches, leaves, dry matter and root nodules in blackgram.

Govindan and Thirumurugan (2000) recorded significantly higher LAI and dry matter production in greengram either with foliar application of KNO₃ (1 %) or KCl (1 %) alone or in combination during *kharif* on clay loam soils of Madhurai, Tamilnadu.

Reddy *et al.* (2000) reported that foliar application of NAA @ 20 ppm along with 0.5 per cent KNO₃ significantly increased the dry matter production in pigeonpea compared to control on black soils of Guntur, Andhra Pradesh.

The highest plant height was recorded when mungbean was supplied with soil application of potassium @ 90 kg ha⁻¹ in sandy clay loam soils of Rawalpindi, Pakistan (Hussain *et al.*, 2011).

Ayub *et al.* (2012) observed higher plant height, stem diameter, number of branches and leaf area plant⁻¹ with application of 70 kg K₂O ha⁻¹ over control at Faisalabad, Pakistan.

Enhanced plant height was observed in urdbean with foliar application of potassium at the time of flowering @ 1 kg ha⁻¹ at Azamgarh, Uttar Pradesh (Beg *et al.*, 2013).

At Varanasi, Uttar Pradesh, Ganga *et al.* (2014) conducted a field experiment on chickpea (*Cicer arietinum* L.) during *rabi* on sandy clay loam soils and observed an increase in plant height with soil application of 60 kg K₂O ha⁻¹ at sowing and foliar spraying of 2 % urea along with 0.25 % multiplex at pre-flowering stage.

Deotale *et al.* (2015) revealed that foliar application of 0.5 per cent Ca (NO₃)₂ at 25 and 35 DAS appreciably increased plant height (64.54 cm) of greengram over control (51.33 cm) during *kharif* at Nagpur, Maharashtra.

Foliar spray of KNO₃ @ 1 per cent at flowering and pod initiation stages recorded significantly higher plant height (19.45 cm), which was on par with K₂SO₄ @ 1 per cent spray (19.14 cm) under receding soil moisture conditions in blackgram on black cotton soils during *rabi* season at Lam, Guntur (Rao *et al.*, 2015).

Kurhade *et al.* (2015) observed higher plant height and number of branches plant⁻¹ with application of 25 kg potassium ha⁻¹ and 6 kg sulphur ha⁻¹ in blackgram compared to control on clay soils of Akola.

Hussain *et al.* (2016) recorded the highest plant height and number of branches plant⁻¹ with the application of 125 kg K₂O ha⁻¹ over control in greengram at Tandojam, Pakistan.

Ranpariya *et al.* (2017) recorded maximum plant height and number of branches plant⁻¹ with application of 60 kg potassium ha⁻¹ in greengram over the control on clay soils of Junagadh, Gujarat.

2.1.2 Yield Attributes

Govindan and Thirumurugan (2000) recorded significantly higher number of pods plant⁻¹, length of pod and number of seeds pod⁻¹ in greengram with foliar application of KNO₃ (1 %) or KCl (1 %) alone or in combination during *kharif* on clay loam soils of Madhurai, Tamilnadu.

Reddy *et al.* (2000) reported that foliar application of NAA @ 20 ppm along with 0.5 per cent KNO₃ significantly increased the number of pods plant⁻¹, seeds pod⁻¹ and test weight compared to control in pigeonpea in black soils of Guntur, Andhra Pradesh.

Foliar application of 0.5 per cent potassium nitrate at 50 per cent flowering recorded maximum values of pods plant⁻¹, length of pod, seeds pod⁻¹ and 1000 seed weight in grasspea on gangetic alluvial soils of Baruipur, West Bengal (Sarkar and Malik, 2001).

Yakadri and Ramesh (2002) stated that application of K₂O @ 25 kg ha⁻¹ along with DAP spray at pre flowering and pod initiation stages in blackgram increased the number of pods plant⁻¹, length of pod, seeds pod⁻¹ and 1000 seed weight during *kharif* on sandy loam soils of Rajendranagar, Hyderabad under irrigated conditions.

Thalooth *et al.* (2006) revealed that foliar application of 2 per cent potassium nitrate resulted in increase in number, weight of pods plant⁻¹ and seeds pod⁻¹ in mungbean grown under water stressed conditions on clay loam soils at Shalakan, Egypt.

Soil application of potassium @ 90 kg ha⁻¹ in mungbean recorded maximum number of pods plant⁻¹, seeds pod⁻¹ and 1000 seed weight in mungbean over no potassium application in sandy clay loam soils of Rawalpindi, Pakistan (Hussain *et al.*, 2011).

Ibrahim and Al-Bassyuni (2012) observed higher plant height and number of branches plant⁻¹ in greengram with application of 30 kg phosphorus and 36 kg potassium ha⁻¹ over other treatments.

Beg *et al.* (2013) observed increase in number of pods plant⁻¹, pod length, seeds pod⁻¹ and 1000 seed weight in urdbean with foliar application of potassium @ 1 kg ha⁻¹ during flowering at Azamgarh, Uttar Pradesh.

At Ludhiana, Singh and Singh (2013) conducted a field experiment on soybean [*Glycine max* (L.) Merrill] during *kharif* on sandy loam soils and recorded higher number of pods plant⁻¹ and pod weight with the application of 20 kg N ha⁻¹ as basal + 10 kg N kg ha⁻¹ at pod filling + 30 kg K₂O ha⁻¹ at sowing indicating the beneficial effect of split application of nitrogen along with potassium.

Experiment conducted on chickpea (*Cicer arietinum* L.) at Varanasi, Uttar Pradesh observed higher number of seeds pod⁻¹ and 100 seed weight with soil application of 60 kg K₂O ha⁻¹ and foliar spraying of 2 % urea along with 0.25 % multiplex at pre flowering stage (Ganga *et al.*, 2014).

Soil application of 100 per cent RDF with potassium sulphate @ 20 kg ha⁻¹ plus foliar spray of 0.5 per cent potassium sulphate at 30 DAS and 45 DAS recorded higher number of seeds pod⁻¹ in blackgram on sandy clay loam soils of Madurai, Tamil Nadu (Gokila *et al.*, 2015).

Singh (2017) revealed that application of 60 kg K₂O ha⁻¹ in greengram significantly increased the grain and straw yield over the control on sandy loam soil of Agra, Uttar Pradesh.

Chaudhari *et al.* (2018) recorded higher number of pods, dry matter, and seed yield with application of RDF + 60 kg potassium ha⁻¹ in blackgram compared to control on clay soil of Badnapur, Maharashtra.

2.1.3 Yield

Govindan and Thirumurugan (2000) recorded significantly higher test weight and grain yield in greengram with foliar application of KNO₃ (1 %) or KCl (1 %) alone or in combination during *kharif* on clay loam soils of Madhurai, Tamilnadu.

Reddy *et al.* (2000) recorded significantly higher seed yield and harvest index in pigeonpea with foliar application of NAA @ 20 ppm along with 0.5 per cent KNO₃ compared to control on black soils of Guntur, Andhra Pradesh.

Yakadri and Ramesh (2002) recorded 66 per cent higher seed yield (13.8 q ha⁻¹) in blackgram due to application of K₂O @ 25 kg ha⁻¹ along with DAP spray at pre flowering and pod initiation stages over control during *kharif* on sandy loam soils of Rajendranagar, Hyderabad under irrigated conditions.

Thalooth *et al.* (2006) revealed that foliar application of 2 per cent potassium nitrate resulted in higher seed yield over application of magnesium sulphate @ 50 ppm and zinc-EDTA @ 300 ppm grown under water stressed conditions in mungbean on clay loam soils of Shalakan, Egypt.

Maximum seed yield (753 kg ha⁻¹) in mungbean was obtained with the soil application of 90 kg potassium per hectare over no potassium application in sandy clay loam soils of Rawalpindi, Pakistan (Hussain *et al.*, 2011).

Significantly higher grain (1587 kg ha⁻¹) and haulm yields (2047 kg ha⁻¹) of cowpea were recorded with the soil application of 60 kg K₂O ha⁻¹ during *kharif* on clay soils of Junagadh, Gujarat (Chavan *et al.*, 2012).

Tiwari *et al.* (2012) reported that application of potassium @ 60 kg K₂O ha⁻¹, significantly increased the grain and stover yield in pigeonpea during *kharif* on sandy soils of Kanpur, Uttar Pradesh.

Beg *et al.* (2013) observed increase in grain yield in urdbean with foliar application of potassium @ 1 kg ha⁻¹ at the time of flowering at Azamgarh, Uttar Pradesh.

Higher grain yield was recorded with the application of 30 kg K₂O ha⁻¹ at sowing in soybean on sandy loam soils of Ludhiana, Punjab (Singh and Singh 2013).

Vekaria *et al.* (2013) reported that foliar application of potassium nitrate @ 0.4 % significantly increased grain yield in greengram by 18.4 per cent as compared to water spray only during rainy season on Vertic Ustocrepts soils of Rajkot, Gujarat.

At Varanasi, Uttar Pradesh, Ganga *et al.* (2014) observed higher seed yield in chickpea with soil application of 60 kg K₂O ha⁻¹ at sowing and foliar spraying of 2 % urea along with 0.25 % multiplex at pre flowering stage.

Singh *et al.* (2014) stated that application of 60 kg K₂O ha⁻¹ at sowing along with combined foliar spraying of 2 % urea and 0.25 % multiplex at pre-flowering stage in chickpea resulted in maximum grain yield.

Rao *et al.* (2015) stated that foliar spray of K₂SO₄ @ 1 per cent at flowering and pod initiation stages relatively increased seed yield (577.82 kg ha⁻¹) over water spray (492.77 kg ha⁻¹) under receding soil moisture conditions in blackgram on black cotton soils during *rabi* season at Guntur, Andhra Pradesh.

Soil application of 100 per cent RDF along with potassium sulphate @ 20 kg ha⁻¹ plus foliar spray of 0.5 per cent potassium sulphate at 30 DAS and 45 DAS recorded haulm yield of 1645 kg ha⁻¹ in blackgram on sandy clay loam soils of Madurai, Tamil Nadu (Gokila *et al.*, 2015).

Manoja *et al.* (2018) recorded highest seed and stalk yield with application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation and pod formation stage along with RDF in redgram on sandy loam soils of Tirupati, Andhra Pradesh.

2.1.4 Quality

Foliar application of potassium nitrate @ 2 per cent significantly increased the proline content and crude protein per cent in mungbean under water stressed conditions when compared with 50 ppm magnesium sulphate and 300 ppm zinc-EDTA on clay loam soils of Shalakan, Egypt (Thalooth *et al.*, 2006).

Tiwari *et al.* (2012) recorded significantly higher protein content in pigeonpea with application of 60 kg K₂O ha⁻¹ during *kharif* in sandy soils of Kanpur, Uttar Pradesh.

Increased protein content of mungbean was noticed with application of potassium @ 90 kg ha⁻¹ over no potassium application in sandy clay loam soils of Rawalpindi, Pakistan (Hussain *et al.*, 2011).

Kumar *et al.* (2014) recorded maximum grain protein content (25.63 %) with application of 120 kg potassium ha⁻¹ as compared to control treatment (23.3 %).

Manoja *et al.* (2018) recorded highest protein and zinc content in grain with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ twice at flower bud initiation and pod formation stage along with (RDF) in redgram on sandy loam soil at Tirupati, Andhra Pradesh.

Chaudhari *et al.* (2018) recorded the highest protein content (20.11 %) with application of RDF + 60 kg K₂O ha⁻¹ in blackgram as compared to control in clay soil at Badnapur, Maharashtra.

2.1.5 Nutrient Uptake

Potassium content in leaves and seeds of pigeonpea were maximum with foliar application of NAA @ 20 ppm along with KNO_3 @ 0.5 per cent (0.810 and 1.219 %) compared to control (0.472 and 0.920 %) on black soils of Lam, Guntur (Reddy *et al.*, 2000).

Increase in levels of potassium from 0 to 30 kg ha⁻¹ recorded higher potassium uptake with a significant disparity among themselves (Prasad *et al.*, 2000) in mungbean.

Ibrahim and Al-Bassyuni (2012) reported that with each increase in phosphorus and potassium levels, there was progressive increase in total protein, phosphorus and potassium percentage in the mungbean grains.

Chavan *et al.* (2012) observed increased NPK uptake due to application of 60 kg K₂O ha⁻¹ in cowpea during *kharif* on clay soils of Junagadh, Gujarat.

Balpande *et al.* (2016) observed the highest potassium uptake with application of 45 kg potassium and 20 kg sulphur ha⁻¹ in pieonpea on clayey soil of Nagapur, Maharashtra.

Ranpariya *et al.* (2017) recorded significantly higher potassium in greengram seed with application of potassium @ 60 kg K₂O ha⁻¹ on clayey soil of Junagadh, Gujarath.

2.1.6 Economics

Malik *et al.* (1999) observed maximum grain yield (893.6 kg ha⁻¹) with application of 70 kg each P₂O₅ and K₂O ha⁻¹, which also gave highest net income of ₹13469 ha⁻¹, which was 46.2 per cent increase over the control.

Govindan and Thirumurugan (2000) reported that application of 1 % KCl + 1 % KNO₃ recorded the highest values for B : C ratio (2.53).

Foliar application of potassium nitrate @ 0.4 % in greengram significantly increased grain yield by 18.4 per cent as compared to water spray only and

gave higher economic benefits of ₹ 2043 ha⁻¹ over that of water spray (Vekaria *et al.* 2013).

Kumar *et al.* (2014) reported that the application of 80 kg K₂O ha⁻¹ resulted in the highest B: C ratio of mungbean.

2.2 EFFECT OF ZINC

2.2.1 Growth Parameters

Soil application of zinc @ 10 µg g⁻¹ of soil resulted in higher dry matter accumulation, leaf area, nodule weight and number in soybean (Sarkar and Aery, 1990).

Foliar application of DAP (2 %) + KCl (1 %) + ZnSO₄ (0.5%) at 15, 30 and 45 DAS resulted in higher plant height, larger leaf area index and more number of branches plant⁻¹ in greengram during summer season on clay loam soils of Madhurai, Tamilnadu (Krishnaveni *et al.*, 2004).

Togay *et al.* (2004) noticed increase in the plant height and number of branches plant⁻¹ in drybean (*Phaseolus vulgaris* L.) with soil application of zinc @ 30 kg ha⁻¹ during summer season on sandy loam soils at Van, Turkey.

Anitha *et al.* (2005) reported that spraying of 0.5 per cent FeSO₄ and 0.5 per cent ZnSO₄ resulted in increased plant height in cowpea during *kharif* on sandy loam soils of Pattambi, Kerala.

Thalooth *et al.* (2006) observed higher plant height, number of branches plant⁻¹ and stem dry weight with foliar application of zinc-EDTA @ 300 ppm on mungbean grown under water stressed conditions on clay loam soils of Shalakan, Egypt.

From the results of the pot experiment with four different soils and five concentrations of zinc (0, 1, 2, 4 and 8 mg Zn pot⁻¹) it was concluded that the matured plants fertilized with zinc produced more dry matter in chickpea (Valenciano *et al.*, 2009).

Foliar application of zinc to five days old seedlings or pre-treatment @ 4×10^{-5} M resulted in enhanced root and shoot length, total dry matter and number of leaves plant⁻¹ in mungbean (Pandey *et al.*, 2010).

Nasri *et al.* (2011) reported that soil application of potassium @ 120 kg ha⁻¹ along with foliar application of zinc @ 0.6 per cent significantly improved the plant height in *Phaseolous vulgaris* on sandy soils of Varamin, Iran.

Higher plant height and total dry weight were observed with application of 4, 8 and 30 mg of Zn, Fe and Mn respectively per kg soil, in soybean on clay soils at Kermanshah, Iran (Soheil *et al.*, 2011).

Taller plants and high number of branches plant⁻¹ were observed with foliar application of 150 ppm salicylic acid and 500 ppm zinc in mungbean during summer season on sandy soils of Libya, Egypt (Ali and Adel, 2013).

Prasanna *et al.* (2013) noticed higher plant height, leaf area index and dry matter production in clusterbean with foliar application of 0.5 % zinc sulphate at 20 and 45 days after sowing during *kharif* on sandy loam soils of Tirupati, Andhra Pradesh.

Ram and Katiyar (2013) revealed that application of 40 kg S ha⁻¹ and 10 kg Zn ha⁻¹ significantly increased the plant height in mungbean during summer season on silty loam soils of Faizabad, Uttar Pradesh.

According to Puniya *et al.* (2013), maximum plant height and dry matter accumulation plant⁻¹ was recorded with soil application of 5 kg zinc ha⁻¹ along with foliar application of zinc @ 0.5 per cent at 25 and 45 days after sowing in mothbean on loamy sand soils of Jobner, Rajasthan.

Higher plant height and number of branches plant⁻¹ were recorded with foliar application of zinc @ 4 g l⁻¹ along with iron @ 4 g l⁻¹ in faba bean (Usama *et al.*, 2013).

Rakesh *et al.* (2016) observed improved plant height, number of leaves, number of branches, leaf length and leaf to stem ratio with application of 60 kg P₂O₅ and 20 kg ZnSO₄ ha⁻¹ in cowpea at Haryana.

Debnath *et al.* (2018) recorded maximum plant height, number of branches plant⁻¹ and dry matter production with application of RDF + 1.5 kg B ha⁻¹ + 5 kg Zn ha⁻¹ in cowpea over control on sandy loam soil of Arunachal Pradesh.

2.2.2 Yield Attributes

Sarkar and Aery (1990) observed higher 100 seed weight with soil application of zinc @ 10 µg g⁻¹ of soil in soybean.

Foliar application of DAP (2 %) + KCl (1 %) + ZnSO₄ (0.5%) at 15, 30 and 45 DAS recorded higher number of pods plant⁻¹, pod length and 100 seed weight in greengram during summer season on clay loam soils of Madhurai, Tamilnadu (Krishnaveni *et al.*, 2004).

Significantly higher number of pods plant⁻¹ and seeds pod⁻¹ were recorded with application of zinc sulphate @ 25 kg ha⁻¹ in drybean (*Phaseolus vulgaris* L.) during summer season on sandy loam soils of Van, Turkey (Togay *et al.*, 2004).

Prasanna *et al.* (2013) revealed that number of clusters plant⁻¹, pods cluster⁻¹ and seeds pod⁻¹ were increased with foliar application of 0.5 % zinc sulphate at 20 and 45 days after sowing in clusterbean during *kharif* on sandy loam soils of Tirupati, Andhra Pradesh.

Anitha *et al.* (2005) noticed increase in number of pod bearing branches and seeds pod⁻¹ with application of FeSO₄ and ZnSO₄ each @ 0.5 per cent in cowpea during *kharif* on sandy loam soils of Pattambi, Kerala.

Higher number and weight of pods plant⁻¹ were observed in mungbean with foliar application of 2 per cent potassium nitrate along with 300 ppm

zinc-EDTA and 50 ppm magnesium sulphate under water stressed conditions (Thalooth *et al.*, 2006).

Madani *et al.* (2007) revealed that soil application of 40 kg ZnSO₄ ha⁻¹ followed by foliar application of 0.005 M zinc sulphate solution, before flowering and at grain formation significantly enhanced the test weight in soybean on silty clay loam soils of Iran.

From the results of the pot experiment with four different soils and five concentrations of zinc (0, 1, 2, 4 and 8 mg Zn pot⁻¹) it was concluded that application of zinc resulted in more number of pods plant⁻¹ in chickpea (Valenciano *et al.*, 2009).

Enhanced weight of seeds pod⁻¹, test weight and yield plant⁻¹ were observed in mungbean due to foliar application of 4 × 10⁻⁵ M zinc either to 5 days old seedlings or to seeds (Pandey *et al.*, 2010).

Vahid *et al.* (2010) revealed that application of 40 kg ha⁻¹ of zinc sulphate resulted in higher number of pods plant⁻¹, seeds pod⁻¹ and test weight in soybean.

Significant improvement in number of pods plant⁻¹, seeds pod⁻¹, 1000 seed weight and seed yield in soybean was observed due to foliar application of zinc @ 116 ppm along with iron @ 116 ppm (Heidarian *et al.*, 2011).

Nasri *et al.* (2011) reported that soil application of nitrogen @ 300 kg ha⁻¹ and potassium @ 120 kg ha⁻¹ along with foliar application of zinc @ 0.6 per cent in *Phaseolous vulgaris* significantly increased the number of pods plant⁻¹, seed pod⁻¹ and 100 seed weight on sandy soils of Varamin, Iran.

Foliar application of zinc sulphate @ 0.1 per cent alone or in combination with urea @ 1 per cent enhanced the number of pods in mungbean during summer season on clay soils at Cairo, Egypt (Ezzat *et al.*, 2012).

Babu *et al.* (2012) reported that soil application of zinc sulphate @ 20 kg ha⁻¹ at the time of sowing increased the number of pods plant⁻¹, seeds

pod⁻¹ and 100 seed weight in pigeonpea on sandy loam soils of Raichur, Karnataka.

Ali and Adel (2013) observed higher number of pods plant⁻¹, seeds pod⁻¹, and 1000 seed weight in mungbean sprayed with 150 ppm of salicylic acid and 500 ppm zinc during summer season on sandy soils of Libya, Egypt.

Nalini *et al.* (2013) stated that foliar application of 0.1 per cent of zinc had a positive impact on number of pods plant⁻¹, seeds pod⁻¹ and test weight in blackgram on sandy soils at Lucknow.

According to Puniya *et al.* (2013), the highest number of pods plant⁻¹ and seeds pod⁻¹ were recorded with soil application of zinc 0.5 kg ha⁻¹ along with foliar application of zinc @ 0.5 per cent at 25 and 45 days after sowing in mothbean on loamy sand soils of Jobner, Rajasthan.

Ram and Katiyar (2013) revealed that application of 40 kg S and 10 kg Zn ha⁻¹ significantly increased the number of branches plant⁻¹, nodules plant⁻¹, pods plant⁻¹ and seeds pod⁻¹ in mungbean during summer season on silty loam soils of Faizabad, Uttar Pradesh.

Muniswamy *et al.* (2018) stated that application of 25 kg N ha⁻¹ + 40 kg S ha⁻¹ + 0.1 per cent zinc at pre flowering and pod initiation significantly increased the number of pods plant⁻¹ and test weight in greengram on sandy loam soil of Allahabad, Uttar Pradesh.

2.2.3 Yield

Sarkar and Aery (1990) observed increased grain yield in soybean with soil application of zinc @ 10 $\mu\text{g g}^{-1}$ of soil.

Puste and Jana (1995) noticed increase in seed yield in pigeonpea with soil application of ZnSO_4 @ 20 kg ha^{-1} during winter season on sandy loam soils of Mohanpur, West Bengal.

Foliar application of DAP (2 %) + KCl (1 %) + ZnSO_4 (0.5%) at 15, 30 and 45 DAS recorded higher grain yield in greengram during summer season on clay loam soils of Madhurai, Tamilnadu (Krishnaveni *et al.*, 2004).

Prasanna *et al.* (2013) noticed higher 1000 seed weight, seed and stalk yield in clusterbean with foliar application of 0.5 % zinc sulphate at 20 and 45 days after sowing during *kharif* on sandy loam soils of Tirupati, Andhra Pradesh.

Significantly higher seed yield was observed in drybean (*Phaseolus vulgaris* L.) with the application of zinc @ 25 kg ha^{-1} during summer season on sandy loam soils of Van, Turkey (Togay *et al.*, 2004).

Anitha *et al.* (2005) reported that spraying of 0.5 per cent FeSO_4 and 0.5 per cent ZnSO_4 resulted in increased seed yield (599 kg ha^{-1}) in cowpea during *kharif* on sandy loam soils of Pattambi, Kerala.

Biological yield of mungbean was increased due to foliar application of zinc-EDTA @ 300 ppm under water stressed conditions on clay loam soils of Shalakan, Egypt (Thalooth *et al.*, 2006).

Soil application of 40 $\text{kg zinc sulphate ha}^{-1}$ followed by foliar application of 0.005 M zinc sulphate solution, before flowering and during grain formation significantly enhanced the grain yield in soybean (Madani *et al.*, 2007).

Soil application of zinc @ 7.5 kg ha⁻¹ through zinc sulphate recorded the highest grain yield (39.58 q ha⁻¹) in soybean on clay soils of Rahuri, Maharashtra (Kanase *et al.*, 2008).

Vahid *et al.* (2010) observed higher seed and straw yields with application of 40 kg ZnSO₄ ha⁻¹ in soybean.

Foliar application of zinc @ 116 ppm along with iron @ 116 ppm resulted in significant improvement in 1000 grain weight and grain yield in soybean (Heidarian *et al.*, 2011).

Nasri *et al.* (2011) reported that soil application of nitrogen @ 300 kg ha⁻¹ and potassium @ 120 kg ha⁻¹ along with foliar application of zinc @ 0.6 per cent in *Phaseolous vulgaris* significantly increased the seed yield, biological yield and harvest index on sandy soils of Varamin, Iran.

Seifinadergholi *et al.* (2011) reported that foliar application of zinc sulphate @ 0.6 per cent along with manganese sulphate @ 0.6 per cent at flowering and seed setting noticeably improved the yield components and grain yield by 75.1 per cent over control in commonbean on loamy sand soils of Tabriz, Iran.

Soil application of 40 kg zinc sulphate ha⁻¹ resulted in higher grain (1587kg ha⁻¹) and stover yield (2047 kg ha⁻¹) in cowpea, which was 51.69 and 51.13 per cent higher over no zinc application during *kharif* on clay soils of Junagadh, Gujarat (Chavan *et al.*, 2012).

Foliar application of zinc sulphate @ 0.1 per cent alone or in combination with urea @ 1 per cent enhanced the seed yield in mungbean during summer season on clay soils of Cairo, Egypt (Ezzat *et al.*, 2012).

Girish *et al.* (2012) reported that foliar application of 0.1 per cent ZnSO₄ at flowering enhanced the boldness, vigour, zinc content of the seed and seed yield in chickpea.

Shittu and Ogunwale (2012) revealed that during rainy season P-Zn interactions had significant effects on the grain yield of soybean and the best combination was soil application of 30 kg P ha⁻¹ and 2 kg Zn ha⁻¹ during both years of study on sandy loam soils of Ilorin, Nigeria.

Babu *et al.* (2012) reported that soil application of zinc sulphate @ 20 kg ha⁻¹ at the time of sowing resulted in increased seed and stalk yield in pigeonpea on sandy loam soils of Raichur, Karnataka.

Ali and Adel (2013) reported that seed yield of mungbean was increased with spraying of 150 ppm of salicylic acid and 500 ppm zinc during summer season on sandy soils of Libya, Egypt.

Nalini *et al.* (2013) revealed that foliar application of zinc @ 0.1 per cent had a positive impact on seed yield of blackgram on sandy soils at Lucknow.

According to Puniya *et al.* (2013), higher grain yield was recorded with soil application of 5 kg zinc ha⁻¹ along with foliar application of zinc @ 0.5 per cent at 25 and 45 days after sowing in mothbean on loamy sand soils of Jobner, Rajasthan.

Application of 40 kg S and 10 kg Zn ha⁻¹ resulted in significantly higher seed yield in mungbean during summer season on silty loam soils of Faizabad, Uttar Pradesh (Ram and Katiyar, 2013).

Soil application of 5.5 kg zinc sulphate ha⁻¹ along with foliar application of zinc sulphate @ 0.1 % recorded significantly higher seed yield in greengram (Debroy *et al.*, 2014).

Shivay *et al.* (2014) noticed that foliar application of 2 or 3 sprays of zinc sulphate hepta hydrate (ZnSO₄.7H₂O) @ 5 kg Zn ha⁻¹ and Zn-EDTA @ 2.5 kg Zn ha⁻¹ resulted in significantly higher seed yield over single spray or their soil application in chickpea during winter season on sandy clay-loam soils at New Delhi.

Meena and Jat (2016) recorded the maximum seed and stover yield with the application of Zn @ 20 kg ha⁻¹ in cluster bean compared to control on sandy loam soil at Rajasthan.

Debnath *et al.* (2018) recorded higher grain yield in cowpea with application of RDF + 1.5 kg B ha⁻¹ + 5 kg Zn ha⁻¹ on sandy loam soil of Arunachal Pradesh.

2.2.4 Quality

Experiment conducted by Nasri *et al.* (2011) on sandy soils at Varamin, Iran, revealed that soil application of nitrogen @ 300 kg ha⁻¹ and potassium @ 120 kg ha⁻¹ along with foliar application of zinc @ 0.6 per cent in *Phaseolous vulgaris* significantly increased the zinc and nitrate per cent in the pod, carbohydrate percentage, carbohydrate yield, protein per cent, protein yield and chlorophyll content of leaf.

Nalini *et al.* (2013) reported that foliar application of zinc @ 0.1 per cent at pre flowering stage minimized the severity of zinc deficiency and enhanced the seed nutritional status by enhancing seed zinc content, seed carbohydrate (sugar and starch content) and storage proteins (albumins, globulins, glutenins and prolamines) in blackgram on sandy soils at Lucknow.

Rahdari *et al.* (2013) reported that protein content of soybean was increased with application of zinc @ 200 µM.

Application of 40 kg S ha⁻¹ and 10 kg Zn ha⁻¹ resulted in significantly higher protein content in mungbean during summer season on silty loam soils of Faizabad, Uttar Pradesh (Ram and Katiyar, 2013).

Soil application of 5.5 kg zinc sulphate ha⁻¹ along with foliar application of zinc sulphate @ 0.1 per cent recorded significantly higher seed crude protein content and which was 26.9 per cent higher over control in greengram (Debroy *et al.*, 2014).

Shivay *et al.* (2014) recorded significantly higher protein content with 2 or 3 foliar sprays of zinc sulphate hepta hydrate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) @ 5 kg Zn ha⁻¹ and Zn-EDTA @ 2.5 kg Zn ha⁻¹ over single spray or soil application in chickpea during winter season on sandy clay loam soils at New Delhi.

Muniswamy *et al.* (2018) recorded the highest protein content in greengram with the application of 25 kg N + 40 kg sulphur ha⁻¹ + 0.1 percent ZnSO_4 compared to control on sandy loam soil of Allahabad, Uttar Pradesh.

2.2.5 Zinc content

Foliar application of 0.1 % ZnSO_4 at flowering enhanced the zinc content in the chickpea seed (Girish *et al.*, 2012).

Zinc content in seed significantly increased with the soil application of nitrogen @ 300 kg ha⁻¹ and potassium @ 120 kg ha⁻¹ along with foliar application of zinc @ 0.6 per cent in *Phaseolous vulgaris* (Nasri *et al.*, 2011).

Nalini *et al.*, (2013) reported that foliar application of zinc @ 0.1 per cent at pre flowering stage minimized the severity of zinc deficiency and enhanced the seed nutritional status by enhancing zinc content in the seed of blackgram.

2.2.6 Nutrient uptake

Puste and Jana (1995) observed higher nitrogen and phosphorus uptake by seed due to application of 20 kg zinc sulphate ha⁻¹ in pigeonpea during winter season on sandy loam soils of Mohanpur, West Bengal.

Application of zinc @ 7.5 kg ha⁻¹ resulted in increased uptake of manganese, zinc and copper along with N, P and K in soybean on clay soils of Rahuri, Maharashtra (Kanase *et al.*, 2008).

Chavan *et al.* (2012) stated that application of 40 kg zinc sulphate ha⁻¹ increased the uptake of N, P, K and Zn in cowpea during *kharif* on clay soils of Junagadh, Gujarat.

Shivay *et al.* (2014) recorded significantly increased nitrogen uptake with the foliar application of zinc sulphate hepta hydrate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) @ 5 kg Zn ha⁻¹ and Zn-EDTA @ 2.5 kg Zn ha⁻¹ over single spray or soil application in chickpea.

2.3 INTERACTION OF POTASSIUM AND ZINC

2.3.1 Growth Parameters

Foliar application of DAP (2 %) + KCl (1 %) + ZnSO_4 (0.5 %) at 15, 30 and 45 DAS recorded higher plant height, leaf area index, number of branches plant⁻¹ over control in greengram during summer season on clay loam soils of Madhurai, Tamilnadu (Krishnaveni *et al.*, 2004).

Shittu and Ogunwale (2012) observed that plant height, leaf area and number of branches were significantly higher with soil application of 30 kg P ha⁻¹ and 2 kg Zn ha⁻¹ at 4 and 8 weeks after planting in soybean during rainy season on sandy loam soils of Ilorin, Nigeria.

Gowthami and Rao (2014) opined that foliar application of 2 per cent of potassium nitrate + 50 ppm of boric acid + 1 per cent zinc sulphate at 30 and 60 DAS significantly increased the plant height, leaf area, number of branches and total dry matter in soybean on clay loam soils of Bapatla, Andhra Pradesh.

2.3.2 Yield Attributes

Krishnaveni *et al.* (2004) stated that with foliar application of DAP (2 %) + KCl (1 %) + ZnSO_4 (0.5%) at 15, 30 and 45 days after sowing recorded higher pods plant⁻¹, pod length and 100 seed weight was resistance in greengram during summer on clay loam soils of Madhurai, Tamilnadu.

Higher test weight was observed in soybean with foliar application of 2 per cent of potassium nitrate + 50 ppm of boric acid + 1 per cent zinc sulphate at 30 and 60 DAS on clay loam soils of Bapatla, Andhra Pradesh. (Gowthami and Rao, 2014).

2.3.3 Yield

Chavan *et al.* (2012) reported that soil application of 40 kg zinc sulphate ha⁻¹ and 60 kg K₂O ha⁻¹ in cowpea resulted in significantly higher grain (1587 kg ha⁻¹) and stover yields (2047 kg ha⁻¹) during *kharif* on clay soils of Junagadh, Gujarat.

Shittu and Ogunwale (2012) opined that P-Zn interactions had significant effects on the grain yield of soybean and the best combination was soil application of 30 kg P and 2 kg Zn ha⁻¹ for two consecutive years during rainy season on sandy loam soils of Ilorin, Nigeria.

Gowthami and Rao (2014) opined that foliar application of 2 per cent potassium nitrate + 50 ppm of boric acid + 1 per cent zinc sulphate at 30 and 60 DAS significantly increased the seed yield in soybean on clay loam soils of Bapatla, Andhra Pradesh.

2.3.4 Quality

Soil application of 60 kg K₂O along with 40 kg ZnSO₄ ha⁻¹ resulted in higher protein content in grain of cowpea during *kharif* on clay soils of Junagadh, Gujarat (Chavan *et al.*, 2012).

2.4 SOIL FACTORS INFLUENCING THE AVAILABILITY OF POTASSIUM AND ZINC

2.4.1 Potassium

Soil texture is one of the important factors influencing K availability. The recommended K fertilizer rates are usually higher for coarse textured soils than fine textured soils (Doll and Lucas, 1973).

Soils with heavy texture are higher in potassium bearing minerals and therefore generally contain higher reserves of available potassium (Chakrabarti, and Mukherji, 2002).

Sinivasarao *et al.* (2003) reported that exchangeable and non exchangeable K was low in light textured red and lateritic soils with kaolinite as the dominant clay mineral.

Potassium status of soils varies considerably depending on parent material, texture and management practices. In general, black soils with smectite as dominant clay mineral have higher cation exchange capacity and exchangeable and medium to high levels of non exchangeable K. Light textured alluvial soils with higher contents of K rich mica have moderate levels of exchangeable K and high levels of non exchangeable K (Sinivasarao *et al.*, 2003).

2.4.2 Zinc

High soil pH and low organic matter content caused zinc deficiency thereby reduced absorption and uptake of zinc in the dry regions of the world (Marschner, 1993).

Zinc deficiency mainly occur in sandy soils, with low organic matter content. Zinc deficiency is also noticed in the soils derived from parent material having low zinc and also in clay soils with high magnesium levels (Singh *et al.*, 2011).

Zinc deficiency is more frequently observed in sandy soils with low organic matter content and also in saline, alkali and calcareous soils, particularly in semi arid areas (Jat *et al.*, 2012).

Chapter - III

Material and Methods

Chapter – III

MATERIAL AND METHODS

A field experiment was conducted to study the “Productivity and quality of greengram (*Vigna radiata* L.) as influenced by potassium and zinc nutrition” during *kharif*, 2018. The material used and the methods employed during the course of investigation are presented in this chapter.

3.1 LOCATION OF THE EXPERIMENTAL SITE

The field experiment entitled “Productivity and quality of greengram (*Vigna radiata* L.) as influenced by potassium and zinc nutrition” was conducted during *kharif*, 2018 at S.V. Agricultural College dryland farm, Tirupati campus of Acharya N.G. Ranga Agricultural University, which is geographically situated at 13.5°N latitude and 79.5°E longitude, with an altitude of 182.9 m above the mean sea level, which falls under Southern Agro-Climatic Zone of Andhra Pradesh and according to Trolls classification, it falls under Semi-Arid Tropics (SAT).

3.2 WEATHER DURING THE CROP PERIOD

Weather data during the crop period, recorded at S.V. Agricultural College Meteorological Observatory, Tirupati is presented in Table 3.1 and depicted in Fig. 3.1.

The weekly mean maximum temperature during the crop period (13-07-2018 to 9-10-2018) ranged from 31.9°C to 37.2°C, with an average of 34.5°C, while the decennial mean maximum temperature for the corresponding period ranged from 33.3°C to 35.3°C with an average of 34.3°C. The weekly mean minimum temperature ranged from 22.4°C to 27.6°C with an average of 25.0°C, whereas the decennial weekly mean minimum temperature for the corresponding period ranged from 23.2°C to 25.8°C, with an average of 24.5°C.

The weekly mean relative humidity during the crop period ranged from 48.8 to 75.6 per cent, with an average of 62.2 per cent, while the decennial mean relative humidity for the corresponding period ranged from 51.9 to 67.5 per cent, with an average of 59.7 per cent. The weekly mean sunshine hours per day during the crop period ranged from 1.9 to 7.8, with an average of 3.95, whereas the decennial mean sunshine hours for the corresponding period ranged from 3.5 to 5.2, with an average of 4.3 hours per day.

During the crop growth period, total amount of 281.8 mm of rainfall was received in 18 rainy days as against the decennial average of 429.3 mm received in 25 rainy days for the corresponding period.

During the crop growth period, the evaporation (USWB Class-A open pan evaporimeter) ranged from 3.8 to 7.0 mm day⁻¹, with an average of 5.35 mm day⁻¹, whereas the decennial mean for the corresponding period ranged from 4.15 to 6.95 mm day⁻¹, with an average of 5.5 mm day⁻¹.

3.3 SOIL CHARACTERISTICS OF THE EXPERIMENTAL SITE

The initial soil samples were collected at random from 0-30 cm depth from the experimental field and the composite soil sample was analyzed for different physico-chemical properties. The results along with the methods employed for each of them are presented in Table 3.2.

The results of physico-chemical properties revealed that the soil was sandy loam in texture, low in organic carbon, available nitrogen, potassium and zinc and medium in available phosphorus.

Table 3.1. Standard week wise meteorological data during the crop growth period of greengram (13-07-2018 to 09-10-2018)

Standard week	Date and Month	Temperature (°C)				Relative humidity (%)		Rainfall (mm)		Number of rainy days		Evaporation (mm day ⁻¹)		Bright sunshine (hours day ⁻¹)	
		Maximum		Minimum		A	DN	A	DN	A	DN	A	DN	A	DN
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
28	09 July - 15 July	34.7	0.41	26.6	0.75	55.75	-11.52	5.20	-22.14	1	-1	6.0	-1.05	3.3	-0.85
29	16 July - 22 July	36.6	1.72	26.4	0.84	52.20	-15.31	0.00	-24.17	0	-2	7.0	0.84	3.8	0.27
30	23 July - 29 July	36.9	1.9	26.6	1.16	50.15	-15.21	0.00	-25.42	0	-2	6.8	0.52	6.9	2.63
31	30 July - 05 Aug.	37.2	2.47	27.6	1.72	51.40	-13.46	2.60	-5.84	1	0	7.0	1.05	4.2	0.59
32	06 Aug. - 12 Aug.	34.3	-1.01	27.4	1.77	59.50	-3.14	10.0	-14.29	1	-1	5.9	-0.47	1.9	-2.49
33	13 Aug. - 19 Aug.	33.1	-0.89	25.4	0.71	60.75	0.44	12.0	-37.17	1	-2	4.4	-0.79	2.0	-2.14
34	20 Aug. - 26 Aug.	36.0	2.17	26.8	2.05	49.90	-2.85	1.00	-51.67	0	-2	6.9	1.81	3.8	-1.17
35	27 Aug. - 02 Sep.	35.5	1.83	24.9	0.53	60.65	4.06	45.0	16.35	2	0	5.8	1.18	4.4	0.44
36	03 Sep. - 09 Sep.	36.4	2.92	25.9	1.55	48.80	-11.52	12.0	-27.66	1	-1	6.6	1.54	7.8	3.64
37	10 Sep. - 16 Sep.	34.9	1.53	24.4	0.08	50.75	-7.05	99.6	73.42	4	2	5.0	0.62	5.2	0.57
38	17 Sep. - 23 Sep.	31.9	-2.05	25.1	0.54	71.25	14.24	53.8	31.30	3	2	3.8	-1.32	2.6	-2.50
39	24 Sep. - 30 Sep.	34.9	0.75	24.6	0.06	66.15	11.18	4.00	-26.21	1	-1	5.1	0.34	7.2	2.22
40	01 Oct. - 07 Oct.	32.0	-1.3	24.0	0.69	75.65	20.94	12.8	-28.59	1	-1	4.2	-0.18	5.2	-0.02
41	08 Oct. - 14 Oct.	35.1	1.59	22.4	-0.84	65.60	13.7	23.8	-5.42	2	0	5.3	1.26	5.9	0.78

A : Actual; DN : Deviation from normal (decennial mean)

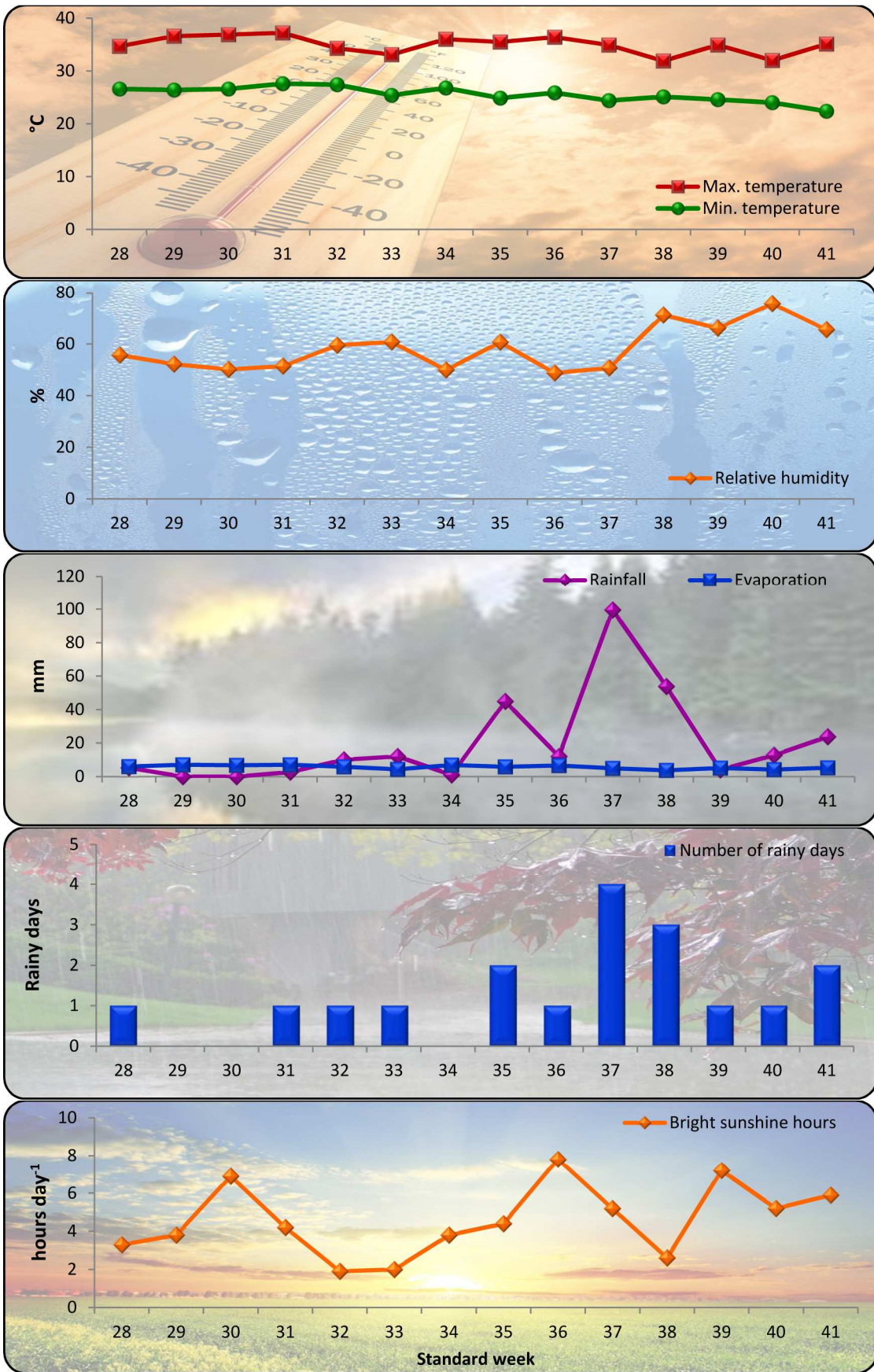


Fig 3.1. Standard week wise meteorological data during the crop growth period of greengram (13-07-2018 to 09-10-2018).

Table 3.2. Physico-chemical properties of the soil of the experimental field

Particulars	Value	Method
I. Physical characteristics		
Coarse sand (%)	61.2	Bouyoucos Hydrometer (Piper, 1950)
Fine sand (%)	23.3	
Silt (%)	6.0	
Clay (%)	9.5	
Soil texture	Sandy loam	
II. Chemical characteristics		
Soil pH (1: 2.5 soil water suspension)	6.9	Glass electrode pH meter (Jackson, 1973)
Electrical Conductivity (dS m ⁻¹)	0.18	Conductivity bridge (Jackson, 1973)
Organic carbon (%)	0.44	Wet digestion method (Walkley and Black, 1934)
Available N (kg ha ⁻¹)	152.5	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P ₂ O ₅ (kg ha ⁻¹)	20.5	Olsen's method (Olsen <i>et al.</i> , 1954)
Available K ₂ O (kg ha ⁻¹)	135.4	Flame photometry (Jackson, 1973)
Available Zn (kg ha ⁻¹)	1.04	Atomic Absorption Spectrophotometer (Tandon, 1993)

3.4 CROPPING HISTORY OF THE EXPERIMENTAL FIELD

Details of the crops grown during the four years preceding the present investigation are given below.

Year	<i>Kharif</i>	<i>Rabi</i>	Summer
2014-15	Groundnut	Groundnut	Fallow
2015-16	Groundnut	Greengram	Fallow
2016-17	Groundnut	Greengram	Greengram
2017-18	Cowpea	Fallow	
2018-19	Present experiment	-	-

3.5 EXPERIMENTAL DETAILS

3.5.1 Design and Layout

The experiment was laid out in a randomized block design consisting of eight treatments with three replications. The layout plan is furnished in the Fig. 3.2.

3.5.2 Treatments

- T₁ : Control (No fertilizer application)
T₂ : Recommended Dose of Fertilizers (*RDF)
T₃ : RDF + 40 kg K₂O ha⁻¹
T₄ : RDF + 25 kg ZnSO₄ ha⁻¹
T₅ : RDF + 40 kg of K₂O ha⁻¹ + 25 kg of ZnSO₄ ha⁻¹
T₆ : RDF + Foliar application of KNO₃ @ 1 % at flower bud initiation stage
T₇ : RDF + Foliar application of ZnSO₄ @ 0.2 % at flower bud initiation stage
T₈ : RDF + Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage

*RDF = 20 - 50 - 0 kg N, P₂O₅ and K₂O ha⁻¹
(KNO₃: 13-0-45)

3.5.3 Plot Size and spacing

Gross plot : 5.4 m × 4.0 m

Net plot : 4.2 m × 3.6 m

Spacing : 30 cm × 10 cm

3.5.4 Variety

The test variety used in the experiment was IPM 2-14, developed from Indian Institute of Pulse Research, Kanpur, Uttar Pradesh. It matures in about 60-70 days during *kharif*. Moderately tolerant to yellow mosaic virus with a yield potential of 15 to 19 q ha⁻¹ in *kharif*.

3.6 CULTIVATION DETAILS

3.6.1 Field Preparation

The experimental field was prepared for sowing by working twice with a tractor drawn cultivator followed by blade harrow. The land was finally leveled with a wooden plank and the plots were laid out as per the layout plan.

3.6.2 Seeds and Sowing

Healthy, well matured and viable seeds of greengram treated with Mancozeb @ 3.0 g kg⁻¹ seed, were used for sowing. Sowing was carried out on 13-07-2018 by dibbling with hand at a depth of 5 cm, with a spacing of 30 cm between the rows and 10 cm between the plants within the row.

3.6.3 Thinning and Gap Filling

The excess seedlings were uprooted, keeping one healthy seedling hill⁻¹ and gap filling was done at each hill, where seeds failed to germinate on 8th day after sowing to maintain the optimum plant population.

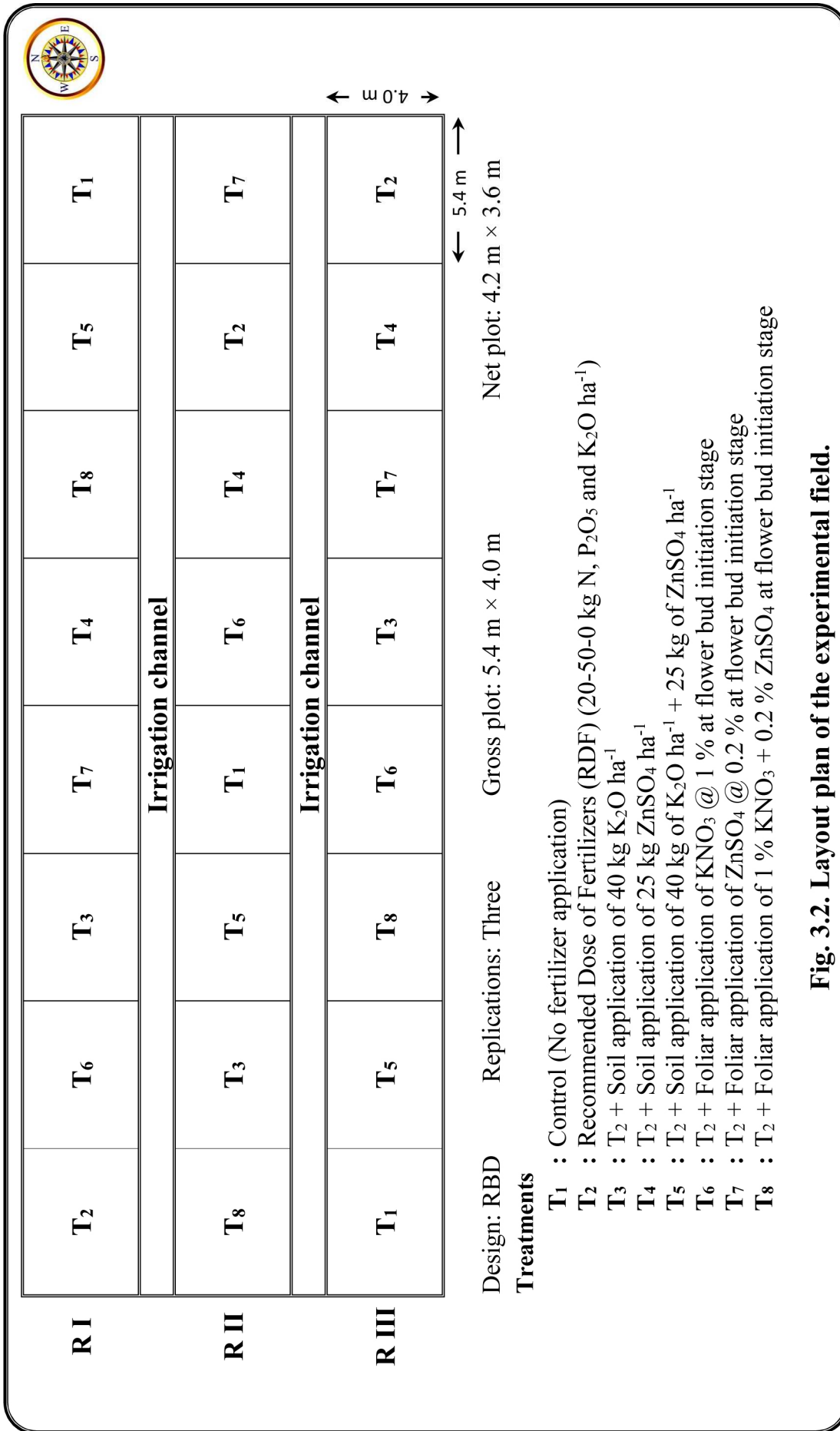


Fig. 3.2. Layout plan of the experimental field.

3.6.4 Fertilizers

The crop was supplied with nutrients as per treatments. Nitrogen was applied through urea, phosphorus through single super phosphate and potassium through muriate of potash and potassium nitrate and zinc through zinc sulphate. Entire dose of nitrogen, phosphorus and soil application of potassium in the respective treatments were applied basally by placement method *i.e.* 5 cm apart by the side of seed rows at a depth of 5 cm at the time of sowing.

3.6.5 Time and Method of Application of Foliar Sprays

Potassium nitrate (13-0-45) @ 1 % (10 g l⁻¹ of water) and Zinc sulphate (ZnSO₄) containing 1 % of zinc @ 0.2 % (2 g l⁻¹ of water) were applied as foliar sprays at flower bud initiation stage as per the treatments.

3.6.6 Weeding

For weed management pendimethalin @ 1.0 kg *a.i.* ha⁻¹ was sprayed as a pre-emergence application on the second day after sowing. Hand weeding was done at 17 DAS to keep the crop free from weeds.

3.6.7 Plant Protection

The crop was not sprayed with any plant protection measures as we have not observed any pest or diseases to the extent to cause the yield loss.

3.6.8 Irrigation

A total of three irrigations were given *i.e.* one post sowing irrigation with sprinklers, second irrigation at flower bud initiation and third irrigation at pod formation stage of the crop.

3.6.9 Harvesting and Threshing

The crop was considered to be matured, when more than 75 per cent of the pods of randomly selected plants had attained black colour in the net plot. The border two rows were harvested first followed by the plants in the net plot

was harvested separately. The pods were picked from the net plot and dried under the sun thoroughly to a constant weight. A total of two pickings were taken up in the net plot area. The pods and haulms obtained from each net plot area were recorded separately and expressed as kg ha⁻¹.

3.7 BIOMETRIC OBSERVATIONS RECORDED

For recording the growth characters and yield attributes, five plants in net plot were randomly selected and labeled with tags and observations were recorded throughout the crop growth period.

3.7.1 Growth Parameters

3.7.1.1 Initial and final plant population

The initial plant population was recorded from the net plot area after 15 DAS and the final plant population before harvesting in the respective treatment and expressed as number of plants m⁻².

3.7.1.2 Plant height

Plant height was measured from the base of the plant to the top most growing point at 15, 30, 45 days after sowing and at harvest and the mean value was expressed in centimeters (cm).

3.7.1.3 Leaf area index

Leaf area from five destructive sampled plants was measured at 15, 30, 45 days after sowing and at harvest using the LI-COR Model LI-3100C leaf area meter with transparent conveyor belt having electronic digital display and expressed in cm². Leaf area index was calculated by dividing the total leaf area with the corresponding land area as suggested by Watson (1952).

$$\text{Leaf Area Index (LAI)} = \frac{\text{Total leaf area}}{\text{Unit land area}}$$

3.7.1.4 Dry matter production

Five plants were uprooted at 15, 30, 45 DAS and at harvest from the destructive sampling area, leaving the extreme border row. The plant samples were dried under sun initially and later dried in hot air oven at 60°C to a constant weight. Then dry weight of all the five plants was taken and dry matter production per hectare was worked out and expressed as kg ha⁻¹.

3.7.2 Yield Parameters and Yield

3.7.2.1 Number of branches plant⁻¹

For the five plants that were labelled from each net plot area at harvest, the total number of branches including those which were developed into pods were counted and average number of branches plant⁻¹ was worked out.

3.7.2.2 Number of pods branch⁻¹

Total number of pods from pod bearing branches of five randomly selected plants in each plot was counted, averaged and expressed as number of pods branch⁻¹.

3.7.2.3 Number of seeds pod⁻¹

The number of seeds per pod from five randomly selected pods was counted, averaged and expressed as number of seeds pod⁻¹.

3.7.2.4 Test weight (g)

Thousand seeds were randomly drawn from the composite sample of seed yield from each of the net plot area, weighed and expressed as test weight in g.

3.7.2.5 Seed yield

Seed yield obtained from each net plot area was sun dried, cleaned thoroughly, weighed and expressed as kg ha⁻¹.

3.7.2.6 Haulm yield

Haulm yield obtained from each net plot area was thoroughly sun dried, until a constant weight and expressed as kg ha⁻¹.

3.8 GRAIN QUALITY PARAMETERS

The grain samples collected at harvest were ground into fine powder and analyzed for assessing the different quality parameters.

3.8.1 Protein Content (%)

Total protein of the seeds from different treatments was determined by the method suggested by Lowry's *et al.* (1951).

3.8.2 Zinc Content

Zinc content of the seeds from different treatments was determined by Atomic absorption spectrophotometer (Tandon, 1993).

3.9 PLANT ANALYSIS

For estimating nitrogen, phosphorus, potassium and zinc content, well dried plant samples collected for dry matter production were powdered and used for chemical analysis.

3.9.1 Nitrogen Uptake

Nitrogen content in dry matter was estimated by microkjeldahl method (AOAC, 1960). The nitrogen uptake was calculated by multiplying the nitrogen content (%) with respective dry matter yields and expressed in kg ha⁻¹.

3.9.2 Phosphorus Uptake

The tri-acid digested plant samples were analysed for phosphorus content by vanado-molybdo phosphoric acid yellow colour method (Jackson, 1973). The intensity of yellow colour developed was measured using spectronic-20 D. The uptake of phosphorus was calculated by multiplying the phosphorus content with the respective dry matter yields and expressed in kg ha⁻¹.

3.9.3 Potassium Uptake

Potassium content of the extract of tri-acid digested material was determined using ELICO flame photometer and uptake of potassium was estimated by multiplying the potassium content with the respective dry matter and presented in kg ha⁻¹.

3.9.4 Zinc Uptake

The estimation of zinc content was done by digesting the dried samples in di-acid mixture (HNO₃ : HClO₄) and then analysed by atomic absorption spectrophotometer (Tandon,1993). The uptake of zinc at harvest was expressed in g ha⁻¹.

3.10 ECONOMICS

The total cost of cultivation of greengram was calculated for all the treatments on the basis of inputs used. Gross returns were computed considering the prevailing market price of the output. Net returns were arrived by subtracting the cost of cultivation of respective treatments from gross returns for the corresponding treatments. Benefit-cost ratio was worked out by dividing gross returns with corresponding cost of cultivation of the respective treatments.

$$\text{Benefit: cost ratio} = \frac{\text{Gross returns (` ha}^{-1}\text{)}}{\text{Cost of cultivation (` ha}^{-1}\text{)}}$$

3.11 POST HARVEST SOIL NUTRIENT ANALYSIS

Initial composite soil samples were collected from the experimental area and were analyzed for soil organic carbon, available nitrogen, available phosphorus, available potassium and zinc.

After harvesting of greengram crop, soil samples were collected from each plot and analysed to find out the nutrient status, as detailed below:

3.11.1 Available Nitrogen

The available nitrogen in the soil was analyzed by alkaline permanganate method as detailed by Subbiah and Asija (1956).

3.11.2 Available Phosphorus

The available phosphorus status in the soil was analyzed by Olsen's method (Olsen *et al.*, 1954).

3.11.3 Available Potassium

The available potassium content in the soil was analyzed by Flame Photometry (Jackson, 1973).

3.11.4 Available Zinc

The available zinc in the soil was determined by using DTPA extract and expressed in mg kg⁻¹ of soil (Tandon, 1993).

3.12 STATISTICAL ANALYSIS

The data recorded on various growth, yield and quality parameters during the course of investigation were statistically analyzed following the analysis of variance procedure suggested by Panse and Sukhatme (1985). Statistical significance was tested by 'F' value at 5 per cent level of probability and wherever the 'F' value was found significant, critical difference (CD) was worked out at 5 per cent level of probability and the values were furnished. The treatmental differences those were non-significant were denoted as NS.

Chapter - IV

Results & Discussion

Chapter – IV

RESULTS AND DISCUSSION

The results of the field experiment entitled “**Productivity and quality of greengram as influenced by potassium and zinc nutrition**” carried out during *khariif*, 2018 on sandy loam soils of S.V. Agricultural College dryland Farm, Tirupati campus of Acharya N.G. Ranga Agricultural University are presented in this chapter. The experimental data was statistically analyzed, apportioned under various heads, sub heads and furnished in tables and illustrated wherever necessary. The results found in the present experiment were discussed critically with cause and effect relationship under following headings.

4.1 WEATHER

Crop growth is mainly dependent on environmental factors and fluctuations in weather conditions greatly influence it. The weekly mean maximum temperature during the crop period ranged from 31.9°C to 37.2°C, with an average of 34.55°C. The weekly mean relative humidity during the crop period ranged from 48.80 to 75.65 per cent, with an average of 62.22 per cent.

The total rainfall received during the crop growth period was 281.8 mm in 18 rainy days (Fig. 3.1). Maximum, minimum temperatures and relative humidity were by and large similar and congenial for the optimum performance of the crop. The insight into the prevailed weather conditions indicated that the weather variables were within the cardinal range so as to enable the crop to reasonably express the effect of imposed treatments.

4.2 GROWTH PARAMETERS

The bio-metric observations with regard to plant height, leaf area index and dry matter production were recorded at periodical intervals *viz.*, 15, 30, 45 DAS and at harvest.

4.2.1 Plant Height

Plant height measured at 15, 30, 45 DAS and at harvest was significantly influenced by soil and foliar application of potassium and zinc (Table 4.1 and Fig. 4.1). The plant height of greengram tended to increase progressively with advance in age of the crop upto harvest.

At 15 DAS, the tallest plants (9.77 cm) were produced with soil application of $K_2O @ 40 \text{ kg ha}^{-1} + 25 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ along with RDF (T₅), which was however comparable with soil application of $25 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ along with RDF (T₄) and $40 \text{ kg K}_2\text{O ha}^{-1}$ along with RDF (T₃). The plant height recorded with foliar application of potassium and zinc individually / in combination at flower bud initiation along with RDF and RDF alone were comparable among themselves (T₆, T₇, T₈ and T₂). The shortest plants (6.92 cm) were recorded in control (T₁).

At 30 DAS, application of RDF supplemented with soil application of $40 \text{ kg K}_2\text{O} + 25 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ (T₅), recorded the tallest plants (16.30 cm), which were on par with soil application of $25 \text{ kg ZnSO}_4 \text{ ha}^{-1}$ along with RDF (T₄) and soil application of $40 \text{ kg K}_2\text{O ha}^{-1}$ along with RDF (T₃), but were significantly superior to the treatments involving foliar application of potassium and zinc. Application of RDF (T₂) recorded the shorter plants, which was however comparable with foliar application of potassium and zinc individually / in combination at flower bud initiation along with RDF (T₆, T₇, and T₈), and significantly superior over control (T₁), which recorded the shortest plants (12.41 cm).

Table 4.1. Plant height of greengram at different growth stages as influenced by soil and foliar application of potassium and zinc

Treatments	Plant height (cm)			
	15 DAS	30 DAS	45 DAS	At harvest
T ₁ : Control (no fertilizers application)	6.92	12.11	18.51	22.41
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	8.11	13.50	22.03	25.68
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	9.49	15.46	24.00	28.74
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	9.58	15.80	24.53	29.61
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	9.77	16.30	26.63	32.08
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	8.41	13.72	24.31	28.98
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	8.39	13.63	25.13	30.27
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	8.36	13.54	26.80	32.17
SEm±	0.30	0.51	0.52	0.53
CD (P=0.05)	0.92	1.47	1.51	1.63

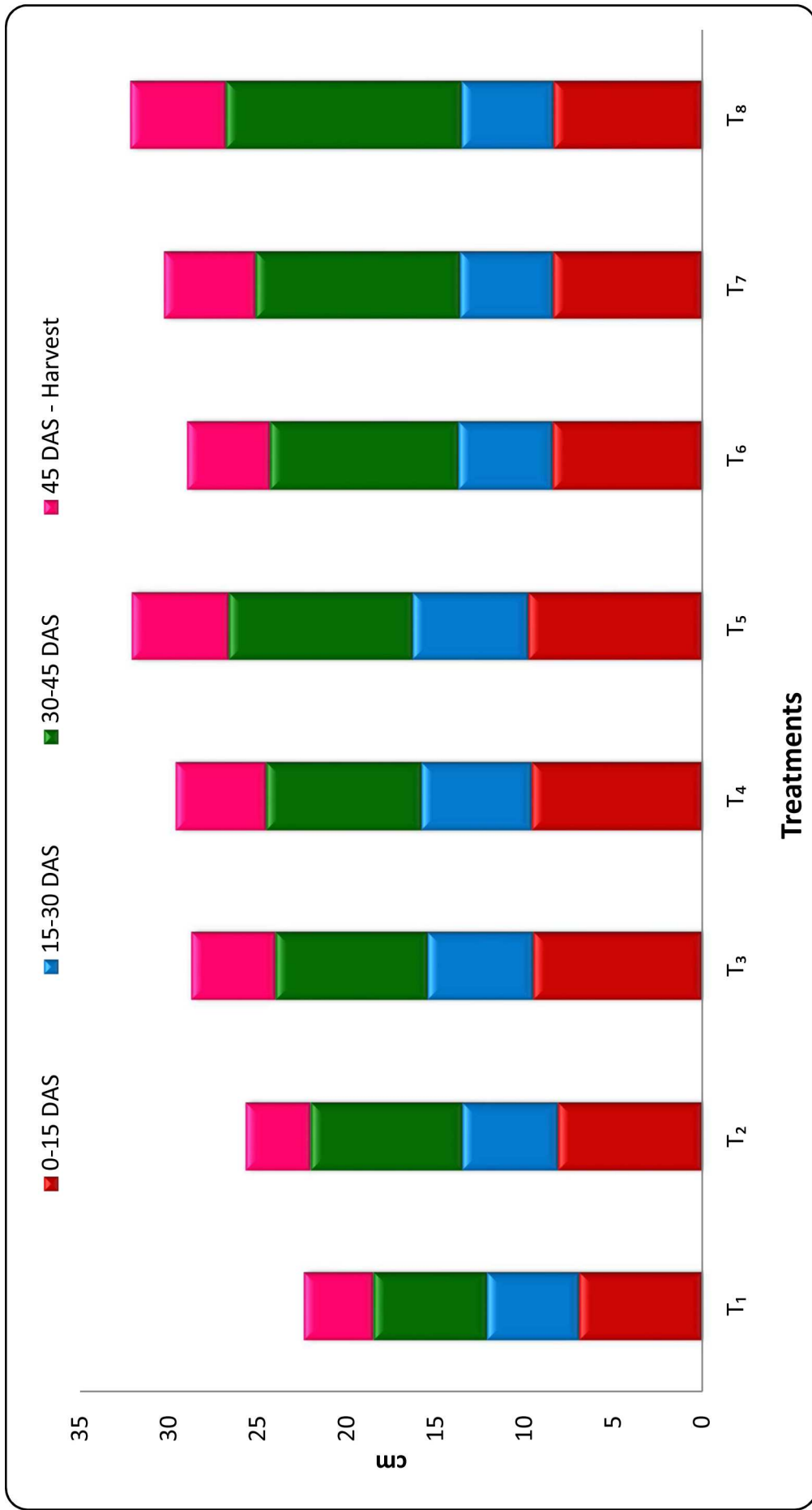


Fig 4.1. Plant height (cm) of greengram at different growth stages as influenced by soil and foliar application of potassium and zinc.

The increase in plant height with application of potassium could be partly attributed to the reason that potassium is known to augment cell division and cell expansion in plants by stimulating the biological activity of photosynthetic pigments and enzymes which in turn promotes the vegetative growth of the plant (Thalooth *et al.*, 2006). These results are inline with Hussain *et al.* (2011) and Ali *et al.* (1996), who observed significantly higher plant height in mungbean with application of 60-100-100 kg NPK ha⁻¹. Zinc is involved in tryptophan synthesis, tryptamine metabolism, protein synthesis, formation of nucleic acid and helps in absorption and efficient utilization of nitrogen as well as phosphorus by plants (Ram and Katiyar, 2013), zinc also promotes nodulation and nitrogen fixation in leguminous crops (Demeterio *et al.*, 1972). Similar results were reported by Togay *et al.* (2004) in bean and Thesiya *et al.* (2013) in blackgram.

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), recorded tallest plants (26.80 cm) in greengram, which was however comparable with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ (T₅), and significantly superior over the rest of the nutrient management practices. The next best treatment was foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) and soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), which were comparable among themselves and significantly superior over RDF (T₂) alone. Control (T₁) recorded the shortest plants at 45 DAS.

At harvest, the tallest plants (32.17 cm) were produced with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ (T₅), and significantly superior over the rest of the nutrient management practices. The highest plant height associated with T₈ and T₅ might be due to role of those nutrients in various physiological and

biochemical processes contributing to the growth of the meristematic region (Cakmak *et al.*, 1989). Zinc is involved in the biosynthesis of plant hormones by activating tryptophan, which is a precursor of indole acetic acid, which in turn promotes the vertical growth. The results were in harmony with the observations of Ali and Adel (2013) and Beg *et al.* (2013) in urdbean. The plant height recorded with foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), were comparable among themselves and were the next best treatments. This might be due to the fact that high root to shoot ratio was associated with potassium uptake (Yang *et al.*, 2004). Control (T₁) recorded the shortest plants at harvest due to non supply of nutrients.

4.2.2 Leaf Area Index

Leaf area index of greengram was significantly influenced by soil and foliar application of potassium and zinc at all the stages of crop growth (Table 4.2 and Fig. 4.2). Leaf area index in greengram tended to increase upto 45 DAS beyond which it was found slightly declined towards harvest due to senescence of lower leaves. Even though there was a decline in leaf area index after 45 DAS, the treatments which received foliar spray of potassium and zinc at flower bud initiation stage maintained higher leaf area index than the rest of the nutrient management practices due to delayed senescence.

At 15 DAS, maximum leaf area index (0.28) was recorded with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which was statistically on par with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and 40 kg K₂O ha⁻¹ along with RDF (T₃), but significantly superior to rest of the nutrient management practices. Foliar application of potassium and zinc individually / in combination at flower bud initiation along with RDF and RDF alone were comparable among themselves (T₈, T₇, T₆ and T₂). The lower leaf area index (0.08) was observed with control (T₁).

Table 4.2. Leaf area index of greengram at different growth stages as influenced by soil and foliar application of potassium and zinc

Treatments	Leaf area index			
	15 DAS	30 DAS	45 DAS	At harvest
T ₁ : Control (no fertilizers application)	0.08	1.10	1.96	1.71
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	0.15	1.24	2.21	1.96
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	0.23	1.75	2.39	2.10
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	0.27	1.78	2.43	2.14
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	0.28	1.82	3.09	2.30
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	0.15	1.26	2.41	2.40
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	0.16	1.29	2.45	2.44
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	0.16	1.31	3.18	2.99
SEm±	0.019	0.023	0.029	0.026
CD (P=0.05)	0.06	0.07	0.09	0.08

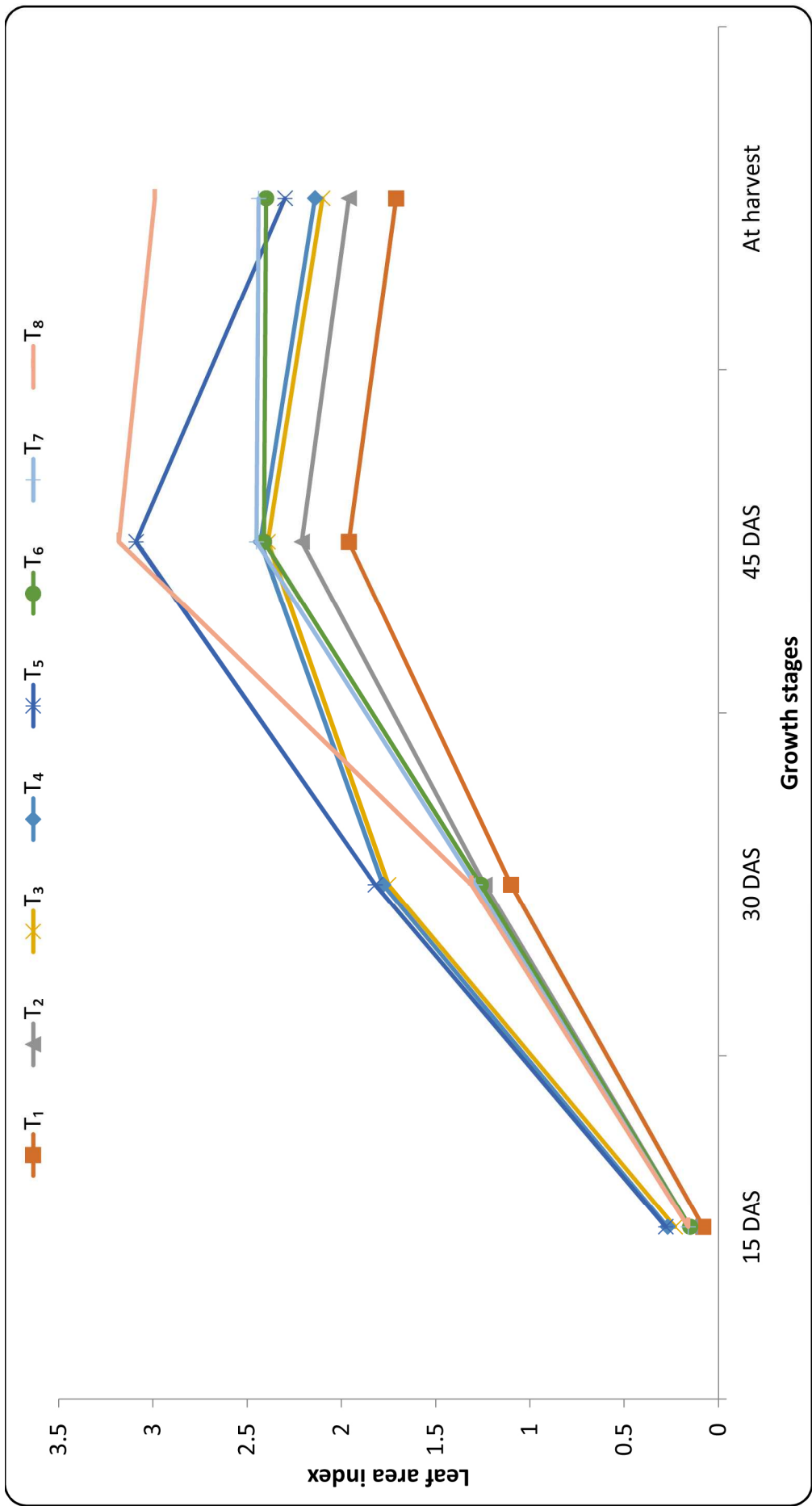


Fig. 4.2. Leaf area index (LAI) of greengram at different growth stages as influenced by soil and foliar application of potassium and zinc.

At 30 DAS, the highest values of leaf area index (1.82) was recorded with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which was however comparable with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and 40 kg K₂O ha⁻¹ along with RDF (T₃), but significantly superior over the rest of the nutrient management practices. The leaf area index recorded with nutrient management practices involving foliar application of potassium and zinc alone or in combination at flower bud initiation stage along with RDF and RDF alone were comparable among them (T₈, T₇, T₆, and T₂) were comparable with each other as the foliar application of potassium and zinc was done at 35 DAS *i.e.* at flower bud initiation stage. The lowest LAI values were recorded with control (T₁).

The increase in LAI with soil application of potassium and zinc at 15, and 30 days might be due to the role of potassium in augmenting cell division and cell expansion resulting in production of more number of larger leaves per plant as well as per unit area. The results are in agreement with those of Thesiya *et al.* (2013). Soil application of zinc improved the physicochemical properties of soil, which favourably increase the availability of nutrients and growth regulators such as gibberellins, kinetin, Indole-3-acetic acid, which enhances the ability of plant to cope up with adverse environment (Chakrabarti and Mukherji, 2002; Data *et al.*, 2004).

At 45 DAS, the highest values of leaf area index (3.18) was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ (T₅), and significantly superior over the rest of the nutrient management practices. The next best treatment were foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), which were comparable among themselves and significantly superior over RDF (T₂). Control (T₁) recorded the lowest LAI at 45 DAS.

At harvest, the maximum leaf area index (2.96) was recorded with foliar application of 1 % KNO₃ + ZnSO₄ @ 0.2 % at flower bud initiation stage along with RDF (T₈), which was significantly superior over the rest of the nutrient management practices. Foliar application of either ZnSO₄ @ 0.2 % (T₇) or 1 % KNO₃ at bud initiation stage along with RDF (T₆), were the next best treatments and were comparable among themselves, followed by soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ (T₅), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and soil application of 40 kg K₂O ha⁻¹ (T₃). The lowest leaf area index (1.71) was associated with control (T₁).

Higher LAI at harvest with foliar application of potassium and zinc at flower bud initiation stage along with RDF (T₈) was due to better absorption and translocation of foliar applied nutrients leading to delayed senescence and abscission. Foliar application of nutrients at the hour of need enable the plants to maintain higher chlorophyll content, leaf area per plant, leaf area index and decreasing the rate of senescence with T₈. As zinc is involved in the synthesis of IAA, which is a component of various enzymes, such as carbonic anhydrase and alcoholic dehydrogenase, which have a suggestive role in chlorophyll formation, photosynthesis and metabolic reactions in plants leading to high LAI. Zinc foliar application increases the tryptophan and indole acetic acid, which were the two main factors in leaf expansion (Seifinadergholi *et al.*, 2011). The above results were in conformity with those of Zayed *et al.*, 2011 and Thalooth *et al.* (2006) in mungbean and Shittu and Ogunwale (2012) in soybean.

4.2.3 Dry Matter Production

The dry matter production in greengram tended to increase progressively with advance in age of the crop up to harvest. Dry matter production was significantly influenced by soil and foliar application of potassium and zinc in greengram (Table 4.3 and Fig. 4.3).

At 15 DAS, soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅) recorded the highest dry matter accumulation (156 kg ha⁻¹),

which was on par with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and 40 kg K₂O ha⁻¹ along with RDF (T₃). The lowest dry matter accumulation (112 kg ha⁻¹) was associated with control (T₁).

The highest dry matter (652 kg ha⁻¹) was produced with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which was however comparable with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and 40 kg K₂O ha⁻¹ along with RDF (T₃) at 30 DAS. The dry matter recorded with foliar application of potassium and zinc alone or in combination at flower bud initiation stage along with RDF (T₈, T₇, T₆) and RDF (T₂) were comparable among themselves as foliar application was not done by the time of sampling *i.e.* at 30 DAS. The lowest dry matter production was observed with control (T₁).

The increase in dry matter accumulation with soil application of potassium and zinc at 15 and 30 DAS might be due to influence of potassium in water economy and crop growth through its effects on water uptake, root growth, maintenance of turgour, transpiration and stomatal behavior (Nelson, 1980; Hsiao and Lauchli, 1986). Zinc application helps in utilization of nitrogen as well as phosphorus by plants consequently activating the cell division and enlargement, which in turn results in higher photosynthetic efficiency owing to higher quantity of dry matter accumulation. The above results are in agreement with findings of Tohamy and Greadly (2007).

At 45 DAS, foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), recorded the highest dry matter accumulation (2151 kg ha⁻¹), which was however comparable with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), and significantly superior over the rest of the nutrient management practices. The next best treatments were foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF

Table 4.3. Dry matter production of greengram at different growth stages as influenced by soil and foliar application of potassium and zinc

Treatments	Dry matter production (kg ha ⁻¹)			
	15 DAS	30 DAS	45 DAS	At harvest
T ₁ : Control (no fertilizers application)	112	427	1390	2955
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	138	500	1595	3537
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	152	607	1790	3928
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	153	623	1829	4158
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	156	652	2098	4580
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	144	525	1810	3953
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	141	510	1900	4229
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	139	505	2151	4700
SEm±	2	18	40	104
CD (P=0.05)	6	56	122	320

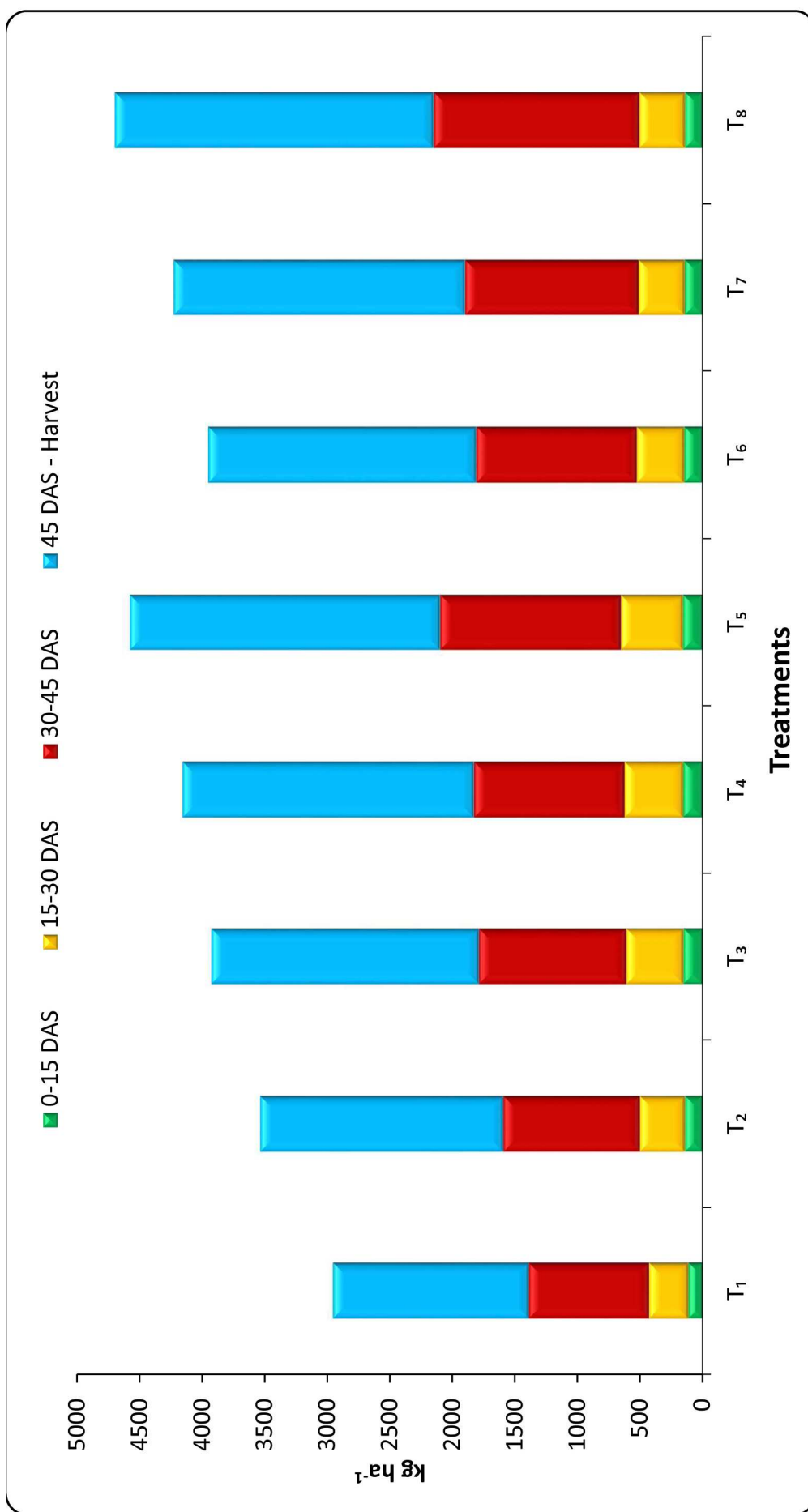


Fig. 4.3. Dry matter production (kg ha⁻¹) of greengram at different growth stages as influenced by soil and foliar application of potassium and zinc.

(T₃), which were comparable among themselves and significantly superior over RDF (T₂). Control (T₁) recorded the lower dry matter accumulation (890 kg ha⁻¹) at 45 DAS.

At harvest, the highest dry matter production (4700 kg ha⁻¹) was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was in parity with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅) and significantly superior over the rest of the nutrient management practices tried. The next best treatments were foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) and soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), which were comparable among themselves and significantly superior over RDF (T₂). The lowest dry matter production (2955 kg ha⁻¹) was associated with in control (T₁).

Higher dry matter production associated with T₈ might be due to the significant role of potassium in better root and shoot development, which increased N, P, K and Zn uptake and in turn increased dry matter production (Chavan *et al.*, 2012). Potassium works as a co-factor or activator of several enzymes involved in protein and carbohydrate metabolism thereby it enhances the efficiency of leaf in manufacturing sugars and starch (Beg *et al.*, 2013). The improvement in dry matter production with application of zinc was due to the fact that zinc is an essential component of several enzymes and plays an important role in nitrogen metabolism and higher uptake of nitrogen in plants, resulting in increased amino acid and protein synthesis in plant cell causing better growth. Zinc also helps in catalyzing various physiological processes and auxin synthesis in plants, which ultimately increased the growth parameters of the plant. The foliar application of potassium and zinc was more effective due to its higher uptake efficiency compared to soil application as they help in increased photosynthetic efficiency by delaying the leaf

senescence (Puniya *et al.*, 2013). Similar results were also reported by (Thalooth *et al.*, 2006) and (Shittu and Ogunwale, 2012) in soybean.

4.3 YIELD ATTRIBUTES

4.3.1 Number of Branches Plant⁻¹

The number of branches plant⁻¹ was significantly influenced by soil and foliar application of potassium and zinc in greengram (Table 4.4 and Fig. 4.4).

The highest number of branches plant⁻¹ (4.68) in greengram were recorded with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which was statistically on par with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and 40 kg K₂O ha⁻¹ along with RDF (T₃), but significantly superior to rest of the nutrient management practices. This might be attributed to the favorable influence of these nutrients on metabolism and its stimulating effect on photosynthetic pigments and enzymes which in turn encourage the number of branches plant⁻¹ (Michail *et al.*, 2004). Several workers like Sinha (1961), Kabir *et al.* (2004) and Musolf *et al.* (2004) also observed the positive effect of potassium in vegetative and reproductive growth of several crops. Zinc is a constituent of number of zinc finger proteins, which forms a structural motif of DNA binding region of the transcriptional regulatory proteins and plays an important role in reproductive development (Gamsjaeger *et al.*, 2007).

The number of branches recorded with foliar application of potassium and zinc individually / in combination at flower bud initiation along with RDF and RDF alone were comparable among themselves (T₈, T₇, T₆ and T₂). This might be due to the fact that number of branches plant⁻¹ was already formed by the time of imposing the foliar treatments *i.e.* at 36 DAS.

The lowest number of branches plant⁻¹ (3.15) were recorded with in control (T₁) due to non application of fertilisers.

Table 4.4. Number of branches plant⁻¹ and pods branch⁻¹ in greengram as influenced by soil and foliar application of potassium and zinc

Treatments	Number of branches plant ⁻¹	Number of pods branch ⁻¹
T ₁ : Control (no fertilizers application)	3.15	3.41
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	3.90	5.04
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	4.49	5.61
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	4.52	5.89
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	4.68	6.90
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	4.07	5.78
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	3.96	5.93
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	3.94	7.61
SEm±	0.11	0.26
CD (P=0.05)	0.33	0.80

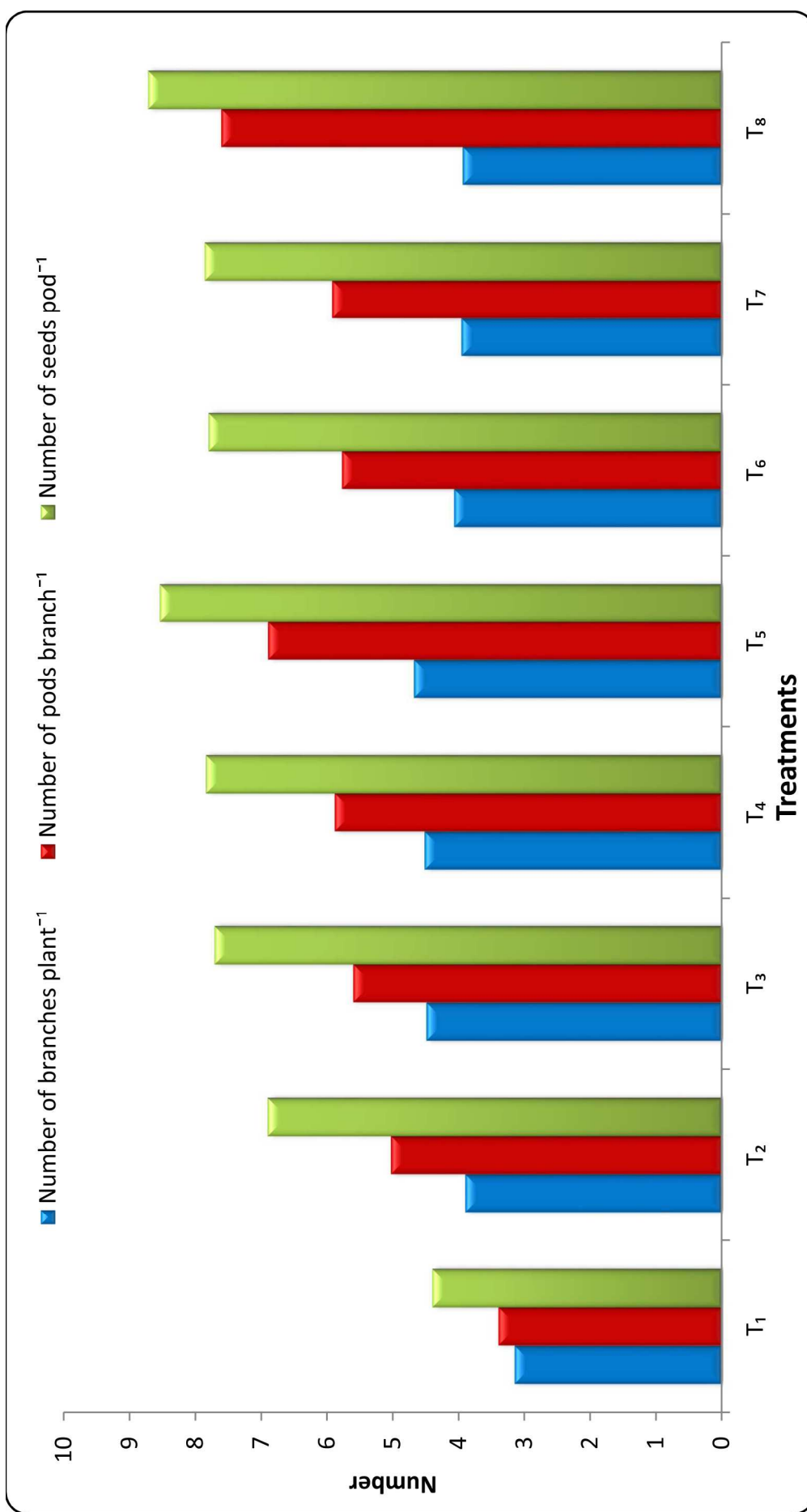


Fig. 4.4. Number of branches plant⁻¹, number of pods branch⁻¹ and number of seeds pod⁻¹ in greengram as influenced by soil and foliar application of potassium and zinc.

4.3.2 Number of Pods Branch⁻¹

The data on number of pods branch⁻¹ as influenced by soil and foliar application of potassium and zinc are presented in Table 4.4 and depicted in Figure 4.4. The number of pods branch⁻¹ was significantly altered by foliar application of potassium and zinc.

Significantly the highest number of pods branch⁻¹ (7.61) were recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however on par with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅). The number of pods branch⁻¹ recorded with foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), were comparable among themselves and significantly superior over RDF (T₂). This might be attributed to increased size of the source and consequently the enhanced partitioning of photosynthates towards newly formed sink. The increase in number of pods branch⁻¹ is due to the role of zinc on reproductive organs, such as stamens and pollen, which increases the number of flowers that can fertile well and as a result, more number of pods branch⁻¹ (Seifinadergholi *et al.*, 2011). Foliar spray of micronutrients considerably enhanced the number of pods branch⁻¹ (Zeidan *et al.*, 2006). The lowest number of pods branch⁻¹ (3.41) was recorded with control (T₁). This might be due to physiological effects of zinc deficiency in pollen function, fertilization and reproductive development of plants (Pandey *et al.*, 2010).

4.3.3 Number of Seeds Pod⁻¹

Soil and foliar application of potassium and zinc significantly altered the number of seeds pod⁻¹ (Table 4.4 and Figure 4.4).

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation and pod formation stage along with RDF (T₈) recorded significantly the

higher number of seeds pod⁻¹ (8.72), which was however comparable with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅). This might be ascribed to the role of potassium in enhancing the availability of other nutrients, carbohydrates redistribution and increased transportation of photosynthates, from source to sink and starch synthesis (Das and Sarkar, 1981 and Hussain *et al.*, 2011). Foliar application of zinc increased the number of seeds pod⁻¹ owing to increased length of flowering period (Banks, 2004). The next best treatments were foliar application of either 0.2 % ZnSO₄ or 1 % KNO₃ at flower bud initiation stage along with RDF (T₇, T₆) and soil application of 25 kg ZnSO₄ ha⁻¹ or 40 kg K₂O ha⁻¹ along with RDF (T₄, T₃) which in turn were comparable among themselves and significantly superior over RDF (T₂). The lowest number of seeds pod⁻¹ (4.4) was recorded with control (T₁) due to non supply of nutrients. The results were in accordance with those of Ghasemian *et al.* (2010) in soybean and Nasri *et al.* (2011) in *Phaseolus vulgaris*.

4.3.4 Test Weight

Test weight of greengram was significantly altered by soil and foliar application of potassium and zinc (Table 4.5 and Fig. 4.5).

Among the nutrient management practices, foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded significantly higher test weight (42.40 g), over the rest of the nutrient management practices tried. This might be due to role of zinc in effective absorption of nutrients by plants and translocation of assimilates more efficiently for development of grains there by proper filling as foliar application is a better way for supplying optimum nutrition for crop to complete its reproductive phases (Puniya *et al.*, 2013). The next best treatments were soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) and soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), which were comparable with each other. The results were in accordance

with those of Arif *et al.* (2006) who observed considerable enhancement in test weight by application of zinc. The lowest test weight was recorded with control (T₁), due to poor partitioning of photosynthates.

4.4 YIELD

4.4.1 Seed Yield

Seed yield of greengram was significantly influenced by soil and foliar application of potassium and zinc (Table 4.6, Figures 4.6 and 4.7).

The highest seed yield (1570 kg ha⁻¹) of greengram was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅) and significantly superior over the rest of the nutrient management practices (Plate 5 and 6).

Table 4.5. Number of seeds pod⁻¹ and test weight in greengram as influenced by soil and foliar application of potassium and zinc

Treatments	Number of seeds pod ⁻¹	Test weight (g)
T ₁ : Control (no fertilizers application)	4.4	36.00
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	6.90	39.21
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	7.71	40.01
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	7.84	41.07
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	8.54	41.30
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	7.80	40.04
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	7.86	41.14
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	8.72	42.40
SEm±	0.207	0.308
CD (P=0.05)	0.64	0.95

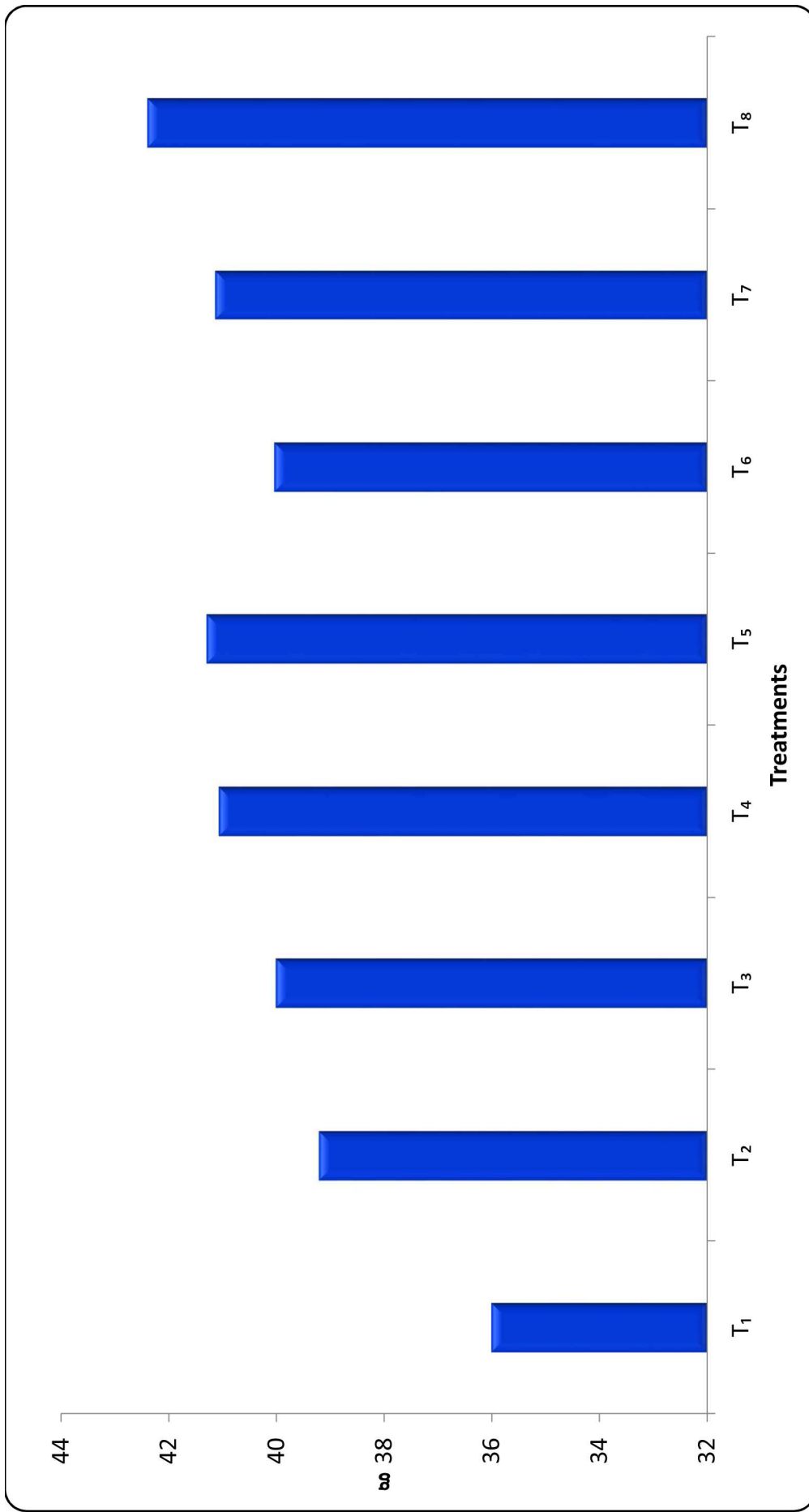


Fig. 4.5. Test weight (g) of greengram as influenced by soil and foliar application of potassium and zinc.

Table 4.6. Seed yield, haulm yield and harvest index of greengram as influenced by soil and foliar application of potassium and zinc

Treatments	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Harvest index (%)
T ₁ : Control (no fertilizers application)	612	1740	26.02
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	1195	2351	33.70
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	1322	2475	34.8
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	1359	2500	35.2
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	1545	2698	36.11
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	1340	2490	34.98
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	1380	2500	35.56
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	1570	2728	36.53
SEm±	39	55	
CD (P=0.05)	120	170	

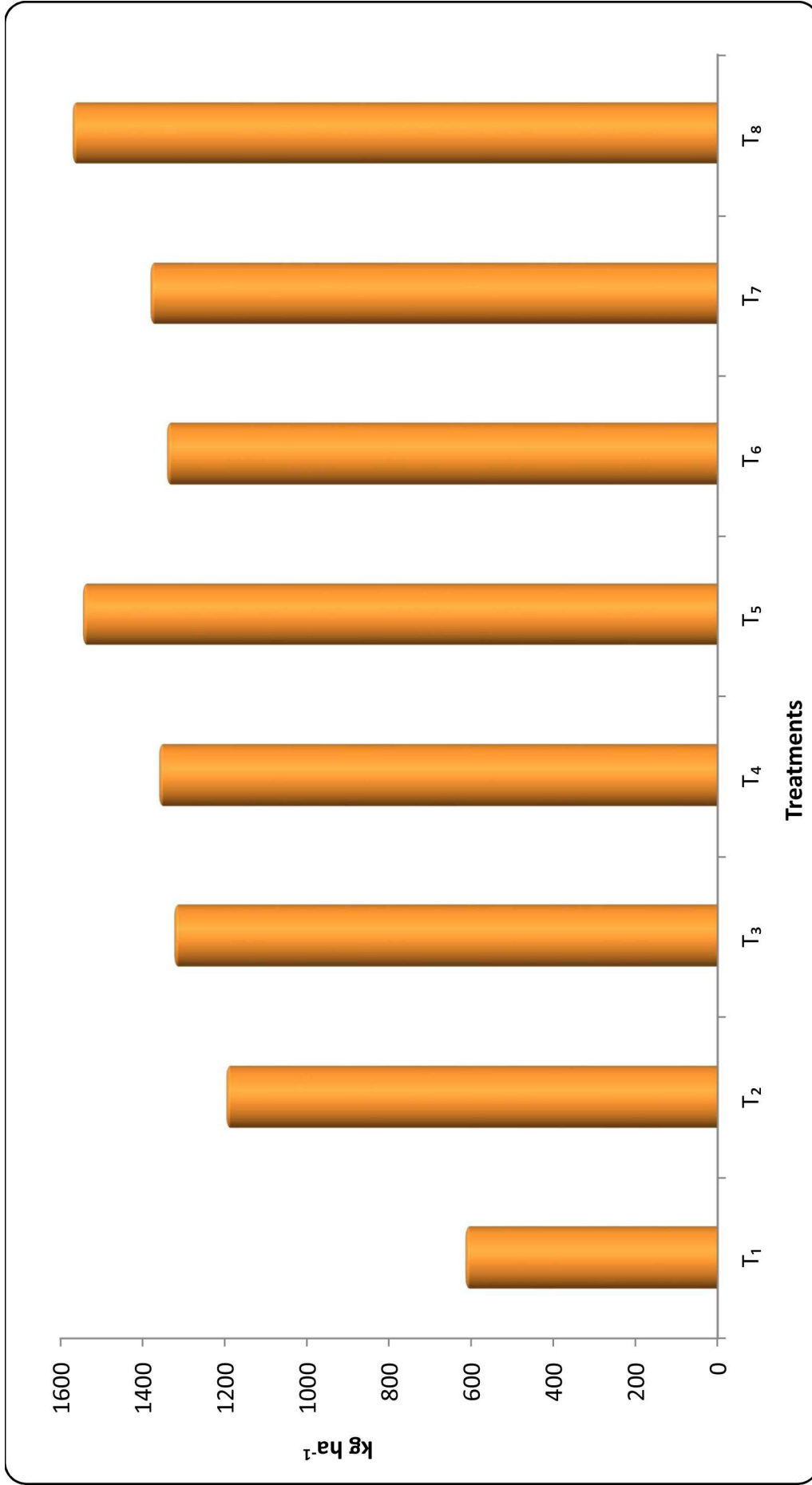


Fig. 4.6. Seed yield (kg ha⁻¹) of greengram as influenced by soil and foliar application of potassium and zinc.

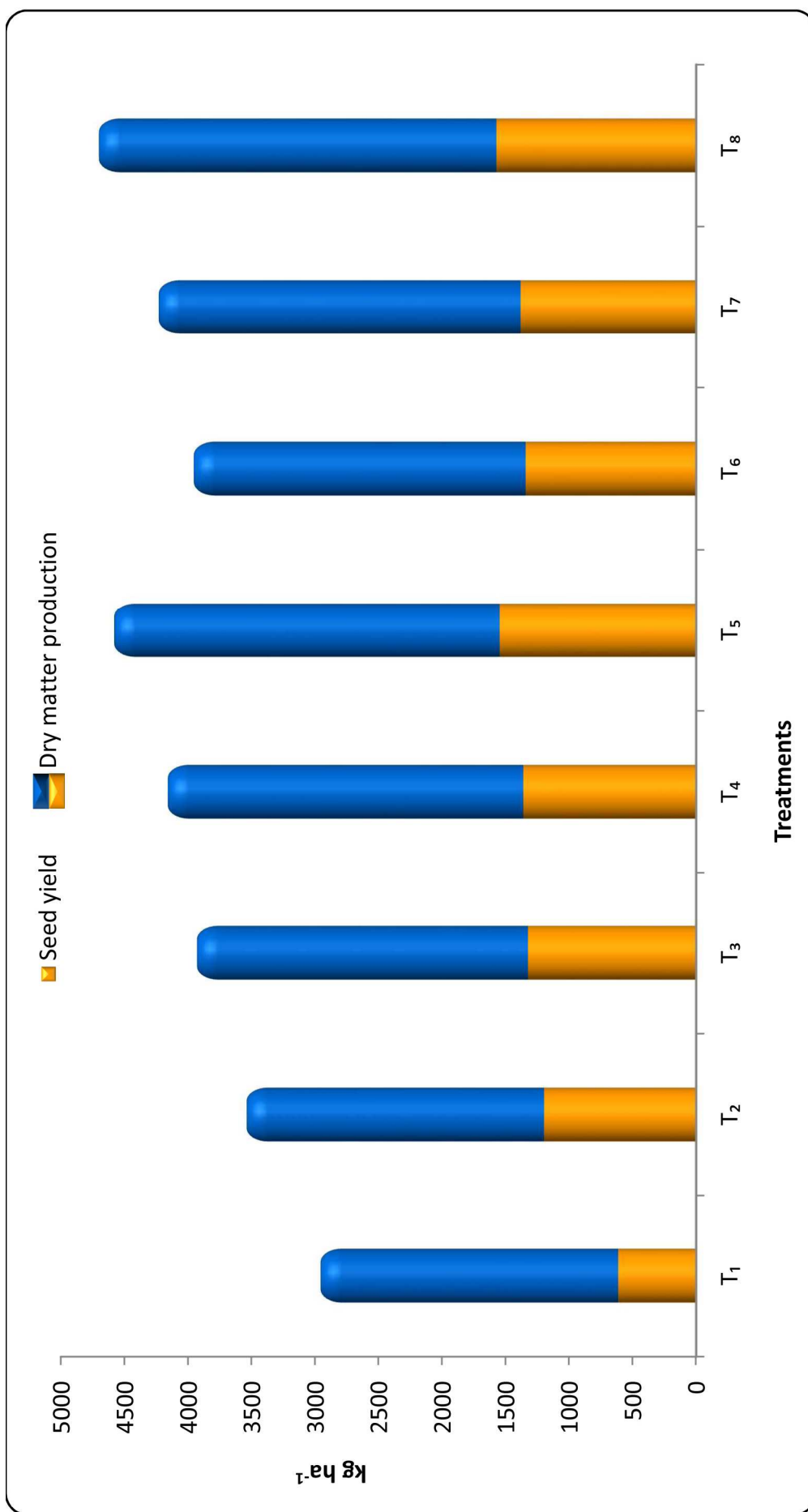


Fig. 4.7. Seed yield Vs Total dry matter production (kg ha⁻¹) of greengram as influenced by soil and foliar application of potassium and zinc.

Foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_8), and soil application of 40 kg K_2O + 25 kg of ZnSO_4 ha^{-1} along with RDF (T_5) resulted in 31.38 and 29.28 per cent higher seed yield compared to application of RDF (T_2). Seed yield of greengram is a function of yield attributes, which were significantly higher with this nutrient management practice. The increase in seed yield ascribed due to the reason that application of potassium along with zinc possibly increased the availability of N, P and K in soil solution and ultimately resulted in the vigorous root development, which promotes growth and development of the plant leading to higher photosynthetic activity, which in turn results in better development of yield attributes and finally higher seed yield (Chavan *et al.*, 2012). These results are corroborated with the findings of Yadav and Nand (2004). Similar results were also reported by Puste and Jana (1995) and Manoj (2015) in pigeonpea.

Foliar application of 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_7), soil application of 25 kg ZnSO_4 ha^{-1} along with RDF (T_4), foliar application of 1 % KNO_3 at flower bud initiation stage along with RDF (T_6) and soil application of 40 kg K_2O ha^{-1} along with RDF (T_3), were the next best treatments, which were comparable with each other and significantly superior over RDF (T_2).

Further, favorable effect of foliar application of potassium might be attributed to key role of potassium in phytomass production and pod filling particularly at post anthesis period and thereby increased photosynthetic activity and effective translocation of assimilates to reproductive parts resulting in more number of seeds pod^{-1} , test weight and higher seed yield (Mengal, 1976). Zinc has a direct influence on auxin production, which in turn enable the plant to produce more dry matter and consequently enhanced the partitioning of photosynthates towards newly formed sink, which resulted in early bloom, prolonged flowering period and better development of yield attributes leading to higher seed yield (Mostafavi, 2012).

Application of RDF (T₂) recorded the lower seed yield (1195 kg ha⁻¹) due to reduced growth parameters and yield attributes and finally lower yield due to deficiency of potassium and zinc as the experimental soils are poor in available potassium (135.4 kg ha⁻¹) and available zinc (1.04 kg ha⁻¹). Similar results were also reported by Nalini *et al.* (2013) and Beg *et al.* (2013) in urdbean. The superiority of foliar nutrition might be to coincidence of foliar application with peak nutrient requirement of the crop, moreover peak absorption of potassium occurs from flowering to early pod development, any deficiency of potassium during this period can result in yield loss without obvious foliar symptoms. The quantity of nutrients absorbed due to soil application of potassium and zinc may not be sufficient to meet the crop demands at pod development stage. Supplementing the nutrients through foliage at flowering and pod formation stages might have resulted in better nutrient balance and thereby regaining the photosynthetic efficiency of the plant at post anthesis period results in increased yield attributes and seed yield of redgram (Reddy *et al.*, 1991). Control (T₁) recorded the lowest seed yield (612 kg ha⁻¹) due to poor soil nutrient status. (Table 3.2). These results corroborate with the findings of Manojja (2015).

4.4.2 Haulm Yield

The data pertaining to haulm yield as influenced by soil and foliar application of potassium and zinc on greengram are presented in Table 4.6.

Among all the nutrient management practices, the highest haulm yield of greengram (2728 kg ha⁻¹) was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅), which was significantly superior over the rest of the nutrient management practices tried. The improvement in the haulm yield might be due to indirect and positive role of potassium in formation and proliferation of lateral and fibrous roots, which increases the

root absorbing surface area for nutrients, which in turn promotes the growth parameters and ultimately enhanced the haulm yield (Chavan *et al.*, 2012). These findings were in accordance with those of Patel and Kotecha (2006). Zinc play a prime role in the biosynthesis of IAA, which in turn promotes the vertical growth leading to higher LAI and dry matter production and thereby resulting in higher stalk yield. The above results are in agreement with those of Babu *et al.* (2012).

The next best treatment was foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), which was however comparable with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), and were significantly superior over RDF (T₂). The next lower haulm yield (2351 kg ha⁻¹) was recorded with application of recommended dose of fertilizers (T₂) due to imbalanced nutrition caused by non supply of potassium and zinc. Control (T₁) recorded significantly the lowest straw yield due to non supply of nutrients.

4.4.3 Harvest index

The highest harvest index in greengram was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈). This might be due to better absorption and translocation of all the nutrients in balanced proportion including potassium and zinc where foliar application coincides with the peak crop demand and thereby maintenance of better source-sink relationship. The lowest harvest index was recorded with control (T₁) due to poor source-sink relationship.

4.5 NUTRIENT UPTAKE OF GREENGRAM

Soil and foliar application of potassium and zinc have exerted significant influence on the nutrient uptake of greengram at harvest (N, P, K and Zn) (Table 4.7, Figures 4.8 and 4.9).

4.5.1 Nitrogen

The highest nitrogen uptake by the plant at harvest was recorded with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_8), which was however comparable with soil application of 40 kg K_2O ha^{-1} + 25 kg ZnSO_4 ha^{-1} along with RDF (T_5), and significantly superior over the rest of the nutrient management practices. The next best treatment was foliar application of 1 % KNO_3 at flower bud initiation stage along with RDF (T_6) which was however, comparable with foliar application of 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_7) and soil application of either 25 kg ZnSO_4 ha^{-1} or 40 kg K_2O ha^{-1} along with RDF (T_4 and T_3).

Potassium might have showed the synergistic effect on nitrogen uptake in plant, which inturn enhances the better root and shoot development, which promote the nodulation in pulses resulting in enhanced biological nitrogen fixation, which in turn increased the N, P, K and Zn uptake of the plant (Chavan *et al.*, 2012). Application of recommended dose of fertilizers (T_2) resulted in the lower nitrogen uptake by the plant due to reduced availability of plant nutrients particularly K and Zn in the soil till harvest. The lowest nitrogen uptake was recorded with control (T_1), which might be due to less availability of plant nutrients as the soil is low in available nitrogen (152.5 kg ha^{-1}).

Table 4.7. Nitrogen, phosphorous, potassium and zinc uptake by greengram at harvest as influenced by soil and foliar application of potassium and zinc

Treatments	Nitrogen uptake (kg ha ⁻¹)	Phosphorous uptake (kg ha ⁻¹)	Potassium uptake (kg ha ⁻¹)	Zinc uptake (g ha ⁻¹)
T ₁ : Control (no fertilizers application)	18.5	4.1	11.0	16.0
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	24.6	5.3	15.5	30.3
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	27.0	6.70	18.1	31.0
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	28.3	6.95	18.8	34.9
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	32.1	9.06	22.6	35.9
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	28.1	6.79	17.9	30.9
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	28.5	7.89	19.5	38.4
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	32.7	9.74	24.0	40.2
SEm±	0.9	0.4	0.62	1.19
CD (P=0.05)	2.8	1.23	1.9	3.7

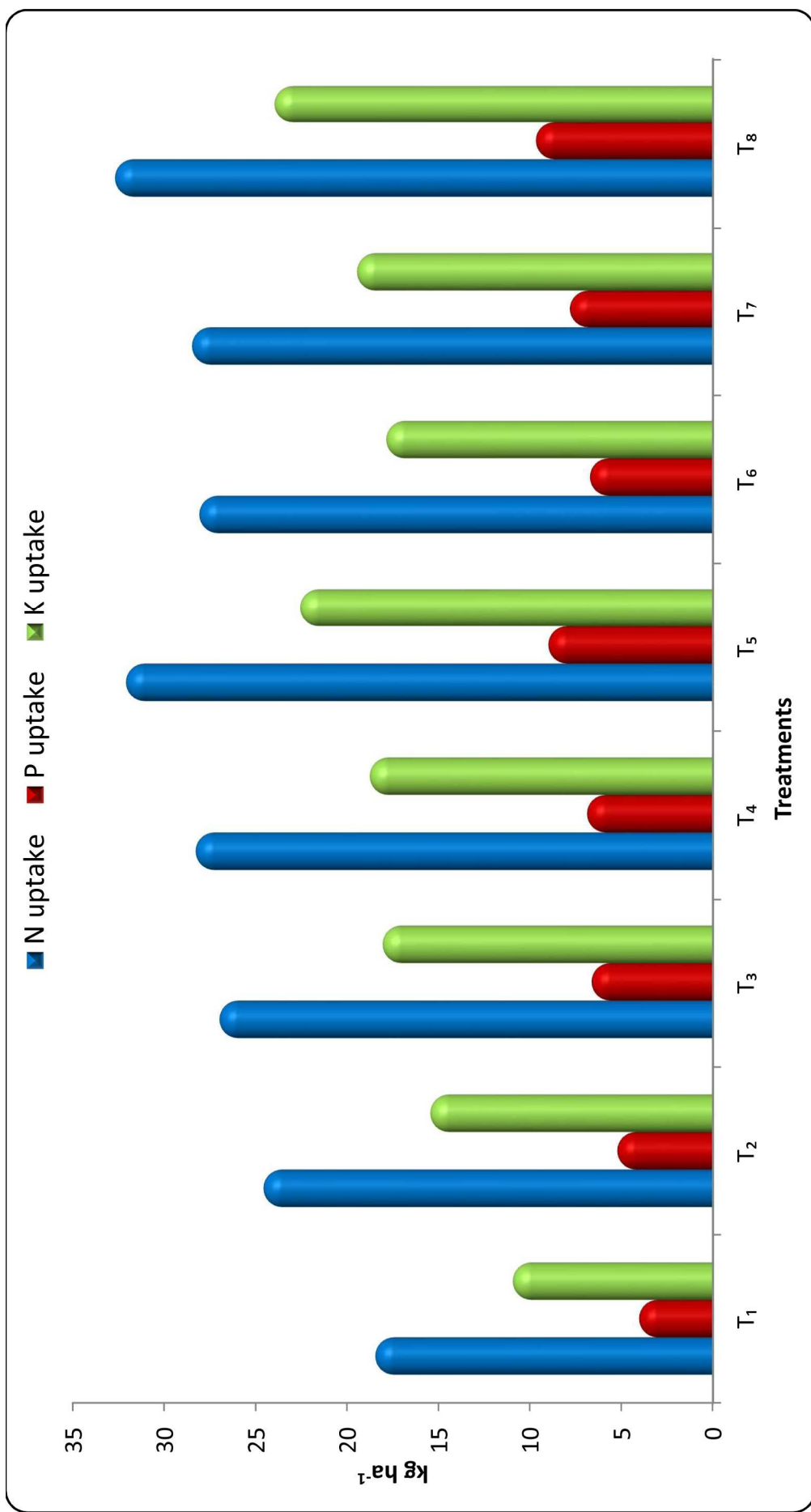


Fig. 4.8. Nitrogen, phosphorous and potassium (kg ha^{-1}) uptake by greengram at harvest as influenced by soil and foliar application of potassium and zinc.

4.5.2 Phosphorus

Foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation and pod formation stage along with RDF (T_8), recorded higher phosphorus uptake, which was at par with soil application of 40 kg K_2O ha^{-1} + 25 kg ZnSO_4 ha^{-1} along with RDF (T_5) over the rest of the nutrient management practices tried. Balanced application of nutrients particularly NPK and Zn helps in enhanced P uptake by the plant.

The next best treatment was foliar application of 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_7), which was however comparable with soil application of 25 kg ZnSO_4 ha^{-1} (T_4), foliar application of 1 % KNO_3 at flower bud initiation stage along with RDF (T_6), and soil application of 40 kg K_2O ha^{-1} along with RDF (T_3). The lowest phosphorus uptake was observed with control (T_1). The findings were in accordance with those of Manojja (2015) in redgram.

4.5.3 Potassium

The highest potassium uptake by the plant was recorded with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation along with RDF (T_8), which was however comparable with soil application of 40 kg K_2O ha^{-1} + 25 kg ZnSO_4 ha^{-1} along with RDF (T_5) and both were significantly superior over the rest of the nutrient management practices. The increase in K uptake by the plant was due to increased K availability in the soil, owing to application of potassium.

The next best treatments were foliar application of 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_7), soil application of 25 kg ZnSO_4 ha^{-1} (T_4), soil application of 40 kg K_2O ha^{-1} (T_3), foliar application of 1 % KNO_3 at flower bud initiation stage along with RDF (T_6), which was statistically comparable among themselves and superior over application of recommended dose of fertilizers (T_2). The lowest potassium uptake was observed with control (T_1). The findings were in accordance with those of Patel and Kotecha (2006).

4.5.4 Zinc

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) resulted in highest zinc uptake by plant, which was in parity with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅) and foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), which was superior over the rest of the treatments tried. Application of zinc lead to higher concentration of zinc in both seed and vegetative parts of the plant, as zinc is an important component of various enzymes that are responsible for driving many metabolic reactions and play a vital role and physiological role in plant cell (Alloway, 2004). The next best treatment was soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ (T₅) and soil application of 25 kg ZnSO₄ ha⁻¹ (T₄), and were comparable among themselves.

Soil application of 40 kg K₂O ha⁻¹ (T₃), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and RDF (T₂) recorded the next lower zinc uptake by plant showing parity among themselves. The lowest zinc uptake by plant is recorded with control (T₁). Similar results were also reported by Shivay *et al.* (2014).

4.6 QUALITY PARAMETERS

4.6.1 Protein Content

Soil and foliar application of potassium and zinc have exerted significant influence on protein content of seeds. Foliar spray of potassium and zinc increased the protein content considerably over soil application (Table 4.8 and Fig. 4.10).

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded significantly higher protein content (26.32 %), which was however comparable with foliar application of 0.2 %

ZnSO₄ at flower bud initiation stage along with RDF (T₇), which in

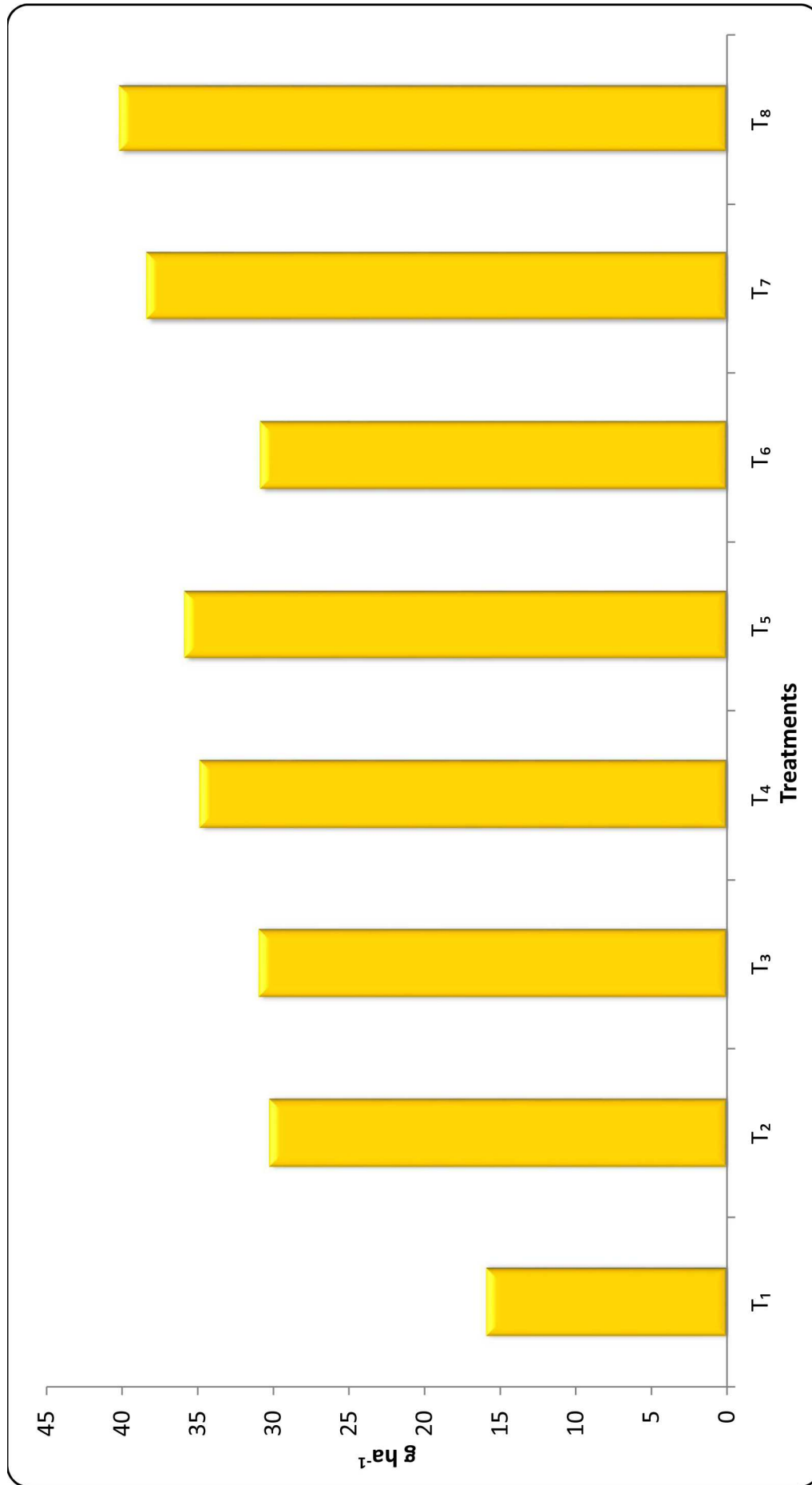


Fig. 4.9. Zinc uptake (g ha⁻¹) by greengram at harvest as influenced by soil and foliar application of potassium and zinc.

Table 4.8. Protein content and zinc content of greengram seed as influenced by soil and foliar application of potassium and zinc

Treatments	Protein content (%)	Zinc content (ppm)
T ₁ : Control (no fertilizers application)	18.62	36.00
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	21.96	41.89
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	22.18	42.98
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	22.34	46.96
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	23.20	48.39
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	22.51	45.04
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	26.08	52.89
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	26.32	54.12
SEm±	0.76	1.08
CD (P=0.05)	2.32	3.33

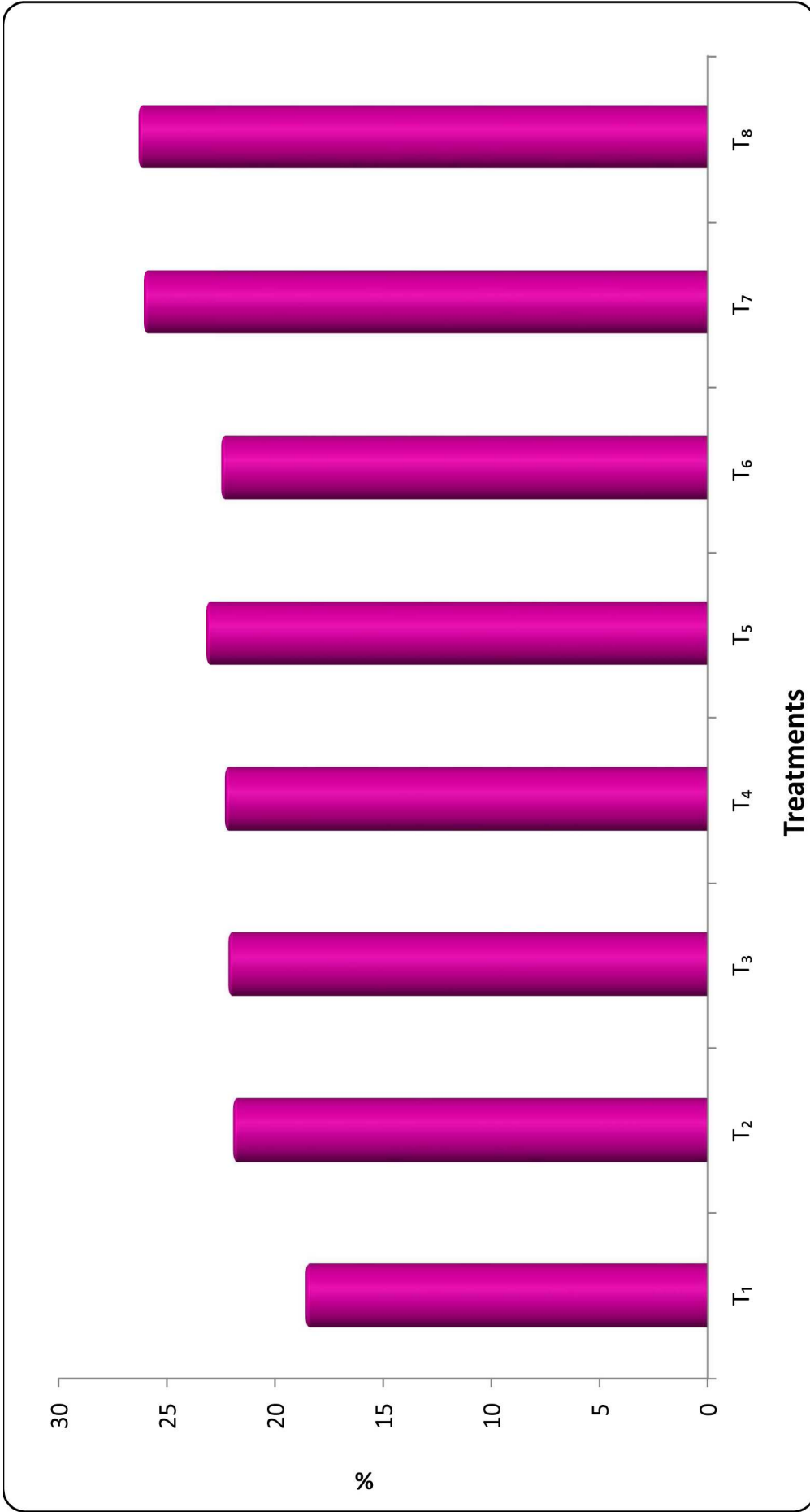


Fig. 4.10. Protein content (%) in greengram seed as influenced by soil and foliar application of potassium and zinc.

turn were significantly superior over the rest of the nutrient management practices tried. The next best treatment was soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅) which was on par with foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃) and application of RDF (T₂). The lowest protein content was recorded with control (T₁).

Higher protein content associated with T₈ might be due to the role of these nutrients in nodulation and biological nitrogen fixation in legume crops, owing to increased nitrogen content, as nitrogen is an important constituent of proteins (Demeterio *et al.*, 1972). Zinc plays a major role in the metabolism of plant as an activator of several enzymes which inturn directly or indirectly affect the synthesis of carbohydrates and proteins (Anitha *et al.*, 2005). Further, foliar spray of zinc keeps RNAase enzyme activity by binding the sulphohydril group and thus protecting disulphide formation which leads to increased protein synthesis (Pandey *et al.*, 2010). These results were in harmony with those of Kumawat *et al.* (2012) and Rahdari *et al.* (2013) in soybean. The lowest protein content (18.62 per cent) was recorded with control (T₁), as the available nitrogen in the soil may not be sufficient to meet the demands of sink at post anthesis period.

4.6.2 Zinc Content

The data regarding zinc content of greengram seed as influenced by soil and foliar application of potassium and zinc are presented in Table 4.8 and depicted in Figure 4.11.

The highest zinc content (54.12 ppm) in the seed was registered with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), was comparable with foliar application of ZnSO₄ @ 0.2 % at flower bud initiation stage along with RDF (T₇) and both were significantly superior over the rest of the treatments. Soil application of

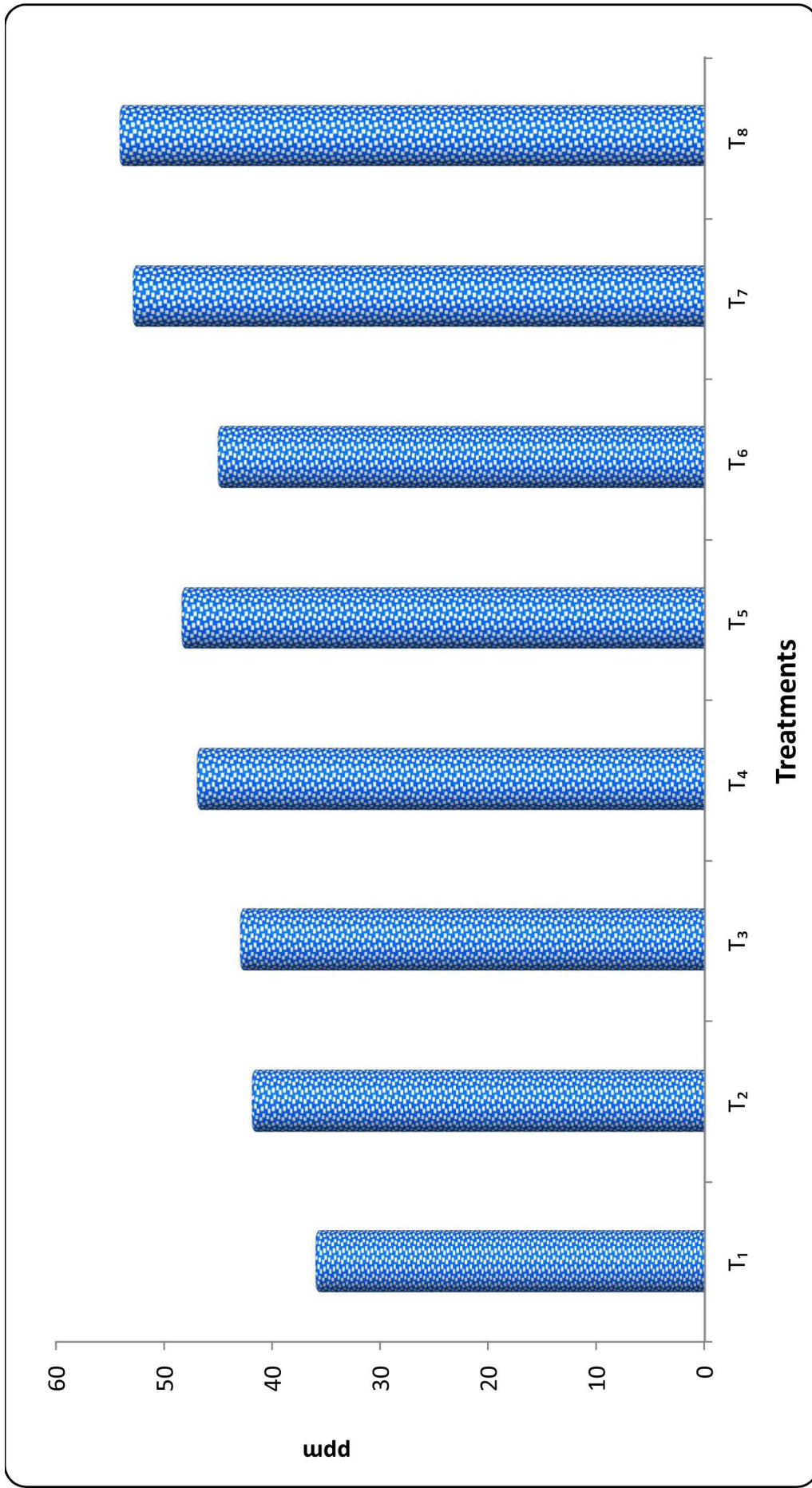


Fig. 4.11. Zinc content (ppm) in greengram seed as influenced by soil and foliar application of potassium and zinc.

40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅) and soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) were comparable among themselves and significantly superior over treatments with no zinc application *i.e.* T₆, T₃ and T₂.

This might be due to the fact that foliar applied zinc ions possess high mobility within the plants leading to increased concentration of zinc in the seed, quality of seed, which in turn enhances the carbohydrates and protein concentration (Pandey *et al.*, 2010). Similar findings were also reported by Nasri *et al.* (2011). The lowest zinc content in the seed was recorded with control (T₁) as the soils are deficit in available zinc.

4.7 ECONOMICS

Economics is the main bone of contention in making the sound recommendations for adoption of any package of practices by the farmers. Gross and net returns as well as benefitcost ratio were altered to a noticeable extent by soil and foliar application of potassium and zinc (Table 4.9 and Fig. 4.12).

4.7.1 Gross Returns

Gross returns of greengram cultivation was significantly influenced by soil and foliar application of potassium and zinc (Table 4.9 and Fig. 4.12).

The highest gross returns (₹ 59660 ha⁻¹) was obtained with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation and pod formation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O ha⁻¹ + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅) and significantly superior over other nutrient management practices tried. It is obvious that realization of higher gross returns was the result of higher yield.

The next best treatment was foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) which was however on par

Table 4.9. Gross returns, net returns and benefit cost-ratio of greengram cultivation as influenced by soil and foliar application of potassium and zinc

Treatments	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	Benefit cost-ratio
T ₁ : Control (no fertilizers application)	23256	10606	1.84
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	45410	29374	2.83
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	50236	33067	2.93
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	51642	34481	3.01
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	58710	40416	3.21
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	50920	33934	3.00
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	52440	36150	3.22
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	59660	42620	3.50
SEm±	649	649	0.06
CD (P=0.05)	2000	2000	0.19

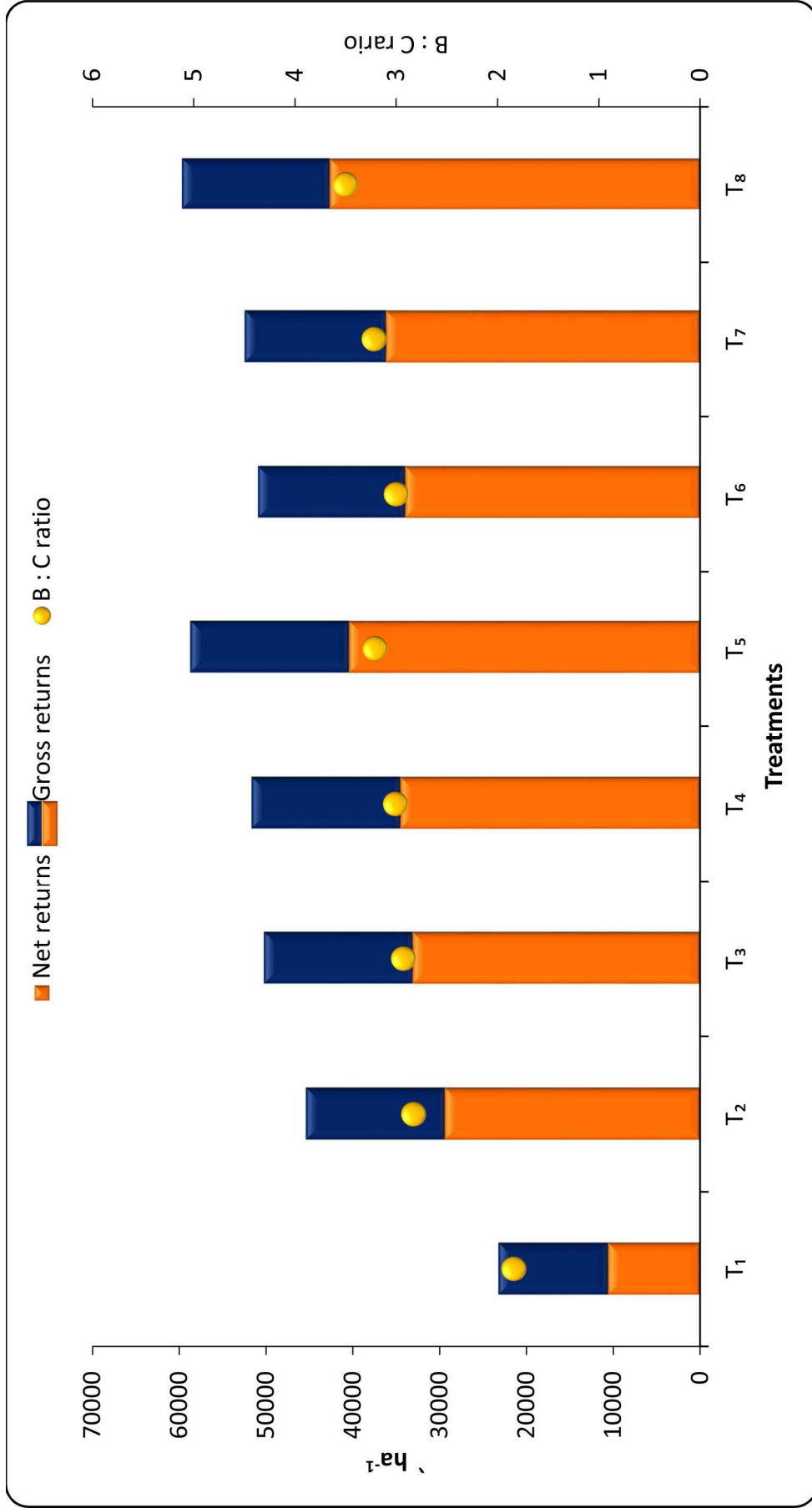


Fig. 4.12. Gross return, net return (₹ ha⁻¹) and benefit cost-ratio of greengram cultivation as influenced by soil and foliar application of potassium and zinc.

with soil application of 25 kg of ZnSO₄ ha⁻¹ (T₄) and foliar application of potassium (T₆) the later two were inturn comparable with soil application of 40 kg K₂O h⁻¹ (T₃). Control (T₁) recorded the lowest gross returns (₹ 23256 ha⁻¹) due to lower yields.

4.7.2 Net Returns

Net returns of greengram was significantly influenced by soil and foliar application of potassium and zinc (Table 4.9 and Fig. 4.12).

The highest net returns (₹ 42620 ha⁻¹) was obtained with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation and pod formation stage along with RDF (T₈), which was significantly superior over other nutrient management practices. The increase in net returns might be due to increased seed yield and reduced cost of foliar application of KNO₃ @ 1 % and zinc sulphate @ 0.2 % (T₈) than soil application of 40 kg K₂O ha⁻¹ (T₃) and 25 kg ZnSO₄ ha⁻¹(T₄). The next best treatment was soil application of 40 kg of K₂O ha⁻¹ + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₄). The lowest net returns (₹ 10606 ha⁻¹) was recorded with control (T₁). These results are in accordance with the findings of Babu *et al.* (2012) and Anitha *et al.* (2005).

4.7.3 Benefit-Cost Ratio

Benefit-cost ratio was significantly influenced by soil and foliar application of potassium and zinc (Table 4.9 and Fig. 4.12).

The highest benefit-cost ratio (3.50) was obtained with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation and pod formation stage along with RDF (T₈), which was significantly superior over other treatments. The lowest benefit-cost ratio (1.84) was recorded with control (T₁). Similar results were also reported by Anitha *et al.* (2005) and Shivay *et al.* (2014).

In the present study, higher yields as well as nutritionally superior quality seed with higher monetary returns were obtained with application of 20 kg N and 50 kg P₂O₅ ha⁻¹ along with foliar application of 1 % KNO₃ + 0.2

% ZnSO₄ at flower bud initiation for greengram during *kharif* in the Southern Agro Climatic Zone of Andhra Pradesh.

4.8 POST-HARVEST SOIL FERTILITY STATUS

Soil and foliar application of potassium and zinc have exerted significant influence on the post-harvest soil nutrient status *viz.*, available nitrogen, phosphorus, potassium and zinc (Table 4.10, Figures 4.13 and 4.14).

4.8.1 Nitrogen

The post-harvest soil available nitrogen status recorded with application of recommended dose of fertilizers (T₂), soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆), 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), and 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) and soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), were statistically comparable among them. Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) resulted in the lower soil available nitrogen. This might be due to increased uptake of nitrogen by the plant owing to increased total biological yield. Control (T₁) recorded the lowest post-harvest soil available nitrogen due to non supply of nutrients leading to exhaustion of soil available nitrogen.

4.8.2 Phosphorus

Available phosphorus in the soil after harvest of greengram crop was significantly influenced by soil and foliar application of potassium and zinc. Significantly the highest available phosphorus status was recorded with application of recommended dose of fertilizers (20-40-0 kg N, P₂O₅

Table 4.10. Post-harvest soil available nutrient status as influenced by soil and foliar application of potassium and zinc in greengram

Treatments	Available Nitrogen	Available Phosphorus	Available Potassium	Available Zinc
T ₁ : Control (no fertilizers application)	169	12.7	172	0.94
T ₂ : Recommended dose of fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	202.7	17.99	174	1.19
T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	202	17.96	230	1.19
T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	198	15.96	185	2.25
T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	194	16.8	225	2.34
T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	199	17.84	188	1.18
T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	196	17.31	185	1.15
T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	181	15.4	188	1.13
SEm±	2.87	0.81	4.34	0.05
CD (P=0.05)	11.6	2.5	13	0.14

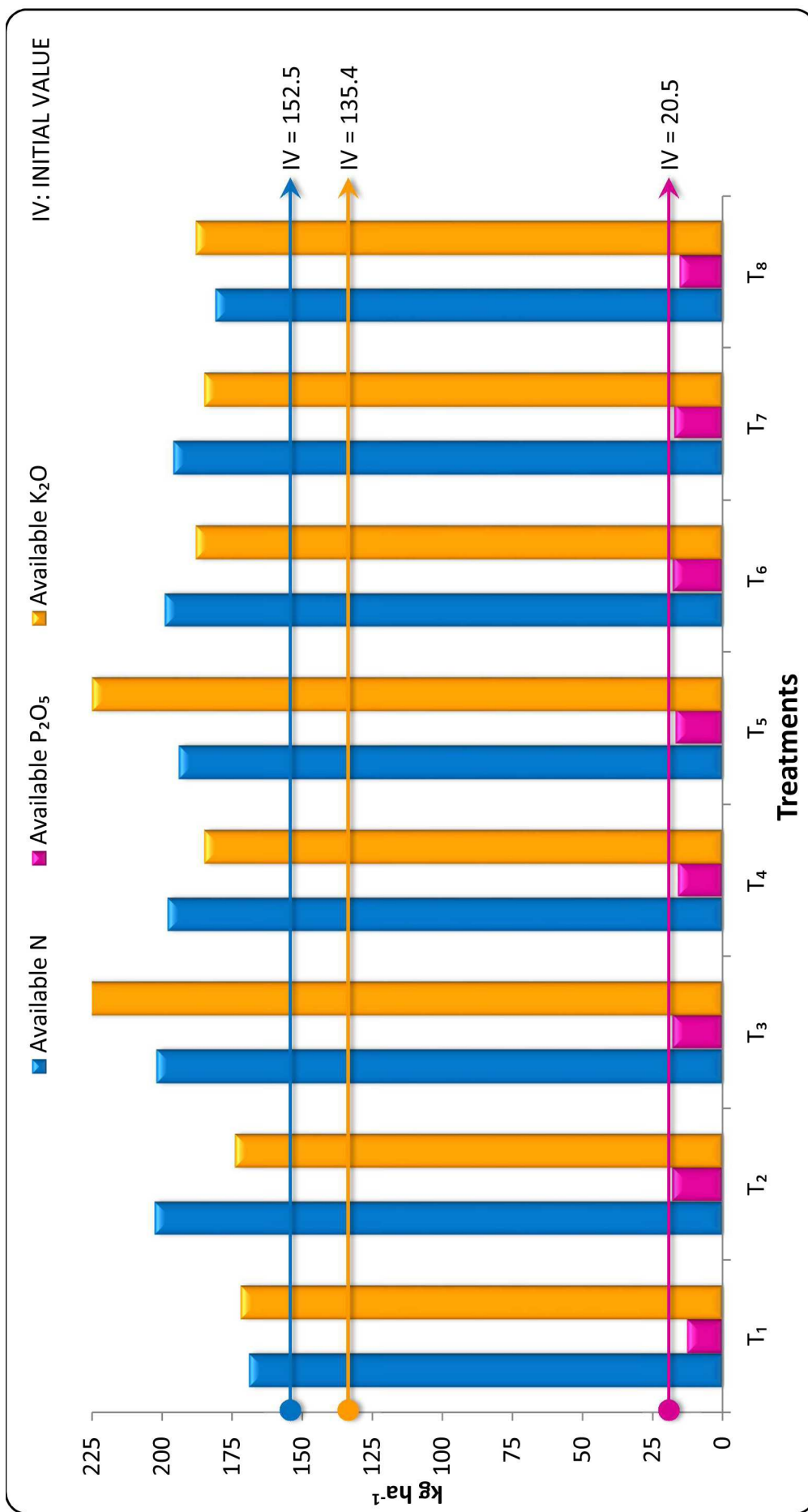


Fig. 4.13. Initial and Post-harvest soil available nitrogen (N), phosphorus (P₂O₅) and potassium (K₂O) (kg ha⁻¹) as influenced by soil and foliar application of potassium and zinc in greengram.

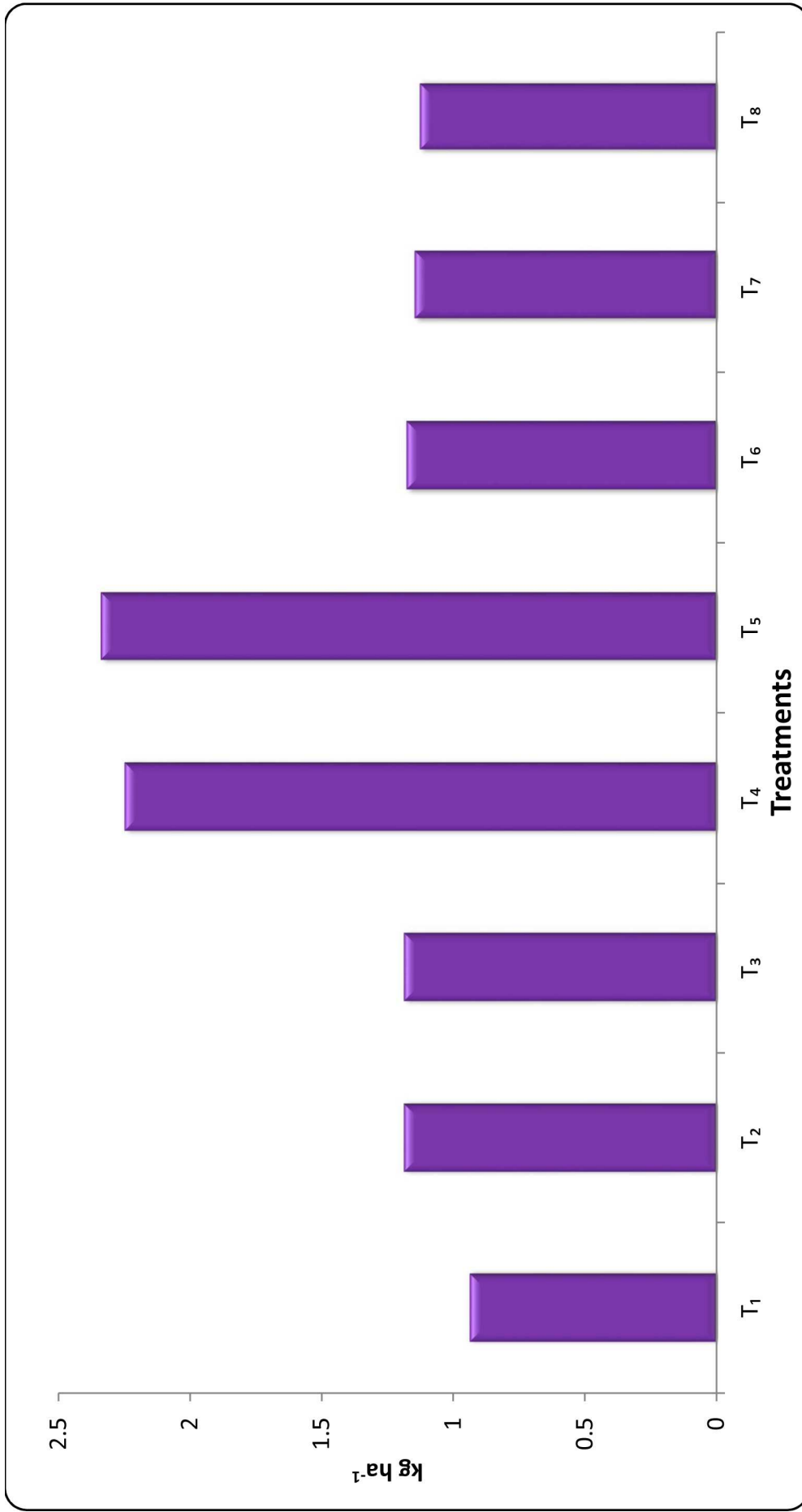


Fig. 4.14. Post-harvest soil available zinc (kg ha⁻¹) status as influenced by soil and foliar application of potassium and zinc in greengram.

and K_2O ha^{-1}) (T_2), 40 kg K_2O ha^{-1} along with RDF (T_3), foliar application of 1 % KNO_3 at flower bud initiation stage along with RDF (T_6), foliar application of ZnSO_4 @ 0.2 % at flower bud initiation stage along with RDF (T_7), soil application of 40 kg K_2O ha^{-1} + 25 kg ZnSO_4 ha^{-1} along with RDF (T_5) and soil application of 25 kg ZnSO_4 ha^{-1} along with RDF (T_4). The lower available phosphorus was observed with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_8). The lowest post-harvest soil available phosphorus was observed with control (T_1) due to non supply of phosphorus.

4.8.3 Potassium

Post-harvest soil available potassium was significantly influenced by soil and foliar application of potassium and zinc.

Soil application of 40 kg K_2O ha^{-1} along with RDF (T_3) recorded significantly higher available potassium, which was however comparable with soil application of 40 kg K_2O ha^{-1} + 25 kg ZnSO_4 ha^{-1} along with RDF (T_5) and significantly superior over the rest of the nutrient management practices. This might be due to soil application of 40 kg K_2O ha^{-1} which might have increased the soil available K at harvest. The treatments involving foliar application of 1 % KNO_3 and 0.2 % ZnSO_4 individually / in combination along with RDF at flower bud initiation stage alone and soil application of 25 kg ZnSO_4 ha^{-1} along with RDF (T_4 , T_6 , T_7 and T_8) were statistically similar with each other. Application of RDF (T_2) and control (T_1) recorded the lowest available potassium due to increased crop removal of soil available potassium.

4.8.4 Zinc

Post-harvest soil available zinc was significantly altered by soil and foliar application of potassium and zinc.

The highest post-harvest soil available zinc was registered with soil application of 40 kg K_2O ha^{-1} + 25 kg ZnSO_4 ha^{-1} along with RDF (T_5), which

was on par with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄). The treatments involving foliar application of potassium and zinc individually / in combination at flower bud initiation stage along with RDF (T₆, T₇ and T₈) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃) and RDF (T₂) were at par with each other. The lowest available zinc was observed with control (T₁).

4.9 RESPONSE OF GREENGRAM TO POTASSIUM AND ZINC FERTILIZATION

Pulses are reportedly responsive to potassium application and on an average 25 per cent of increase in the yield of pulses has been reported across the country, without exception in case of greengram too. In case of pulses, significance of nitrogen and phosphorus fertilization is well known but the need for potassium and zinc nutrition and their combination at different growth stages is not well documented. Next to nitrogen, potassium is the mineral nutrient required in the largest amount by plants. Under intensive cropping system, large amount of potassium is removed leading to serious depletion of potassium reserves. Economic response to 30 kg K₂O ha⁻¹ was apparent in greengram (Srinivasarao *et al.*, 2003). The minimum critical level of potassium requirement in plants for optimal plant growth is 2 to 5 per cent on dry weight basis (Marschner, 1993). Light textured red and lateritic soils with kaolinite as the dominant clay mineral are low in both exchangeable and non-exchangeable K (Ali and Srinivasarao, 2001).

The above fact suggests that when greengram is grown on soils with lower available potassium status, there is a likelihood of obtaining response to its application. As the experimental soils are sandy loam, poor in potassium (135.4 kg ha⁻¹) and zinc (1.04 kg ha⁻¹), soil and foliar application of potassium and zinc once at flower bud initiation stage alone and in combination along with RDF has been tried with control. A treatment with application of recommended dose of fertilizers alone has also been included in the study for comparison.

The results of the investigation have clearly brought out a noticeable trend of response to soil and foliar application of potassium and zinc in greengram.

As could be seen from the data, the yield attributes as well as yield followed a similar trend. Application of potassium and zinc in combination (soil and foliar) at flower bud initiation stage along with RDF (T₈ and T₅) exhibited significant supremacy, over the rest of the treatments tried. This was followed by a descending order of performance of greengram crop with application of either 0.2 % ZnSO₄ or 25 kg ZnSO₄ ha⁻¹ along with RDF (T₇ and T₄), 1 % KNO₃ or K₂O @ 40 kg ha⁻¹ (T₆ and T₃) along with RDF which were comparable between them and significantly superior over application of RDF alone. Obviously control has resulted in poorest performance.

Combined soil application of potassium @ 40 kg ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF has resulted in 13.6 and 16.8 per cent higher seed yield of greengram over soil application of each of the zinc or potassium alone along with RDF. The interaction between K and Zn is often positive and very occasionally additive, because the interaction between K and Zn has already been noticed (Armstrong, 1998).

The present investigation clearly demonstrated that foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) resulted in 13.76 and 17.16 per cent higher seed yield of greengram over the application of these nutrients along with RDF indicating the positive and synergistic response of potassium and zinc.

Though yield recorded with soil application of potassium @ 40 kg ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF were statistically comparable with foliar application of those respective nutrients but remunerative economic returns (net returns and benefit-cost ratio) play a key role, for adopting the refined agrotechniques, accordingly foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at

flower bud initiation stage along with application of 20 kg N and 40 kg K₂O ha⁻¹ (T₈) might be a promising nutrient management strategy for higher productivity and quality as well as economic returns of greengram in Southern-Agro Climatic Zone of Andhra Pradesh.

Chapter - V

Summary & Conclusions

Chapter – V

SUMMARY AND CONCLUSIONS

A field experiment entitled “**Productivity and quality of greengram as influenced by potassium and zinc nutrition**” was conducted during Kharif, 2018 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The experiment was laid out in a randomized block design with eight treatments and replicated thrice.

The treatments consisted of eight nutrient management practices *viz.*, control (T₁), application of recommended dose of fertilizers (RDF) (20-50-0 kg N, P₂O₅ and K₂O ha⁻¹) (T₂), soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), foliar application of KNO₃ @ 1 % at flower bud initiation stage along with RDF (T₆), foliar application of ZnSO₄ @ 0.2 % at flower bud initiation stage along with RDF (T₇) and foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈). Greengram variety, IPM 2-14 was tested in the present experiment. The salient findings of the investigation are summarized below.

Observations were recorded on growth parameters *viz.*, plant height, leaf area index, dry matter production, yield attributes *viz.*, number of branches plant⁻¹, pods branch⁻¹, seeds pod⁻¹, thousand seed weight, seed yield, haulm yield and harvest index and quality parameters of seed like protein and zinc content. Data was also recorded on nitrogen, phosphorus, potassium and zinc uptake by the plant at harvest, economics and post-harvest available nitrogen, phosphorus, potassium and zinc status of the soil for different treatments.

The growth parameters, yield attributes, yield and quality of greengram were significantly influenced by soil and foliar application of potassium and zinc.

At 15 and 30 DAS the highest stature of growth parameters *viz.*, plant height, LAI and dry matter production were recorded with soil application of 40 kg K₂O + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which was however, comparable with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃). Foliar application of potassium and zinc individually / in combination at flower bud initiation stage along with RDF and RDF alone (T₆, T₇, T₈ and T₂), were the next best treatments and were comparable among them.

At 45 DAS and at harvest, foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), resulted in the tallest plants, maximum leaf area index and the highest dry matter production, which was however, comparable with soil application of 40 kg of K₂O ha⁻¹ + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅), and significantly superior over rest of the nutrient management practices. The lowest stature of above growth parameters, at all the stages of observation were observed with control (T₁).

The highest number of branches plant⁻¹ was registered with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which was statistically on par with soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄) and 40 kg K₂O ha⁻¹ along with RDF (T₃), but the other yield attributes *viz.*, number of pods branch⁻¹, seeds pod⁻¹ and thousand seed weight were significantly higher with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however, comparable with soil application of 40 kg of K₂O ha⁻¹ + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅), and significantly superior over the rest of the treatments tried. Foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇), soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF

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(T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃) were comparable with each other in producing number of pods branch⁻¹, seeds pod⁻¹ and test weight. The lowest values of the above said yield attributes were recorded with control (T₁).

Significantly highest seed and haulm yield of greengram was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O + 25 kg of ZnSO₄ ha⁻¹ along with RDF (T₅), which resulted in 31.38 and 29.38 per cent higher seed yield compared to application of RDF alone (T₂). Foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) and soil application of 25 kg ZnSO₄ ha⁻¹ along with RDF (T₄), foliar application of 1 % KNO₃ at flower bud initiation stage along with RDF (T₆) and soil application of 40 kg K₂O ha⁻¹ along with RDF (T₃), were the next best treatments, which were comparable among them significantly superior over recommended dose of fertilizers (T₂).

The highest harvest index of greengram was recorded with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈). Control (T₁) recorded the lowest harvest index.

The highest nutrient uptake (N, P, K and Zn) of greengram was registered with foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈), which was however comparable with soil application of 40 kg K₂O ha⁻¹ + 25 kg ZnSO₄ ha⁻¹ along with RDF (T₅), which in turn was comparable with foliar application of 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₇) with respect to zinc uptake and significantly higher over the rest of the nutrient management practices, while the lowest uptake of above nutrients was observed with control (T₁).

Foliar application of 1 % KNO₃ + 0.2 % ZnSO₄ at flower bud initiation stage along with RDF (T₈) recorded significantly higher protein and zinc

content, which was however comparable with foliar application of 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_7) and significantly superior over the rest of the nutrient management practices. The next best treatment was soil application of 40 kg K_2O + 25 kg of ZnSO_4 ha^{-1} along with RDF (T_5), foliar application of 1 % KNO_3 at flower bud initiation stage along with RDF (T_6) and soil application of 25 kg ZnSO_4 ha^{-1} along with RDF (T_4), soil application of 40 kg K_2O ha^{-1} along with RDF (T_3) and application of recommended dose of fertilizers RDF (T_2). The lowest protein and zinc contents in the seed were registered with control (T_1).

The highest gross returns and net returns as well as benefit-cost ratio were obtained with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_8) which was however comparable with soil application of 40 kg of K_2O ha^{-1} + 25 kg of ZnSO_4 ha^{-1} along with RDF (T_5), with respect to gross returns. Significantly lowest monetary returns and benefit-cost ratio was recorded with non application of fertilizers control (T_1).

The highest post-harvest soil available nitrogen and phosphorus status were recorded with application of recommended dose of fertilizers (T_2), while soil application of 40 kg K_2O ha^{-1} along with RDF (T_3) recorded higher soil available potassium after harvest. The highest post-harvest soil available zinc was registered with soil application of 40 kg of K_2O ha^{-1} + 25 kg of ZnSO_4 ha^{-1} along with RDF (T_5). The lowest post-harvest soil available nitrogen, phosphorus, potassium and zinc were observed with control (T_1).

Based on the foregoing results, the following conclusions could be drawn from the present investigation.

- Potassium and zinc exerted a significant influence on growth and yield of greengram. Among the different treatments tried, foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with RDF recorded significantly higher growth parameters and seed yield, which was however comparable with soil application of 40 kg K_2O + 25 kg of ZnSO_4 ha^{-1} along with application of 20 kg N and 50 kg P_2O_5 (RDF).
- The response of greengram to soil and foliar application of potassium and zinc was significant. Foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with 20 kg N and 50 kg P_2O_5 ha^{-1} (RDF) recorded higher seed yield and increased protein and zinc content in the seed in sandy loam soils of Southern Agro Climatic Zone of Andhra Pradesh.
- Application of 20 kg nitrogen and 50 kg phosphorus ha^{-1} (recommended dose of fertilizers) supplemented with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage was found to be the economically viable nutrient management strategy, which resulted in higher grain yield, net returns as well as benefit-cost ratio than the rest of the treatments.
- In conclusion, the present study revealed that the productivity and quality of greengram were improved with application of RDF (20-50-0 kg N, P_2O_5 and K_2O ha^{-1}) along with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage. The same nutritional management strategy also realized maximum economic returns, apart from enhanced quality of seed in terms of higher concentration of zinc and protein.

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As per the thesis format guidelines of Acharya N.G. Ranga Agricultural University, Guntur, Andhra Pradesh, India.

Appendices

APPENDIX – A

CALENDAR OF OPERATIONS

S. No.	Operation	Date
1	Land preparation with tractor drawn plough followed by blade harrow	09-07-18
2	Layout of individual plots	11-07-18
3	Bunds formation	11-07-18
4	Sowing, basal dose of fertilizer application and irrigation	13-07-18
5	Application of pendimethalin	14-07-18
6	Sprinkler irrigation	13-07-18
7	Thinning	30-07-18
8	Hand weeding	30-07-18
9	Surface irrigation	02-08-18
11	Spraying of KNO ₃ and ZnSO ₄ at flower bud initiation stage	18-08-18
12	Surface irrigation	25-08-18
13	Bulk area harvesting	26-09-18
14	Harvesting and Threshing	09-10-18

APPENDIX – B

COST OF INPUT AND OUTPUT OF THE EXPERIMENT

S. No.	Input/output	Unit	Cost (₹ unit ⁻¹)
1	Seed	kg	50
2	Urea	kg	6
3	Single super phosphate	kg	10
4	Muriat of potash	kg	17
5	Pendimethalin	l	640
6	Zinc sulphate	kg	45
7	Potassium nitrate (13-0-45)	kg	125
8	Grengram seed	kg	38

APPENDIX – C

COST OF CULTIVATION (₹ ha⁻¹) OF GREENGRAM EXCLUDING K AND Zn NUTRITION

S. No.	Particulars	Cost (₹ ha ⁻¹)
1	Cost of seed	750
2	Land preparation	2,500
3	Sowing	3,500
4	Fertilizer application excluding Zn and K	3,386
5	Weeding	2,000
6	Irrigation	900
7	Harvesting and threshing	3,000
Total cost		16,036

APPENDIX – D

TOTAL COST OF CULTIVATION OF GREENGRAM (₹ ha⁻¹)

S. No.	Treatments	Cost of cultivation excluding nutrient management practices	Cost of cultivation including nutrient management practices
1	T ₁ : Control (no fertilizers application)	12,650	12,650
2	T ₂ : Recommended Dose of Fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	12,650	16,036
3	T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	12,650	17,169
4	T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	12,650	17,161
5	T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	12,650	18,294
6	T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	12,650	16,986
7	T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	12,650	16,290
8	T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	12,650	17,040

APPENDIX – E
INITIAL AND FINAL PLANT POPULATION (m²)

S. No.	Treatments	Initial	Final
1	T ₁ : Control (no fertilizers application)	24.0	23.0
2	T ₂ : Recommended Dose of Fertilizer (RDF) (20-50-0 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹)	25.5	25.0
3	T ₃ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹	24.3	24.0
4	T ₄ : T ₂ + Soil application of 25 kg ZnSO ₄ ha ⁻¹	24.6	24.4
5	T ₅ : T ₂ + Soil application of 40 kg K ₂ O ha ⁻¹ + 25 kg ZnSO ₄ ha ⁻¹	26.0	25.6
6	T ₆ : T ₂ + Foliar application of KNO ₃ @ 1 % at flower bud initiation stage	24.0	24.0
7	T ₇ : T ₂ + Foliar application of ZnSO ₄ @ 0.2 % at flower bud initiation stage	24.6	23.6
8	T ₈ : T ₂ + Foliar application of KNO ₃ @ 1 % + ZnSO ₄ @ 0.2 % at flower bud initiation stage	25.6	25.3

Plates



Plate 1. Pre-emergence application of pendimethalin in greengram.



Plate 2. Foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage in greengram.



Plate 3. Overall view of the experimental field of greengram at 20 DAS.



Plate 4. Overall view of the experimental field of greengram at 40 DAS.

S.V.AGRICULTURAL COLLEGE, TIRUPATI
DEPARTMENT OF AGRONOMY Field no: 1-3

**Productivity and Quality of Green gram (*Vigna radiata* L.)
as Influenced by Potassium and Zinc Nutrition**

TREATMENTS:	TECHNICAL WORK:
T ₀ - Control (No fertilizer application)	Crop - Green gram
T ₁ - Recommended Dose of Fertilizer (RDF)	Variety - PM 2-14
T ₂ - RDF + 40 kg ZnSO ₄ ha ⁻¹	Spacing - 30 cm x 10 cm
T ₃ - RDF + 20 kg ZnSO ₄ ha ⁻¹	Season - Kharif, 2019
T ₄ - RDF + 40 kg of K ₂ O ha ⁻¹ + 20 kg of ZnSO ₄ ha ⁻¹	Design - RBD
T ₅ - RDF + Foller application of 40kg K ₂ O at flower bud initiation stage	Replications - Three
T ₆ - RDF + Foller application of 20kg K ₂ O @ 0.2% at flower bud initiation stage	Crop size - 5.4 m x 4.8 m
T ₇ - RDF + Foller application of 15 kg K ₂ O + 0.2% ZnSO ₄ at flower bud initiation stage	Net - 8.2 m x 3.6 m
T ₈ - RDF + 20 - 95 - 5 kg N, P ₂ O ₅ and K ₂ O ha ⁻¹ (RDF ₁₅ - 8 - 40)	Des - 213 / 17 / 2019

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Plate 5. Greengram at pod formation stage with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage (T_8).



Plate 6. Greengram at pod maturity stage with foliar application of 1 % KNO_3 + 0.2 % ZnSO_4 at flower bud initiation stage along with RDF (T_8).



Plate 7. Greengram at pod maturity stage with application of RDF (20 N, 50 P₂O₅ and 0 kg K₂O ha⁻¹).



Plate 8. Greengram at pod maturity stage with control (T₁).