STUDIES ON EFFECT OF POTASSIUM ON GROWTH, YIELD AND UPTAKE OF NUTRIENTS BY GREEN GRAM

BY

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B. Sc. (Agri.)

DISSERTATION

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I, hereby declare that the entire work embodied

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This is to certify that the dissertation entitled "**STUDIES ON EFFECT OF POTASSIUM ON GROWTH, YEILD AND UPTAKE OF NUTRIENTS BY GREEN GRAM**" submitted by **Miss PARAMITA DEB** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

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ABBREVIATIONS

%	per cent
/	per
C.D.	Critical difference
cc	Cubic centimeter
cm	centimeter
Cu	Copper
Cv	Coefficient of variation
DAS	Days after sowing
dSm^{-1}	desi simen per metre
EC	Electrical conductivity
et al.	and others
etc.	etceteras
Fe	Iron
Fig.	Figure
g	Gram(s)
ha	Hectare(s)
i.e.	that is
K	Potassium
kg ha^{-1}	kilogram per hectare
kg	kilogram
Lb	Leg-haemoglobin
m	meter
mg kg^{-1}	milligram per kilogram
mm	millimeter
Mn	Manganese
N	Nitrogen
No.	number
^{o}C	Degree centigrade
P	Phosphorus
RBD	Randomised Block Design.
SEm±	Standard Error
viz.,	namely
Zn	Zinc

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ABSTRACT

"Studies on effect of potassium on growth yield and uptake of nutrients by Green gram"

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Field experiment was conducted in *kharif* season 2012-13 at experimental farm of Department of Soil Science and Argil. Chemistry, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani using green gram as a test crop to study the effect of potassium on growth, yield and uptake of nutrients. The experiment was laid out on Vertisols with eight treatment combination, replicated three times in randomized block design. The treatment consists of T_1 Absolute control (No fertilizer application), T_2 RDF (20:50 N and P_2O_5 kg ha^{-1}), T_3 (RDF + 25 kg K_2O ha^{-1}), T_4 (RDF + 50 kg K_2O ha^{-1}), T_5 (RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient), T_6 (RDF+ 50 kg K_2O ha^{-1} + Grade I Micronutrient), T_7 (RDF + 25 kg K_2O ha^{-1} + Grade II 0.5% foliar spray), T_8 (RDF + 50 kg K_2O ha^{-1} + Grade II 0.5% foliar spray). The results emerged out clearly indicated that various growth parameters like plant height, number of pods, number of nodules, fresh weight of nodules, total biomass

of nodules, fresh weight of nodules, total biomass production and dry matter and seed yield was increased due to application of potassium. It was inferred from the results that application of 25 kg N, 50 kg P_2O_5, or 25 kg or 50 kg K_2O per hectare + Grade I micronutrient fertilizer (10 kg ha^{-1}) or grade II foliar spray (0.5 %) found superior over only N and P application i.e. RDF (20:50 N and P_2O_5 kg ha^{-1}). The K application shows synergistic effects on other nutrients (N, P, Fe, Zn, Cu, Mn) uptake. Soil fertility was found to be improved due to application of potassium and micronutrients to green gram.

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CHAPTER-I

INTRODUCTION

India is one of the important pulse producing countries in the world. It is producing 14.76 million ton of pulses from an area of 23.63 million hectare. Even though India is one of the largest pulse producing countries in the world, about 2-3 million tons of pulses are imported annually to meet the domestic consumption requirement. The current per capita availability of pulses of 80 gm/capita/day as recommended by FAO is very low which could not meet the per capita requirement. Therefore, it is necessary that the agricultural scientists should keep the strategy for increasing the production of pulses to meet the protein requirement of increasing population of the country (Subbulakshmi *et al.*, 2009). Being leguminous crop pulses utilize and fix atmospheric nitrogen. They play an important role in restoring soil fertility and improving soil physical properties. They are valued for protein rich food, feed and fodder and therefore, have been rightly described as unique jewels of Indian crop husbandry by Swaminathan (1981).

Among pulse crop, green gram or moong bean contributes 11% in the national pulse production. Green gram or moong (*Vigna radiata* L. Wikzek), is an important pulse crop of India after chickpea and pigeon pea. It is a native of India, part of central Asia and it is spread all over the southern Asian countries *viz*., Pakistan, Bangladesh, Srilanka etc. Green gram is grown in Indian states like Maharashtra, Orissa, Rajasthan, Karnataka and Uttar Pradesh. It contains about 25% protein, 10.4% moisture, 1.3% fat, 3.5% minerals, 4.1% fibers, 56.7% carbohydrates, and small amount of Vitamin B complex. Its calorific value is 334kcal 100 gram of edible portion (Gopalan *et al.*, 2002).

It is also used for green manuring, as it has capacity to fix the atmospheric nitrogen. Green gram commonly known as golden bean is a subtropical, short duration and drought resistance crop, grows in a wide range of climatic conditions and soil type. A warm humid climate with temperature range of 25^0C to 35^0C, with moderate rains of 800-1000 mm, well distributed during growing period of 100 days, is quite suitable for its cultivation. The crop grows from sea level to as high as 2000 meters. It is particularly rich in leucine, phenylalanine, lysine, valine, isoleucine, etc. It has also remarkable quantity of ascorbic acid when sprouted and also bear riboflavin (0.2 mg/100 g) and minerals (3.54 percent). The total estimated production of moong bean of India in the year of 2013-2014 was 0.90 million ton. It spreads over 34.4 lakh ha (18.07%) with production of 14 lakh tones (11.48%) and productivity 406.98 kg ha^{-1}. In Maharashtra, it occupies 6.71 lakh hectare (19.51%) with production of 3.71 lakh tones (26.50%) and productivity of 552.91 kg ha^{-1}(Agropedia).

Green gram needs all essential 17 elements for its growth and development. Amongst all, Potassium is an alkali metal that occurs naturally in most of the soils. The total K content of the earth crust is about 2.3 to 2.5 %, but a very small proportion of its become available to plants (Leigh and Jones, 1984). Potassium is one of the major essential plant nutrients is often required equal to or greater than other major nutrients like nitrogen, phosphorous. Even though its not a part of any plant structure, it is found in the plant sap involved in many physiological and biochemical functions of plant growth. Plants require K in large quantities; hence, it is regarded as one of the three major food elements (Golakiya and Patel, 1988; Leigh and Jones, 1984; Dev, 1995).

Potassium is involved in many physiological process such as photosynthesis (Vyas *et al.,* 2001), photosynthetic translocation (Umar, 1997; Tiwari *et al.*, 1998), protein and starch synthesis, water energy relations (Rao and Rao 2004), translocation of assimilates (Tomar, 1998) and activation of number of enzymes (Vyas *et al.*, 2001; Sharma and Agrawal, 2002).It also improves the water use efficiency (Singh *et al.,*1997) through its influence on maintenance of torgor potential (William, 1999). Potassium nutrition affects the quantity and quality of low molecular compounds in roots and root exudates and the composition of the rhizosphere microflora and microbial transformation in the root activity (Trolldenier, 1987). Potassium is most abundant cation in the cytoplasm and has an outstanding role in plant–water relations (Hsiao and Lauchli, 1986). High availability of K enhances root development, producing more branching and lateral roots (Egilla *et al.,* 2001).

It has been described as the “quality element” for crop production (Usherwood, 1985; Pettigrew, 2000). Potassium increases the protein content of plants, the starch content in grains and tubers, Vitamin C, and the solid soluble contents in fruits. The crucial importance of K in quality formation stems from its role in promoting the production of photosynthates and their transport to storage organs such as fruits, grains, and tubers and enhancing their conversion into starch, protein, vitamins, and oil (Mengel and Kirkby, 2001). With a shortage of K, many metabolic processes are affected, like the rate of photosynthesis and the rate of translocation and enzyme systems (Marschner, 2002; Mengel, 1997). Excess K may have a negative impact on quality of produce mainly because of decreasing organic acids, which results in an increased pH (Mpelasoka *et al.*, 2003).

Potassium is one of the three main pillars of balanced fertilizer use, along with N and P. Leaves, straw and strover retain about 70 to 75 % of the K absorbed. The remaining portion such as grains, fruits, nuts etc. Whenever soil cannot adequately supply the K required to produce high yields, farmer must supplement soil reserves with fertilizer K.

Pulses growing regions of India consist of different soil types and available K status varying from low to high (Srinivasarao *et al.*, 2001). Pulses in India are grown mostly on marginal and sub marginal lands without proper inputs with low inputs such as fertilizer. Patil *et al*., (2001) reported that average use of K in Maharashtra was 11.10 kg ha^{-1}, which is very low as against its mining 118.20 kg ha^{-1}causing K depletion in a very high rate. Potassium (K) is rarely applied to pulse crops despite larger K requirements of pulses and continued mining of soil potassium (K), resulting in imbalanced nutrient supply and lower crop yield. Under intensive cropping systems, larger amounts of K are removed leading to serious depletion of soil potassium (K) reserves. Among production inputs, fertilizer application plays a key role in enhancing productivity levels.

However, fertilizer recommendation practices for pulse crops have been paid less attention. There has been a dramatic decrease in the fertilizer consumption of K compared to fertilizer N and P while K removal from the soil is generally as much as or higher than N; still its use in fertilizer is negligible. A steep rise in their price accompanied by no such increase in the price of N greatly made it imbalanced in the favour of N. As a result the N: P_2O_5: K_2O ratio which was already imbalanced at 1: 0.41: 0.17 in 1991 deteriorated further to 1: 0.41: 0.15 during 1999-2000 whereas the ideal ratio is

1: 0.5: 0.25 (Pasricha, 2000). This derived nutrient imbalance in fertilizer consumption shows a distinctive pattern, increasingly in favour of N and increasing by negative for P and K. Cultivation of high yielding crop and hybrids and diversification towards P and K demanding crops such as vegetables, potatoes, oilseeds and pulses will place even more strain on K budgets of the soil. This means diminishing soil fertility and declining fertilizer use efficiency, which increases cost of production and restricts water use efficiency.

In general, response of crop to applied potassium is very low due to high potassium content of soils derived from basaltic parent material. However, available data in recent years indicate that the magnitude of crop response to potassium in these soils is increasing in areas of higher cropping intensity (Tandon and Sekhon, 1988). Supply of pulse growing agro ecological region of India vary widely in their K supplying capacity. Light textured alluvial soils, red and lateritic soils and shallow black soils with low levels of available K and even black cotton soil needs K supplementation to enhance the productivity. Based on a number of field studies, it can be suggested that the application of 20-40 kg K_2O ha^{-1} is beneficial for higher pulse production (Ali and Srinivasa Rao, 2001).

Marathwada region of Maharashtra state is known for the kharif pulse particularly green gram, black gram and red gram. The soils of this region are low in N, low in phosphorus and high in K and hence the agronomic recommendation includes only N and P application @ 25:50 kg ha^{-1} respectively. However, from last few years it was found that crops are responding for K application. The response for K application might be due to continuous mining of K, from soil by various crops and by the lowered K status of soil. It is estimated that every year nearly 2,095939 tonnes of K is removed from Maharashtra soil as against only 177,191 tones of K is added. So there is net 3,67,132 tonnes of negative balance of K every year (Patil *et al*., 2001), therefore due to continuous mining of K, K reserves are depleted and hence they respond for K application. On the other hand, if we look into the agronomic recommendation, no K is recommended and this might be the one of reasons of low yield of pulses particularly green gram. Hence, a project was formulated to study the effect of application of graded levels of potassium on growth, yield and K uptake by green gram to achieve balance in the use of N, P and K nutrients.

The present investigation was undertaken with the following objectives.

1. To study the effect of graded levels of potassium application on growth and yield of green gram under rainfed condition.
2. To find out the temporal changes in uptake of potassium by green gram under different treatments.
3. To study the effect of potassium application on quality of green gram.
4. To find out the soil potassium dynamics at critical growth stages of green gram under varied potassium application treatments.

CHAPTER-II

REVIEW OF LITERATURE

The present study is aimed to assess the effect of different levels of potassium on yield and yield components, nutrient availability, nutrient uptake at critical growth stages and quality in terms of protein content of green gram. The pertinent literature on these aspects is reviewed under following heads.

2.1 Effect of levels of potassium on growth, yield and yield attributing characters.

2.2 Effect of levels of potassium on nutrient concentration and temporal changes during uptake of nutrients in critical growth stages.

2.3 Effect of levels of potassium on quality.

2.4 Effect of levels of potassium in soil potassium dynamics at critical growth stages of crop.

2.1 Effect of potassium levels on growth, yield and yield attributing characters

Potassium (K) has special position as evident by its role in increasing the crop yield (Yadav *et al.,* 2003; Read *et al.,* 2006). It plays a major role in growth and yield as it is involved in assimilation, transport, and storage tissue development (Cakmak, 2005).

2.1.1 Green gram and Black gram

Asghar *et al.* (1994) reported that application of 75 kg K_2O in addition to 25 and 75 kg N and P_2O_5 ha^{-1} showed a significant increase in yield(10.49 q ha^{-1}) of black gram.

Sood *et at.* (1996) revealed that the base yield of 457 kg ha^{-1} could be increased to 853 kg ha^{-1} with the application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} in case of chickpea and urd bean respectively.

Mitra and Sahoo (1998) concluded that yield of green gram (576 kg ha^{-1}) were significantly increases due to application of 20 kg K_2O ha^{-1} even without application of any N fertilizer.

Tiwari and Tiwari (1999) concluded that the number of nodules per plant with applied K at 40 kg K_2O ha^{-1} increased from 39.1 to 42.6 in chickpea, 38.4 to 46.8 in pea, 10.3 to 14.8 in lentil, 48.0 to 55.5 in urd bean and 35.2 to 46.8 in mung bean.

Oad *et al.* (2003) showed that the application of potassium and phosphorous @ of 100:100 P: K kg ha^{-1} for achieving satisfactory seed yield of mung bean.

Kabir *et al.* (2004) concluded that higher levels of K fertilization (14, 40, 60 kg ha^{-1} of K) increased the growth and yield parameters significantly under mild level of saline conditions in mung bean.

Kalaichelvi and Chinnusamy (2005) revealed that soil application of 40 kg ha^{-1} potassium humate to the preceding cotton increases the yield attributes characters like pods $plant^{-1}$ (19.3), grains per pod (7.2), grain yield $plant^{-1}$ (6.0 g) and grain yield (992 kg ha^{-1}) of black gram.

Gupta *et al.* (2007) revealed that yield responded linearly to successive increase in K application rate. Yields at 0, 20, 40, 60 kg K_2O ha^{-1} were 70, 80, 98, and 103 % above the zero K control in summer black gram.

Patil and Dhonde (2009) revealed that plant height, dry matter and grain yield were significantly higher in the treatment of 50 kg K_2O ha^{-1} applied in the soil with RDF at all the growth stages of summer green gram.

Singh *et al.* (2009) showed that plant height (64.3 cm), branches per plant (6.73), seeds per pod (5.02), pods per plant (63.5), test weight of 1000 grain weight (35.67g) and yield (10.06 q ha^{-1}) of black gram was significantly increased with 50 % K through wood ash plus 25% inorganic P than the 100% chemical fertilizer treatment.

Rao (2012) studied the impact of participatory site specific potassium management in green gram in Nalgonda region with low K fertility and showed that the SSNM of green gram brought about a mean yield increases from 0.54 mt ha^{-1} to 0.75 mt ha^{-1}. The yield of green gram responses varied from 18 to 44 % (Fertilizer given: Urea, MOP, and $ZnSO_4$: 50, 65, 50 kg ha^{-1} respectively).

Banik and Sengupta (2013) reported that in addition to potassium (N, P, K @ 20: 40: 40 kg/ha) application of sulphur recorded highest grain yield (1.11 t ha^{-1}) than the absolute control in green gram.

Shankar *et al.* (2013) reported that maximum grain yield was obtained by green gram due to integration of micronutrient i.e. NPK (13: 25: 25 kg ha^{-1}) + $ZnSO_4$ at 12.5 kg ha^{-1} + Borax at 10 kg ha^{-1} + Mo at 2 g kg^{-1} seed.

Thesiya *et al.* (2013) revealed that there was a significant effect of potash levels on plant height (55.45 cm), number of branches per plant (5.67), number of pods per plant (25.26), length of pod (4.83 cm), number of grains per pod (5.90), 100-grain weight (5.19 gm) and straw yield 18.28 q ha^{-1} with the application of 20 kg K_2O ha^{-1} in black gram.

Kumar *et al*. (2014) showed that potassium application up to 80 kg ha^{-1} significantly increased the growth parameters, i.e. plant height, plant canopy, number of trifoliate leaf $plant^{-1}$, number of branches $plant^{-1}$, number of nodules $plant^{-1}$ and total dry matter accumulation $plant^{-1}$ than control in mung bean.

2.1.2 Soybean

Nagre *et al.* (1991) observed that the height of the plant, number of branches and number of leaves per plant were significantly increased with the application of 40 + 30 + 30 kg NPK ha^{-1} over lower dose of 20 + 15 + 15 kg NPK ha^{-1}. Similarly a fertilizer level up to 40 + 30 + 30 NPK ha^{-1} showed significant favorable influence on yield attributes and grain yield of soybean.

Singh *et al.* (1993) conducted a pot culture experiment to evaluate the response of soybean to potassium nutrition. Due to K application significant increase in pods/plant observed up to 9.25 ppm K in agro climate zone III and IV of H.P while, in zone II and I up to 18.50 and 27.5 ppm respectively.

Annadurai *et al.* (1994) showed significant increase in grain and straw yield of soybean due to residual effect of K and 40 kg K_2O ha^{-1} was optimum dose for soybean.

Deshmukh *et al.* (1994) conducted a field experiment at two locations and reported that application of K up to 60 kg K_2O ha^{-1} produced favorable effects on the parameters including test weight and subsequently on soybean grain.

Grewal *et al.* (1994) conducted a field experiment on loamy sand soil involving four levels of K and four levels of N on soybean PK - 416. Soybean responds significantly to potassium up to 50 kg K_2O ha^{-1} with 60, 90, or 120 kg N ha^{-1}. Potassium and nitrogen increased leaf area index, chlorophyll contents of leaves, yield attributes and consequently seed yield.

Singh and Singh (1994) studied the effect of four graded levels of potassium (0, 40, 80, 120 kg K_2O ha^{-1}) increased grain yield of soybean. The result revealed that the grain yield increased significantly due to 120 kg K_2O ha^{-1} in first year and 40 kg K_2O ha^{-1} in second year crop.

Anuradha and Sharma (1995) reported that the seed yield of soybean was increased with applied potassium @ 50 kg ha^{-1} in Vertisol.

Rajagopal and Velu (1995) observed that the soybean responded to application of only up to 40 kg K_2O ha^{-1} and the magnitude of response was higher in *kharif* than *rabi*.

Mandal and Pramanik (1996) observed influence of potassium on yield parameters and seed yield of soybean. The highest yield was recorded with application of 80 kg K_2O ha^{-1}.

Singh *et al.* (1999) application of 30 kg K_2O ha^{-1} or N-K interaction significantly increased the nodule number and yield attributes in soybean.

Ravankar *et al.* (2000) revealed that the application of 150 percent recommended NPK + S + Zn to soybean recorded highest grain yield (23.23q ha^{-1}).

Billore *et al.* (2009) revealed that increase in seed yield of soybean over the control (1965 kg ha^{-1}) was 13.5, 25.2, 35.6% through the application of 16.6 kg K ha^{-1}, 33.2 kg K ha^{-1}, and 49.8 kg K ha^{-1} respectively, and also increase in yield attributing characters and root nodules parameters with the increasing levels of potassium.

Wan-Tai Yu *et al*. (2009) reported that maximum grain yield of soybean (2,424 kg ha^{-1}) were obtained in the plots under treatment with N, P, and K fertilizers (150, 25, 60 kg ha^{-1} as Urea, Double SSP, KCl) and recycled manure.

Farhad *et al.* (2010) reported that application of potassium @ 40 kg ha^{-1} produced the highest plant height (68.13 cm), 1000-seed weight (83.78 g) and seed yield (2.90 t ha^{-1}), in soybean.

Thenua *et al.* (2010) found that application of 40 kg K_2O ha $^{-1}$ recorded higher growth like plant height(43.80), branches per plant (32.16), yield attributes like pods per plant (51.43), pod yield (18.30 g $plant^{-1}$), and grain yield (1380 kg ha^{-1}) of soybean.

Sawarkar *et al*. (2013) revealed that grain yield of soybean (1.84 t ha^{-1}) obtained in 100% NPK (20: 80: 20 kg ha^{-1}) + FYM treatment was significantly higher than 150 % NPK treatment (1.56t ha^{-1}).

Singh and Singh (2013) concluded that higher number of pods (108.4), pod weight (39.7 g), number of grains (2.19), grain yield (25.1 q ha^{-1}) and straw yield (43.5 q ha^{-1}) was obtained with application of 20 kg N ha^{-1} at sowing + 10 kg N ha^{-1} at pod filling + 30 kg K_2O ha^{-1} at sowing in soybean.

Singh *et al.* (2013) found that yield attributes like pods per plant (145.1), seed plant $^{-1}$ (297.7), seed weight $plant^{-1}$ (39.6 g) and stover $plant^{-1}$ (62.8 g) and yield [seed (2.90 t ha^{-1}) and stover (4.57 t ha^{-1})] had the maximum value with the application of 15 - 13.1 - 16.6 NPK kg ha^{-1} + 5 t poultry manure in soybean.

2.1.3 Groundnut

Mandal and Goswami (1991) conducted a field experiment with three levels of K *viz*., 40, 80 and 120 kg K_2O ha^{-1} applied as a basal and split to groundnut.(Var. JL.24).Maximum pod yield of groundnut (14.18 q ha^{-1}) was observed when higher dose of potassium (80 kg ha^{-1}) applied in spilt.

Deshmukh *et al.* (1993) conducted a field experiment on Vertisol to study the influence of K fertilizer on yield quality and nutrient uptake by kharif groundnut. The pod and haulm yield of groundnut increased significantly with the application of K up to 40 kg K_2O ha^{-1} at sowing.

Deshmukh *et al.* (1993) reported the application of K up to 75 kg K_2O ha^{-1} produced significantly favorable effect on all growth and yield parameter expect height and shelling percentage. Yield of groundnut was improved by application of K up to 75 kg K_2O ha^{-1}.

Hameed Ansari *et al.* (1993) reported that application of potassium up to 45 kg ha^{-1} significantly improved the pod yield (3392 kg ha^{-1}) and its contributing characters compared to lower dose of 15 and 30 kg K ha^{-1}.

Mitra *et al.* (1993) reported that application of 40 kg K_2O ha^{-1} in addition to N-20 and P_2O_5-40 kg ha^{-1} to summer groundnut grown on the lateritic soils of Bhubaneswar significantly increased from 10.6 q ha^{-1} to 15.88 q ha^{-1}.

Basith *et al.* (1995) studied the response of groundnut genotypes in rainy season to varying levels of potash. The filled pods/plant, 100 kernel weight, pod and haulm yields were increased at 30 kg K_2O ha^{-1} over control.

Laximinarayana and Subbaiah (1995) observed in rainy season on coastal sand soil higher pod and haulm yields of groundnut with the application of 75 kg K_2O ha^{-1}, while lowest yields were recorded at control.

Patra *et al*. (1995) studied the influence of potassium fertilization in groundnut and showed that application of 50 kg K_2O ha^{-1} increased pod, kernel by 2.6, 3.2 percent in summer.

Balasubramanian and Palaniappan (1996) reported that application of N and K in two equal splits at basal and 45 DAS improved the yield of groundnut.

Lakshmanna *et al.* (1996) recorded increase in dry matter yield of groundnut due to Ca, P, and K application and there were 26.6, 29.2, 26.0, and 84.4 percent higher yields with Ca, P, K, and combined application of all these nutrients, respectively over control.

Patra *et al.* (1996) recorded that the application of 50 kg K_2O ha^{-1} significantly increased pod, seed and haulm yields of groundnut over control.

Ponnuswamy *et al*. (1996) reported that 150 % of the recommended dose of K (79 kg ha^{-1}) applied in two equal split viz, 50 percent at basal and remaining 50 percent at 40 DAS gave significantly higher dry pod yield of 2383 kg ha^{-1} in groundnut.

Sahu *et al.* (1996) found on a lateritic soil that application of potassium increased the yield, shelling outturn of groundnut .The pod yield from 14.68 q ha^{-1} to 18.7 q ha^{-1} with the application of 33 kg K ha^{-1}.

Singh and Vidya Chaudhari (1996) concluded that application of potassium at 100 kg ha^{-1} significantly increased the plant height, nodule weight, and pod number, pod and haulm yields of groundnut.

Golakiya (1999) studied the potassium fertilization of groundnut in summer season and revealed that pod yield increased by 36% with the application of 80 kg K_2O ha^{-1}.

Patra *et al.* (1999) observed that application of 50 kg K_2O ha^{-1} significantly increased the nodulation and pod production however it had no effect on shoot dry matter production in groundnut.

Subrahmaniyan *et al.* (2000) reported that application of NPK levels up to 100 % of the recommended dose of fertilizer (17: 34: 54 kg NPK ha^{-1}) gave significantly better effect on growth and yield parameters and pod yield of 1848 kg ha^{-1} of groundnut.

Laximinarayana (2001) showed that pod yield (2.13t ha^{-1}), haulm yield (2.67 t ha^{-1}), shelling % (68.5), test weight (32.1g), number of kernels pod^{-1} (1.86) and number of filled pods $plant^{-1}$ (10.07) of groundnut were significantly increase with the application of K @ 75 kg K_2O ha^{-1} in low potassium sandy soil.

Mitra *et al.* (2001) studied N-K interaction in alluvial soils for three years on the farmers field and showed that 60 kg K_2O ha^{-1} to groundnut to get significantly higher yield, (20.93 q ha^{-1}), shelling percentage (68%) and to prevent the depletion of K.

Mandal *et al.* (2002) reported that on an average, groundnut required 160-180 kg of N, 20-25 kg of P and 80-100 kg of K to produce 2.0 to 2.5 t ha^{-1} of economic yield.

Munda *et al.* (2004) observed increased branches per plant (10.1) and number of pods per plant (12.3) in groundnut as compared to control (9.9 and 9.2) when 20 : 60: 40 kg N, P_2O_5, K_2O ha^{-1} was applied.

Chitdeshwari *et al.* (2007) observed that application of 34: 64: 108 kg NPK ha^{-1} as three splits of N and K at basal (50% N and K), flowering (25% N and K) and peg formation stage (25% N and K) and 100 % P as basal were found to be optimum dose for getting the highest pod yield in groundnut.

Karunakaran *et al.* (2010) showed that the application of 125% RDF + 5 t ha^{-1} enriched compost increased the growth and attributes of groundnut that led to its significantly higher productivity (2.25 and 5.00 t ha^{-1} of mean pod, haulm yield) [RDF :17-34-54 kg N-P- K ha^{-1}].

Salve and Gunjal (2011) showed that the application of 30 and 45 kg K_2O were found to be at par with each other but significantly increased number of branches $plant^{-1}$, dry matter production $plant^{-1}$, root nodules and their weight $plant^{-1}$ at flowering and pod development stage in summer groundnut.

2.1.4 Pea and pigeon pea

Yadav *et al*. (1993) conducted a experimental research on the response of different crops to potassium on cultivars field in Uttar Pradesh under irrigated and rainfed conditions and revealed from 205 chickpea field trials in various district of Uttar Pradesh that application of 20 kg K_2O ha^{-1} increased the grain yield by 95 kg ha^{-1} over check K plots receiving only 20-40 kg N- P_2O_5 ha^{-1}. At the lowest K rate, 20kg K_2O ha^{-1}, the average chickpea grain yield response was 4 kg grain per kg K_2O.

Jamadagni and Birar (1994) concluded that grain yields of cowpea improved significantly up to 50 kg K_2O ha^{-1} on lateritic soils of Dapoli, Maharashtra.

Sood *et at.* (1996) revealed that the base yield of 707 Kg ha^{-1} could be increased to 1258 kg ha^{-1} with the application of 30 kg N + 60 kg P_2O_5 + 30 kg K_2O ha^{-1} in case of chickpea.

Singh and Prasad (1997) studied the differential response of three chickpea cultivar to three potash levels. Potassium application significantly increased dry matter production, grain yield and test weight over control.

PPII (1999) stated that variety of pigeon pea UPAS120 showed a 28 % yield increase, where variety S 5 showed a 16% yield increase to 20-40-20 kg N-P_2O_5-K_2O ha^{-1} over 20-40 kg N-P_2O_5 ha^{-1}.

Geetha and Varughese (2001) concluded that potassium at 20 kg ha^{-1} gave the maximum yield (9520 kg ha^{-1}) indicating the possibility of higher requirement of K for vegetable cowpea.

Kushwala (2001) concluded that application of 60 kg K_2O ha^{-1} to dwarf field pea produced significantly higher yield (3435 kg ha^{-1}) as compared to 0 kg K_2O and highest value for grain weight, pods and nodes /plant, seeds/pod ,100 seed weight were recorded with 60 kg ha^{-1} of K_2O application.

Panda *et al.* (2003) concluded that highest level of NK (100 kg ha^{-1}) to yambean-pigeon pea intercropping system registered the maximum plant height (45 cm), dry matter production (30.8 q ha^{-1}) number of pods per plant (23.8), number of seed per pod (25.1) and grain yield of succeeding mung (9.43q ha^{-1}) which was 33% higher than the control (N_0K_0). Panda *et al.*, (2003) further showed that the maximum grain yield of pigeon pea (14.38 q ha^{-1}, pooled), stick and bhusa yields were recorded with the application of 80 kg NK ha^{-1} in two splits of yam bean –pigeon pea intercropping system.

Balai *et al.* (2005) showed that the total number of nodules (22.8), number of effective nodules (17.25) and weight of effective nodules (29.2 mg), dry matter accumulation (5.7 g $plant^{-1}$), pods per plant (13.45), test weight (75.95 g) and seed yield (8.1 q ha^{-1}) of cowpea increased significantly with the levels of 40 kg K_2O ha^{-1}

Balai and Majumdar (2007) showed that the leg hemoglobin content of root nodules, phenol allantonic acid, urease and relative water content of cowpea leaves increased with the increased level of potassium application (0, 20, 40 kg K_2O ha^{-1}).

Meena *et al.* (2012) found that in pigeon pea ,application of fertilizer NPK at soil based recommended rates (60 :60 :40) produced 1.44 t ha^{-1} grain yield which was significantly higher as compared with unfertilized control. The highest grain yield (1.79 t ha^{-1}) was recorded with NPK+FYM (20: 20: 25 + 2.5 t ha^{-1}) in pigeon pea-wheat cropping system.

Tiwari *et al.* (2012) observed that increasing dose of potassium up to 60 kg K_2O ha^{-1} significantly increased grain and stover yields of pigeon pea. Mean yields of pigeon pea grain and stover were raised from 1,358 to 1764 and 5647 to 6594 kg ha^{-1}.

2.1.5 Other Crops

Kumar *et al.* (2004) concluded that application of 120 N: 60 P_2O_5, 45 K_2O kg ha^{-1} enhanced significantly the growth and all yield attributing characters of French bean like plant height (25.25 cm), number of pods per plant (7.40), weight of pod per plant (8.70), length of pod (9.20 cm), number of grain per pod (3.72) and 100 seed weight (42.42). The highest seed yield was 17.43 q ha^{-1} and straw yield was obtained 17.82 q ha^{-1}.

Mona *et al.* (2011) revealed that the addition of potassium through K_2SO_4 at the beginning of flowering stage shown significant increase in the plant height (115.0 cm), number of branches $plant^{-1}$ (6.35), number of pods $plant^{-1}$ (19.95), number of seeds $plant^{-1}$ (81.42), seed yield $plant^{-1}$ (96.805), 100-seed weight (118.705 g) of faba bean.

Sahay *et al.* (2013) showed improvement in the plant height (41.49 cm), branches per plant (7.57), dry matter accumulation (10.09 g), pods per plant (116.9), grain pod^{-1} (2.11), test weight (26.33 gm) and grain (19.07 q ha^{-1}) and straw yield (32.26 q ha^{-1}) of lentil with the application of 90 kg K_2O ha^{-1}.

2.2 Effect of levels of potassium on nutrient concentration and temporal changes during uptake of nutrients in critical growth stages

The different levels of applied potassium decide the quantity of uptake by crop. The present study was undertaken to see the effect of levels of potassium on its uptake at different critical growth stages of legumes crop. The pertaining literature in following paragraphs.

2.2.1 Green gram and Black gram

Kabir *et al.* (2004) concluded that the uptake of nutrients i.e. N, P, K showed an increasing tendency with the increased level of K (i.e. 14, 40, 60 kg ha^{-1}) in mung bean.

Gupta *et al.* (2007) revealed that successive increases in K application rate enhanced N uptake by 2 To 20%, P uptake by 5 to 22%, and K uptake by 8 to 33% compared to control in black gram (K application rate 0, 20, 40, 60 kg K_2O ha^{-1}).

Patil *et al.* (2011) studied the effect of potassium humate on nutrient uptake of black gram and recorded that potassium humate (1.0%) treated crops showed significant increased on calcium uptake (25 mg /100 g of dry matter), and phosphorous uptake (73.2 mg /100 g of dry matter) of black gram.

2.2.2 Soybean

Bansal (1992) conducted a long term fertilizer experiment on Vertisol and recorded the total uptake value for soybean were from 42.8 to 141 kg ha^{-1}.

Joshi and Rudradhya (1993) studied the uptake of K_2O by whole soybean plants and were able to utilize 39.8 % of applied K_2O at lower level of K dose (25 kg K_2O ha^{-1}) while at higher doses (75 kg K_2O ha^{-1}). The efficiency of root to adsorb and utilize K was to extent of and 71.7 percent.

Singh *et al.* (1993) reported that content and uptake of potassium by soybean plant was increased with increased level of K up to 37.00 ppm.

Annadurai *et al*. (1994) showed that the residual K had no effect on N and P uptake of soybean but it had significant effect on K uptake at 30 and 60 days after sowing.

Singh and Singh (1994) studied the uptake of Potassium by soybean. The application of 80 kg K_2O ha^{-1} significantly increased K uptake by grain and straw.

Hoeft *et al.* (2000) reported that young seedlings of soybean do not use of much potassium, but the rate of uptake climbs to a peak during the period of rapid vegetative growth. The potassium is transferred to seed during pod fill process. The mature seed contains nearly 60% of the total K in plant.

Ravankar *et al.* (2000) revealed that the application of 150 percent recommended NPK + S+ Zn to soybean recorded highest uptake of N (169.28 kg ha^{-1}), P (18.13 kg ha^{-1}), K (70.26 Kg ha^{-1}), S (13.10 kg ha^{-1}), Zn (117.18 g ha^{-1}).

Swarup *et al.* (2001) reported that 101 kg /ha of K has been removed in case of soybean in the state of Madhya Pradesh.

Bhattacharaya *et al.* (2008) showed that highest uptake of K of soybean was 83.4 kg ha^{-1} yr^{-1} observed in NPK+FYM treated plot (20 kg N + 35 kg P + 33.2 kg K + 10 t FYM ha^{-1}).

Billore *et al.* (2009) concluded that application of graded levels of potassium (0, 16.6, 33.2, 49.8 K kg ha^{-1}) led to an increase in total K uptake (23.45, 28.02, 31.62, 35.16 kg ha^{-1}) by soybean.

Wan –Tai Yu *et al.* (2009) reported that K concentration was greater in both grain yield (10.96 -11.91 g kg^{-1}) and straw (3.39 - 4.88 g kg^{-1}) of soybean where potassium is applied over control.

Patil *et al.* (2011) studied the effect of potassium humate on nutrient uptake of Soybean and observed that potassium humate (1.0%) treated crops showed a significant increased in calcium uptake (307 mg/100 g of dry matter), and phosphorous uptake (86 mg /100 g of dry matter).

Sawarkar *et al.* (2013) studied the effect of long-term application of inorganic fertilizers and organic manure on potassium uptake under soybean - wheat system and revealed that highest K uptake was observed in 100% NPK + FYM (136.8 kg ha^{-1}) followed by 150 % NPK (111.1 kg ha^{-1}) and lowest uptake in control plot (45.2 kg ha^{-1}) in soybean.

Singh *et al.* (2013) concluded that maximum N and P uptake was recorded with 15-13.1-16.6 kg NPK ha^{-1} + 5 t ha^{-1} poultry manure both in seed and stover of soybean.

Pande *et al*. (2014) reported that highest percentage of K in leaf (2.75%) was observed at the higher rate of foliar application (K_2SO_4 at rate of 2.5%) compared to control (1.90%). Nitrogen and Iron concentration in leaf tissue was also high in K foliar applications (K_2SO_4 at the rate of 1.75%) and K soil application (K_2SO_4 at the rate of 190 mg/kg) treated soybean plants.

2.2.3 Groundnut

Deshmukh *et al.* (1992) found that application of K increased N, P and K content in all parts at harvest stage. On an average 137.3, 16.6 and 63.34 kg N, P, K ha^{-1}, respectively were removed by groundnut crop.

Deshmukh *et al.* (1993) recorded that the uptake of NPK was increased in groundnut at 40 kg K_2O ha^{-1} level when full dose of K was applied at sowing followed by application of 75 % at sowing plus 25 percent K at flowering.

Basith *et al*. (1995) observed that potassium application significantly increased uptake of N and P up to 30 kg K_2O ha^{-1} but K uptake by groundnut plant continued to increased up to the applied level of 90 kg K_2O ha^{-1} with significant response being between 30 and 90 kg K_2O ha^{-1}.

Balasubramanian and Palaniappan (1996) reported that application of N and K in two equal splits at basal and 45 DAS improved the nutrient uptake of groundnut.

Zharare (1996) demonstrated that potassium application increased the nitrogen uptake but did not affect the uptake of phosphorous and potassium in groundnut.

Laximinarayana (2001) showed that application of potassium up to 75 kg K_2O ha^{-1} causes a significant increase in N (2.46%), K(2.15%) and Zn (92 mg kg^{-1}) at mid flowering of groundnut and significant increase in the concentration of N (3.39%), P (0.52%), K (0.94%), Ca (0.64%), Mg (0.19%), Fe (79 mg kg^{-1}) and Cu (32 mg kg^{-1}) in kernels.

Dutta *et al.* (2003) reported that the potassium content both in kernel and haulm was significantly increased by increased potassium application and highest was observed at 50 kg K_2O ha^{-1}. Application of graded levels of potassium produced notable difference in uptake of N, P, K and the increase was significant at higher dose of potassium application (50 kg K_2O ha^{-1}) in groundnut.

Chitdeshwari *et al*. (2007) reported that increasing levels of the respective nutrients (34: 64: 108 kg NPK ha^{-1}) increased the nutrient content in groundnut and uptake.

Viradiya *et al.* (2008) studied the effect of potassium and salinity levels on nutrient concentration of groundnut and showed that application of K (0 to 100 kg K_2O ha^{-1}) significantly increased the concentration of N (0.79 to 0.81%), P (0.16 to 0.22%), K (0.82 to 0.98%), Ca (0.62 to 0.81%) and Mg (0.50% to 0.64%) in groundnut.

Salve and Gunjal (2011) concluded that the uptake of N (162.70, 174.84, 180.76 kg ha^{-1}), P (19.82, 22.53, 24.20 kg ha^{-1}), K (74.22, 79.87, 83.16 kg ha^{-1}) with the increased graded levels of potassium (15, 30, 45 kg ha^{-1} K_2O) respectively in groundnut.

2.2.4 Pigeon pea and pea

Patil *et al.*(2011) revealed that significantly higher total uptake of N (173.02 kg ha^{-1}), P (12.13 kg ha^{-1}), K (99.26 kg ha^{-1}), Ca (22.86 kg ha^{-1}), Mg (10.64 kg ha^{-1}) and S (9.68 kg ha^{-1}) was recorded with the treatment N : P_2O_5 :K_2O @ 30 :50: 30 kg ha^{-1} along with seed inoculation by cowpea.

Sepehya (2012) concluded that integrated nutrient management through application of FYM in combination with 75 % NPK enhanced N, P, and K uptake (101.5%, 21.2%, and 61.2% respectively) by garden pea as compared to organics or 100% NPK alone.

Tiwari *et al.* (2012) reported that K content in grain and stover of pigeon pea increased with the use of K (K_0, K_{20}, K_{40}, K_{60}, K_{80} kg K_2O ha^{-1}) over the control. K content ranged from 1.53 to 1.58 percent in the grain but only from 2.51 to 2.56 percent in the stover (when treatment includes K_0 to K_{80}. The removal of K increased as yield increased, up to 194 kg K_2O ha (K_{80}).

2.2.5 Other crops

Singh *et al*. (1995) concluded significant increase in potassium uptake of French bean when potassium was applied @ 60 kg $ha^{-1.}$

Rao *et al.* (2012) studied the potassium uptake by tap and lateral roots of different aged fababean. The time course of K uptake was near linear (R_2=0.97-0.99) for the period between 5 min to 60 min of incubation. Potassium uptake was close to linearity in 0.01 mM to 0.1mM range of external K. At higher concentration i.e. from 0.01mM to 10 mM uptake rates tended to decline. Uptake of K by tap roots was higher than that by an equivalent mass of lateral roots.

Ram *et al.* (2013) found that maximum uptake of nutrients (N, P, K, and S) was recorded with N, P, K and S (20, 17, 20, 20 kg ha^{-1}) + vermicompost @ 2 t ha^{-1} to the tune of 138.3, 252.0 , 149.1 and 196.3% over absolute control respectively in lentil.

Sahay *et al.* (2013) concluded that uptake of N, P, K in lentil grain and straw increased significantly with the increasing level of K. The N, P, K uptake by grain (67.2, 5.8, 18.0 kg ha^{-1}) and straw (36.4, 4.2, 61.2 kg ha^{-1}) is highest with the application of 90 kg K_2O ha^{-1}.

2.3 Effect of levels of potassium on quality

Potassium has been described as the “quality element” for crop production (Usherwood 1985; Pettigrew 2000). The research work done on quality attributes like protein have been reviewed and presented below.

2.3.1 Black gram

Asghar *et al.* (1994) revealed that application of 75 kg K_2O in addition to 25 and 75 kg N and P_2O_5 ha^{-1} showed a significant increase in protein content (28.3%) in black gram.

2.3.2 Soybean

Deshmukh *et al.* (1993) conducted a field experiment at two locations Akola and Amravati on Vertisol and observed that K levels had significant positive effect of protein of soybean. The maximum protein content was recorded at 90 kg K_2O at both locations while highest protein yield was obtained at 60 and 90 kg K_2O ha^{-1} at Amravati and Akola respectively.

Anuradha and Sarma (1995) reported that potassium at higher levels improved protein content of soybean in Vertisol.

Billore *et al.* (2009) showed that significant increase in protein content in seed (15.48%) was observed up to 33.3 kg K ha^{-1} in soybean.

Farad *et al.* (2010) reported that application of potassium @ 40 kg ha^{-1} resulted in highest protein content (42.22 %) in soybean than control (K_0).

Pande *et al*. (2014) showed a significant increase in seed protein (42.40%) was found in soil application of K (K_2SO_4 @ 190 mg kg^{-1}) in soybean.

2.3.3 Groundnut

Basith *et al.* (1995) studied the response of groundnut genotypes to varying levels of potassium. It is observed that application of increasing levels of Potash showed positive influence of protein of kernel up to 60 kg K_2O ha^{-1} (23.44%).

Lakhsmanna *et al.* (1996) noticed that the application of K increased the protein contents in groundnut.

Salve and Gunjal (2011) revealed that application of 30 and 45 kg K_2O ha^{-1} were found to be at par with each other but significantly increased protein content (25.35 and 25.48 % respectively) as compared to application of 15 kg K_2O (25.13 %) in groundnut.

2.3.4 Pigeon pea

Tiwari *et al.* (2012) reported that protein content of pigeon pea was increased significantly by K application. Protein content in pigeon pea grain increased from 21.01% in the control to 29.95 % at the highest K treatment, (80 kg K_2O ha^{-1})

2.3.5 Others crop

Singh *et al.* (1995) observed that crude protein content in French bean increased with increasing K levels but not to the significant level. However, protein harvest significantly enhanced due to potassium application up to 60 kg $ha^{-1.}$

Mona *et al.* (2011) showed that highest protein content (28.20%) of fababean was recorded with application of potassium sulphate after 3-4 weeks of sowing.

Ayub *et al.* (2012) showed that the crude protein content (18.35%) of cluster bean showed a steady increase up to 80-85 kg PK ha^{-1}.

Sahay *et al.* (2013) concluded that the protein content in lentil grain was significantly influenced by the application of K. The protein increased from 21.58% to 22.01% in grain with 90 kg K_2O ha^{-1}.

2.4 Effect of levels of potassium in soil potassium dynamics at critical growth stages of crop

Potassium is one of the major nutrients for crops. Bansal and Umar (1998) estimated that a total of 13.7 million tonnes of K_2O per year is removed by crops in India against the present fertilizer consumption of only 1.57 million tonnes of K_2O. After considering all the organic and inorganic additions, and deficit of 7.049 million tones K_2O per year has been estimated which means a depletion of India soils at the rate of 37.5 kg K_2O $ha^{-1}year^{-1}$. Therefore the reviewed of Potassium dynamics of soil are given below:

2.4.1 Green gram

Chatterjee and Mandal (1996) studying the potassium nutrition under intensive cropping system in Entisol of West Bengal, observed that any reduction in the recommended dose without compensating through organic matter/manure, resulted in depletion of soil available K at 0-15 cm soil depth. At 150% of the recommended dose, the available K status improved in 0-15 cm soil depth in rice - potato - mungbean and in 0-15 and 15-30 cm depth in rice – potato - groundnut system. The non-exchangeable K in 0-15 cm soil depth of rice-potato-mungbean and rice - potato-groundnut was also reduced in all the treatments but the depletion was low whenever organic matter/manure or 150% recommended dose of K were added. Even the non-exchangeable K at 15-30 cm soil depth also got depleted similarly.

Bhuma and selvakumari (2003) conducted a field experiment using potassium with greengram revealed the beneficial effect of potassium humate in enhancing the availability of nutrients to the plants. The treatment S_6 (30 kg ha^{-1} humic acid) at M_2 (recommended dose of fertilizer) register the highest carbon content of 0.53% in green gram with 9% more over the RDF (0.44%).Soil application of humic acid along with RDF exhibited a distinct improvement in the available N, P, K over RDF alone. The availability of secondary nutrients and micronutrients were also favorably influenced by the conjoint application of humic acid and mineral fertilizer.

2.4.2 Soybean

Kundu *et al.* (1990) conducted a long term field experiment on soybean - wheat cropping sequence and recorded that the depletion of available and non-exchangeable K in soil profile varied from 5.4 to 148.5 and 96 .0 to 522.8 kg K ha^{-1} profile applications.

Sharma and Dixit (1994) observed that the grain yield of soybean was significantly related with water soluble, exchangeable, non-exchangeable, total as well as available K which were increased by 54.1, 9.1, 3.6, 7.7, and 0.7 percent after the harvest of the crop when potassium is applied @ 60 kg ha^{-1}

Ved Prakash *et al.* (2001) found that the values of net depletion of K (sum total of available and non exchangeable K) from soil profile after 27 cropping cycles of soybean-wheat were quantitatively much higher than the expected K depletion values (based on K input - output balance sheet) suggesting considerable loss of K from soil profile.

Rupa *et al*. (2003) studied that in soybean and wheat cropping systems, irrespective of the treatments, potassium was depleted significantly in all the plots under intensive cropping, thereby indicating a state of continuous stress on soil system to meet the K requirements of the crops.

Bhattacharaya *et al*. (2008) concluded that the total removal of K by the crops exceeded K applied to the soil in all the treatments showing a net negative K balance, from 3.7 (in NK-treated plots) to 81.7 kg $ha^{-1}yr^{-1}$ (in N + FYM treated plots).Continuous application of recommended doses of NPK + 10 t FYM annually to soybean result in buildup of available K (+56 kg K ha^{-1}) in 0-45 cm soil depth over the initial soil value despite the highest average annual uptake by the system (150.8 kg $ha^{-1}yr^{-1}$) whereas, there was net depletion of available K(-80 kg K ha^{-1}) in 0-45 cm depth under the NPK -treated plots. The non-exchangeable K decreased substantially from 1274 to 1052 kg ha^{-1} in the NPK treatment and to 986 kg ha^{-1}in 0-15 cm soil layer in NPK + FYM treatment after 30 years of soybean-wheat cropping. The decrease in total soil K was significantly correlated to decrease in non-exchangeable soil K.

Wan –Tai Yu *et al.* (2009) studied the effects of nutrient cycling on grain yields and potassium balance and showed after 18 years of Soybean-maize rotation, treatment with treatment with N, P, and K fertilizers appreciably improved the fertility level of the soil, increased the concentration of soil exchangeable K, and decreased the non-exchangeable K concentration. In soils under treatment with N, P, and K fertilizers and recycled manure, the soil-exchangeable and non-exchangeable K levels in the 0–20 cm deep soil layer increased by 34% and 2%, respectively, over the initial levels. Both soil-exchangeable and non-exchangeable K concentrations were the highest with on treatment with N, P, and K fertilizers and recycled manure, followed by treatment with N, P, and K fertilizers. These concentrations were lowest in unfertilized soil; the other treatments yielded intermediate results. The results showed a total removal of K by the crops, and the amount removed exceeded the amount of K added to the soil; in treatments that did not include K fertilizers, a net negative K balance was observed, from 184 to 575 kg ha^{-1}.

Sawarkar *et al.*(2013) showed that available - K was found to be maximum with 100% NPK + FYM (295.2 kg ha-1) followed 150 % NPK (284.2 kg ha-1).moreover ,K fractions (water soluble - K, exchangeable - K, non-exchangeable - K, lattice - K, and total - K) were significantly decreased with increasing soil depth. All the K fractions at 0-20 cm soil depth exhibited significant and positive correlation with yield. Minimum depletion of K rate was recorded in 100%NPK + FYM (-2.08 kg $ha^{-1}yr^{-1}$) to that of treatments, while control showed maximum K depletion rate (-4.65 kg $ha^{-1}yr^{-1}$). Apparent K balance in soil was lowest (-58.6 kg $ha^{-1}yr^{-1)}$ in control plot followed by (100.2 kg $ha^{-1}yr^{-1}$) in treatment 100%NPK + FYM in soybean-wheat cropping system [100%NPK=20:80:20 kg ha^{-1}].

2.4.3 Groundnut

Jadhav *et al.* (1992) recorded decline in K availability in groundnut - sorghum cropping system and observed that available K increased with K fertilizer application.

Patel *et al.* (1993) observed that if intensive cropping continued without K additions the available K in more calcareous clay will be exhausted considerably in all the treatments and more so in NP treatments. It was indicated that a close correlation between net removal of K by groundnut - wheat - jowar sequence and decrease in non exchangeable K, showed that the crop had to depend on soil reserve K in the absence of optimum solution K.

2.4.4 Pigeon pea

Tiwari *et al.* (2012) reported that K balance in all treatments was negative, ranging from almost 200 (K=0) to 100 (K=80) kg K_2O $year^{-1}$. It also indicates that even at the high rate K application; there is still significant K mining from soil in pigeon pea-mustard crop rotation system.

CHAPTER-III

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season 2012-2013 to study the effect of potassium on growth, yield and uptake of nutrients in green gram at departmental farm of Soil Science and Agril. Chemistry, VNMKV, Parbhani. The details of materials used and methods adopted during the course of present investigation are explained in this chapter with appropriate heads.

3.1 Experimental site

The present experiment was undertaken at research farm of Soil Science and Agril. Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experimental site lies between 19^0 $60^,$ North latitude and 76^0 $47^,$ East longitude which is 423.46 meters above mean sea level. Topographically experimental plot was fairly levelled. The soil was well drained, developed over weathered basaltic materials.

3.2 Experimental soil

Taxonomically soil is classified as mixed montomorillonite hyperthermic Typic Haplusterts. Further, these soils constitute bulk iron ores along with traces of zircon, tourmaline, feldspar, quarts, muscovite, pyrites and pyroxenes (Maniyar, 1979).The experimental soil had clay texture, moderately calcareous in nature and slightly alkaline in reaction, normal in salt content. Before sowing, initial soil sample was collected randomly from 0-15 cm depth covering experimental area which was analysed for various physico-chemical characteristics and data are presented in Table 3.1.

3.3 Climate and weather condition

The average rainfall on the basis of annual rainfall of the region is 830 mm and region comes under assured rainfall zone. The rainfall mostly concentrated during the monsoon months from June to September.

The meteorological data i.e. variation in rainfall distribution, temperature and atmospheric humidity which was recorded at Agricultural Meteorological Observatory, VNMKV presented in Table 3.2. The data revealed that total rainfall received during crop growth period was 642.3 mm.

The mean maximum and minimum temperature varied between 33.3^{0}C and 21.7^{0}C, respectively. However, mean relative humidity was found in the wider range of 82 % to 93% as minimum and maximum, respectively.

Table 3.1 Initial physico-chemical properties of experimental soil.

Sr. No	Soil characteristics	Unit	Value
1	pH (2.5)	-	7.84
2	EC (2.5)	dSm^{-1}	0.286
3	Organic carbon	$g\ kg^{-1}$	7.7
4	$CaCO_3$	$g\ kg^{-1}$	48
5	Available nitrogen (N)	$kg\ ha^{-1}$	159.58
6	Available phosphorous (P_2O_5)	$kg\ ha^{-1}$	7.01
7	Available potassium (K_2O)	$kg\ ha^{-1}$	841.71
8	Available iron (Fe)	$mg\ kg^{-1}$	3.36
9	Available zinc (Zn)	$mg\ kg^{-1}$	0.60
10	Available manganese (Mn)	$mg\ kg^{-1}$	8.10
11	Available copper (Cu)	$mg\ kg^{-1}$	1.98

Table 3.2 Metrological data from June to October, 2013, recorded at Agricultural Meteorological Observatory, VNMKV, Parbhani.

MW	Period	Rainfall (mm)	Rainy Days.	Temparature ^{0}C		Humidity (%)		EVP	Bright sunshine hours	Wind Velocity (Kmph)
				Max	Min	AM	PM			
24	11-17June	29.2	2.0	31.4	22.9	86	66	4.3	1.8	6.8
25	18-24June	24	1.0	33.3	23.0	85	61	5.4	6.0	7.1
26	25-1July	41.8	3.0	30.1	25.5	85	64	4.7	2.9	6.2
27	2-8July	80.1	4.0	32.1	22.6	92	62	5.1	5.4	5.9
28	09-15July	96.4	4.0	29.2	22.7	90	79	3.4	2.2	4.5
29	16-22July	154	5.0	26.7	22	93	84	2.9	0.8	5.7
30	23-29July	50.5	2.0	29.4	22.6	86	65	3.7	2.5	5.3
31	30-05Aug	77.5	3.0	28.3	21.8	91	75	3.5	2.8	6.5
32	06-12 Aug	19.7	2.0	29.8	22.5	89	67	4.6	3.2	4.7
33	13-19Aug	59.8	4.0	30.5	22.7	91	65	3.6	4.2	4.3
34	20-26Aug	9.3	2.0	28.5	21.7	89	71	4.3	1.5	7.2
35	27-02sep	0.0	0.0	31.0	22.9	82	59	3.6	5.7	3.9

3.4 Experimental details

The experiment was laid out in Randomised Block Design (RBD) with 8 treatments and replicated thrice. The green gram was sown on 16th June 2013 by adopting 30 cm X 5 cm spacing and was harvested on 28th august 2013 at maturity. The green gram variety BM 04 was used. The treatment details are given below

3.4.1 Treatment details

T_1 Absolute control (No fertilizer application)

T_2 Recommended dose of fertilizer RDF (20:50 N and P_2O_5 kg ha^{-1})

T_3 RDF + 25 kg K_2O ha^{-1}

T_4 RDF + 50 kg K_2O ha^{-1}

T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient (soil application)

T_6 RDF + 50kg K_2O ha^{-1} + Grade I micronutrient (soil application)

T_7 RDF + 25kg K_2O ha^{-1} + Grade II 0.5% foliar spray

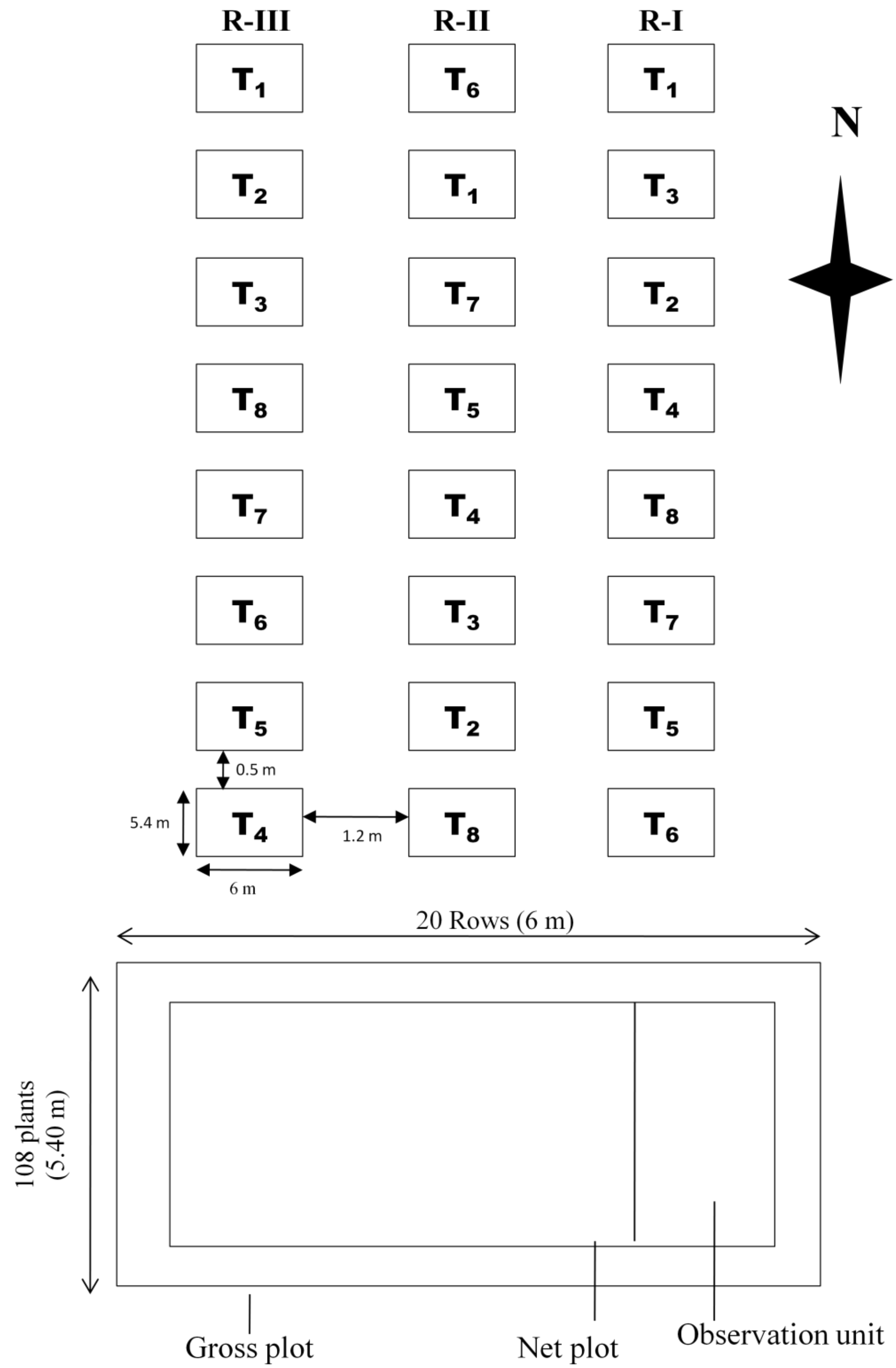
T_8 RDF + 50kg K_2O ha^{-1} + Grade II 0.5% foliar spray

Where,

Composition of Grade I micronutrient soil application: Fe - 2%, Zn - 5%, Mn - 1%, B - 1%, Cu - 0.5%.

Composition of Grade II micronutrient foliar spray: Zn - 3%, Fe - 2.5%, Mn - 1%, Cu - 1%, B - 0.5%, Mo - 0.1%.

Basal dose of RDF i.e. 20: 50 N and P_2O_5 kg ha^{-1} and K_2O as per treatment was applied at the treatment at the time of sowing (before sowing). The quantity of fertilizers applied per plot as per the treatments are given in Table 3.3.



Gross plot	: 6.40 m x 5.40 m
Net plot size	: 4.2 m x 5.35 m
Observation unit	: 1.5 m x 5.35 m

Plan of layout and Observation Unit

Plate I. General view of experimental field during *kharif* 2013

(T$_1$) Absolute control

(T$_2$) RDF (20:50 N and P_2O_5 kg/ha)

(T$_3$) RDF + 25 kg K_2O/ha

(T$_4$) RDF + 50 kg K_2O/ha

Plate II. Experimental field plots with different treatments

(T$_5$) RDF + 25 kg ha^{-1} K_2O + Grade I micronutrient

(T$_6$) RDF + 50kg ha^{-1} K_2O + Grade I micronutrient

(T$_7$) RDF + 25 kg ha^{-1} K_2O + Grade II micronutrient 0.5% foliar spray

(T$_8$) RDF + 50 kg ha^{-1} K_2O + Grade II micronutrient 0.5% foliar spray

Plate III. Experimental field plots with different treatments

Table 3.3 Quantity of nutrient applied in each plot

Treatment	Urea (g)	DAP (g)	MOP (g)	Micronutrient Grade I (g)	Micronutrient Grade II
T_1 Absolute control	-	-	-	-	-
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	40	351.5	-	-	-
T_3 RDF + 25 kg K_2O ha^{-1}	40	351.5	134	-	-
T_4 RDF + 50 kg K_2O ha^{-1}	40	351.5	268	-	-
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	40	351.5	134	81	-
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I Micronutrient	40	351.5	268	81	-
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II 0.5% foliar spray	40	351.5	134	-	0.5% (50 gm in 10 L)
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II 0.5% foliar spray	40	351.5	268	-	0.5% (50 gm in 10 L)

The calculated amount of K as Muriate of Potash (MOP) and recommended dose of N and P was applied as Urea, and DAP and grade I micronutrient was applied at the time of sowing. Grade II (0.5 %) micronutrient was applied as a foliar spray after 40 days after sowing (DAS).

3.4.2 Seed and sowing

Green gram variety BM - 04 was selected for kharif season for present investigation. The germination test out was carried out before sowing (90% germination).The sowing was done by line showing maintained the spacing of 30 cm from row to row. Gap filling was done wherever it is necessary to maintain the plant population in each plot, and the plant to plant distance was 5 cm. Periodical intercultural operations like thinning, weeding were carried out and treatment plots were maintained for good crop environment. As a plant protection measures i.e. application of choloropyriphos (15 ml of 10 L) were sprayed to get rid of the insect attack in the plots.

3.5 Other details

3.5.1 Soil and plant sample collection

Green gram plant samples (5 plants from each observation unit of treatment plot) were uprooted at critical growth stage i.e. flowering (30 days) pod development (45 days) and harvesting stage (74 days) for chemical analysis. At the same time, soil samples from each plot were also collected to study the plant nutrient content.

3.5.2 Biometric observations

Observations on the crop characteristics indicating growth of the crop i.e. plant height, number of nodules per plant, pods per plant were recorded at the critical growth stages of the crop i.e. flowering, pod development and at harvesting stage from the plants, uprooted from observation unit.

3.5.3 Height of the plant

It was measured in cm with the help of meter scale from the base of the plant i.e. from ground level to base of the terminal bud of main shoot, and observations were recorded.

3.5.4 Leaf area

The leaves from each plant were categorized viz., small, medium, and large, and it was measured with the help of meter scale and then multiplied with the leaf area constant (0.66).

3.5.5 Nodulation

Five plants from observation unit plot were randomly removed with the help of the fork without damaging the roots at flowering, pod development and harvesting stage of green gram. The roots were washed carefully to remove the soil stucking to them and nodules were counted.

3.5.6 Dry matter per plant:

Five plants uprooted from the observation unit for recording the dry matter studies and after removing the roots, plant samples were kept in well labelled brown paper bag. First the samples are dried in shade and after that kept in oven at $65^0C \pm 2^0C$, and then weight of dry matter was taken and expressed on per plant basis.

3.5.7 Total number of pods per plant

Number of pods from five selected plants were counted and an average number of pods per plant were worked out.

3.5.8 Seed yield

The plants from each net plot were harvested and seeds were separated by threshing, after sun drying the pods seed yields obtained in each net plot were weighted (kg) and further it was calculated on the hectare basis (kg ha^{-1}).

3.6 Estimation of Leghemoglobin content:

Materials and reagents required

1. Diluent buffer:0.1M sodium/potassium phosphate buffer (pH 7.4)
2. Alkaline pyridine reagent: Dissolve 0.8 g NaOH in 50 ml water and cool. Add 33.8 ml of pyridine (33.2g) dissolve and dilute to100ml with water. This produces 4.2M pyridine in 0.2 M NaOH
3. Sodium dithionate : Grind finely and store in small stopped tubes in a desiccators
4. Potassium hexacynoferrate

Procedure

1. Extraction: Mix fresh and thawed nodules with 1-3 volumes of phosphate buffer and macerate in a mixer. Filter through two layers of cheese cloth. Discard the nodule debris. Clarify the turbid reddish brown filtrate by centrifugation at 10,000 for 10-30 min. Dilute suitably
2. To a suitable volume (2 to 5ml) of the extract add an equal volume of alkaline pyridine reagent and mix. The solution becomes grennish yellow due to formation of ferric hemochrome
3. Divide the hemochrome equally between two tubes
4. To one portion add a few crystals of sodium dithionate to reduce the hemochrome. Stir without aeration
5. Read at 556nm after 2-5 min against a reagent blank
6. To the other potion add a few crystals of potassium hexacynaferrate to oxide the hemochrome and read at 539 nm
7. Calculate A_{556} minus A_{539}

Calculation:

$$\text{Lb concentration (mg/g)} = \frac{(A_{556} - A_{539}) \times 2D}{23.4}$$

2D = Dilution factor.

3.7 Soil analysis

Surface soil samples (0-30 cm) were collected from different plots of the layout and were thoroughly mixed, air dried and ground with wooden mortar and pestle and passed through 2mm sieve. The sieved sample was stored in bag with proper labelling. The methods given below adopted for analysis of physico-chemical properties of soil.

3.7.1 Soil reaction (pH)

It was determined in 1: 2.5 Soil: Water Suspension using digital pH meter (Jackson, 1973).

3.7.2 Electrical conductivity (EC)

It was estimated in (1: 2.5) Soil: Water suspension using direct read type conductivity meter (Jackson, 1973).

3.7.3 Organic carbon

Walkley and Black's wet digestion method was used for the determination of organic carbon from soil (Jackson, 1973).

3.7.4 Free calcium carbonate

It was determined by rapid titration method as suggested by Piper (1966).

3.7.5 Available soil nitrogen

It was determined by using alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.7.6 Available soil phosphorous

Phosphorous from soil was extracted by 0.5 M sodium bicarbonate at a constant pH 8.5 and measured colorimetrically at 420 nm as described by Olsen (Olsen *et al.*, 1954).

3.7.7 Available soil potassium

It was determined by using neutral normal ammonium acetate as an extractant using flame photometer (Jackson, 1973).

3.7.8 Available Micronutrients

It was determined by using DTPA extractant as described by Lindsay and Norvell (1978) by using AAS (Parkin Elmer AAnalyst 200 model)

3.8 Plant analysis

3.8.1 Preparation of Plant samples.

For the determination of nutrient contents in plant samples, the samples were collected at different growth stages of the crop. First of all the fresh plants were washed with tap water and roots were discarded. Preparation of plants samples are carried out first by sun drying and then oven drying. The dried samples were ground in electrically operated stainless steel grinder to maximum fineness. All the precautions were taken to avoid the contamination from other plant materials. The ground plant materials were stored in the paper bags and used for further chemical analysis.

3.8.2 Digestion

0.5 g of fine powdered plant sample was taken in 100 ml conical flask.5 ml concentrated nitric acid added to it and kept for over night. On the next day, 10 ml of diacid mixture (HNO_3 and $HClO_4$ in 9:4) was added and digested in hot plate as described by Piper (1966). After digestion, known volume was prepared with glass distilled water and filtered. The same extract was used for the estimation of P, K, Fe, Zn, Cu and Mn.

3.8.3 Nitrogen concentration

Total Nitrogen in plant and seeds were determined by micro-kjeldhal's method as described in A.O.A.C (1975). One gram of plant/defatted seed sample was digested with 1 g K_2SO_4, 0.5 g $CuSO_4.5H_2O$ and 25 ml H_2SO_4 and then it was distilled with 40 % NaOH. The distillate was collected in a beaker containing 4 % boric acid. The methyl red and bromocresol green indicator was used. The contents were back titrated with 0.1 N H_2S0_4 until pink colour was obtained.

3.8.4 Phosphorous concentration

The digest prepared with diacid mixture was used for determination of phosphorous by using vanadomolybdate solution. The phosphorous was estimated by vanadomolybdophosphoric acid yellow colour method prepared using spectrophotometer, Jackson (1973). The intensity of yellow colour was measured on at 420 nm wavelength.

3.8.5 Potassium concentration

The diacid extract was used for potassium determination. It was determined on flame photometer as suggested by Jackson (1973).

3.8.6 Total micronutrient (Fe, Zn, Cu and Mn)

It was determined by using plant digestion obtained from digestion by HNO_3 and $HClO_4$ and measurements were taken on an atomic absorption spectrophotometer as described by Lindsay and Norvell (1978).

3.9 Analysis for quality parameters.

3.9.1 Protein content

The nitrogen content from the grain samples was estimated by Microkjeldhals method (AOAC. 1975) and N content was multiplied by 6.25 to get percent crude protein.

3.9.2 Seed index

The weight of 100 seeds of green gram from each net plot was recorded and designated as seed index of green gram.

3.10 Uptake of nutrients

Nutrient uptake i.e. uptake of N, P, K, Fe, Zn Cu, Mn was calculated by considering grain and dry matter yield at harvest in particular treatment plot in relation concentration of the particular nutrient in respective treatment plot using the formula.

$$\text{Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration \% X (dry matter yield (kg ha}^{-1}\text{)}}{100}$$

3.11 Economics in terms of green gram

Economics of cultivation was worked out as per the following formulae.

Gross Monetary Returns (GMR) = Yield X selling price of green gram.

Net Monetary Returns (NMR) = GMR – Cost of cultivation

$$\text{Benefit Cost Ratio (B: C Ratio)} = \frac{\text{NMR}}{\text{COC}} \text{ X 100}$$

Where,

GMR - Gross monetary return.

NMR - Net monetary return.

B : C - Benefit cost ratio.

3.12 Statistical Analysis

The data obtained from growth parameters, yield attributing characters, quality parameters, soil analysis and plant analysis was complied and statically analysed as per the method given in “Statistical Methods for Agricultural Workers” by Panse and Sukhatme (1985) using computer programme. Appropriate Standard Errors (SE) were worked out. Critical differences (C.D.) at 5 % and CV were calculated and presented in chapter results and discussion.

CHAPTER IV

RESULT AND DISCUSSION

The present investigation was undertaken to study the effect of potassium on growth, yield and uptake of nutrients in green gram .The results obtained in respect of various growth and quality parameters and nutrient uptake under various treatments are presented, interpreted and discussed in this chapter under following subheads.

4.1 Initial nutrient status of the experimental soil.

4.2 Effect of graded levels of potassium on germination and final plant stand.

4.3 Effect of graded levels potassium on growth parameters and grain yield of green gram.

4.3.1 Effect of levels of potassium on plant height.

4.3.2 Effect of levels of potassium on leaf area.

4.3.3 Effect of levels of potassium on number of flowers and pods per plant.

4.3.4 Effect of levels of potassium on number of nodules per plant.

4.3.5 Effect of levels of potassium on fresh weight of nodules per plant.

4.3.6 Effect of levels of potassium on total biomass production (g $plant^{-1}$)

4.3.7 Effect of levels of potassium levels on dry matter (kg ha^{-1}).

4.3.8 Effect of levels potassium on Economic yield of green gram.

4.3.9 Effect of levels potassium on leghemoglobin (mg g^{-1}) content of green gram

4.4 Effect of graded levels of potassium on quality parameters of green gram.

4.4.1 Effect of levels of potassium on protein and seed index.

4.5 Effect of Graded Levels of Potassium on Plant Nutrient Concentration at Critical Growth Stages

4.5.1 Effect of levels of potassium on nitrogen concentration at critical growth stages.

4.5.2 Effect of levels of potassium on phosphorous concentration at critical growth stages.

4.5.3 Effect of levels of potassium on potassium concentration at critical growth stages.

4.5.4 Effect of levels of potassium on micronutrient concentration (Fe, Zn, Cu, Mn) at critical growth stages.

4.6 Nutrient status of the experimental soil at various crop growth stages

4.7 Effect of graded levels of potassium nutrient uptake by green gram

4.7.1 Effect of graded levels of potassium on N uptake.

4.7.2 Effect of graded levels of potassium on P uptake.

4.7.3 Effect of graded levels of potassium levels on K uptake.

4.7.4 Effect of graded levels of potassium on micronutrients (Fe, Zn, Cu, Mn) uptake.

4.8 Economics of green gram

4.1 Initial nutrient status of the experimental soil

The soil analysis of the treatment plots were carried out before the establishment of field experiment and at the harvest of the crop. The data thereof are presented in Table 4.1.

Table 4.1 Soil properties of the experimental soil before sowing and after harvest of crop.

Treatments	**pH**	**EC (dSm^{-1})**	**Organic Carbon ($g\ kg^{-1}$)**	**$CaCO_3$ ($g\ kg^{-1}$)**
Initial				
Before Sowing	7.84	0.286	7.7	48
After harvest				
T_1 Absolute control (No fertilizer)	7.61	0.269	8.00	53.37
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	7.79	0.264	7.60	52.85
T_3 RDF + 25 kg K_2O ha^{-1}	7.60	0.262	7.90	54.05
T_4 RDF + 50 kg K_2O ha^{-1}	7.82	0.267	7.87	55.60
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	7.72	0.264	7.40	59.30
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	7.79	0.258	8.23	61.33
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	7.57	0.271	7.67	55.66
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	7.65	0.273	8.47	59.39
Grand Mean	7.69	0.265	7.89	56.44
SEm±	0.06	0.003	0.25	2.07
CD at 5%	NS	NS	0.78	NS

The experiment was conducted on research farm of Department of soil science and agricultural chemistry, College of Agriculture, VNMKV, Parbhani. The experimental soil was fine, smectitic calcareous, iso-hyperthermic Typic Haplusterts. The soil was alkaline in reaction ($pH_{2.5}$, 7.84), safe in soluble salt concentration ($EC_{2.5}$ 0.206 dSm^{-1}) and high in organic content (7.7 g kg^{-1}). However, there was increase in organic carbon due to application of the treatment. The free $CaCO_3$ content was 48 g per kg. At harvest, pH, EC, and $CaCO_3$ were not influenced significantly due to application of various levels of graded potassium. The organic carbon content was varied inconsistently due to the application of the fertilizers. The mean calcium carbonate after harvest of crop was 56.44 g kg^{-1} which was found to be increased by 0.8 %, that seems to be very negligible. It was obvious that the primary soil properties like pH, EC, OC, $CaCO_3$, content could not change significantly due to one crop season, as black soils are lightly buffered.

4.2 Effect of graded levels of potassium on germination and final plant stand.

The data on germination count and final plant stand at harvest are presented in Table 4.2. From the table it was observed that germination of green gram varied from 1989 (92%) to 2097 (97%) and final plant stand varied between 1790.67 (83%) to 1888 (87%) plants but no significant variation was observed. This showed that there was no population bias in expression of treatments effects. Panse and Sukhatme (1985) reported that plant population of the field experiment must be non - significant so as to get clear effect of treatments administered.

Table 4. 2 Effect of graded levels of potassium on germination and final plant stand.

Treatments	**Plant Population**	
	Germination count	**Final plant stand**
T_1 Absolute control (No fertilizer)	1989.00 (92%)	1790.67 (83%)
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	1995.00 (92.36%)	1798.67 (83.27%)
T_3 RDF + 25 kg K_2O ha^{-1}	2022.00 (93.61%)	1820.33 (84.25%)
T_4 RDF + 50 kg K_2O ha^{-1}	2007.33 (92.93%)	1806.33 (83.26%)
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	2048.00 (94.81%)	1843.67 (85.35%)
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	2078.67 (96.23%)	1871.00 (86.62%)
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	2097.33 (97%)	1888.00 (87%)
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	2068.33 (96%)	1862.00 (86.20%)
Grand Mean	2038.20	1835.08
SEm±	113.87	97.14
CD at 5%	NS	NS
CV %	9.68	9.17

4.3 Effect of graded levels of potassium on growth parameters and grain yield.

4.3.1 Effect of levels of potassium on plant height.

The height of green gram was monitored throughout the growth period of crop. Periodical observations recorded on various dates under different potassium level treatments are presented in Table 4.3. It was observed that there was continuous increase in plant height throughout growth period of crop due to each additional nutrients application (25.80 cm to 55.61 cm). Significant variation was observed on the plant height at green gram at all the stages. The plant height was significantly highest in treatment RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) (43.46 cm) at flowering stage, whereas treatment RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8) had significantly highest height at pod development (57.16 cm) and harvesting stage (67.04 cm).

Table 4.3 Effect of levels of potassium on plant height.

Treatments	Plant Height (cm)			Mean
	Flowering	Pod development	Harvest	
T_1 Absolute control (No fertilizer)	17.83	28.38	31.20	25.80
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1}	35.50	49.57	54.67	46.58
T_3 RDF + 25 kg K_2O ha^{-1}	37.47	52.77	57.67	49.30
T_4 RDF + 50 kg K_2O ha^{-1}	41.37	55.21	63.74	53.44
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	39.96	53.67	60.67	51.4
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	43.46	56.25	65.64	55.12
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	40.20	54.13	62.43	52.25
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	42.35	57.46	67.04	55.61
Grand Mean	37.28	50.92	58.13	-
SEm ±	2.560	2.41	2.71	-
CD at 5%	7.766	7.32	8.22	-
CV %	11.9	8.21	8.08	-

However, minimum height was observed in controlled treatment at all the growth stages. The increase in plant height could be partly being attributed due to the beneficial effect of potash fertilization. Potash is known to augment cell division and cell expansion resulting in increasing positive effect of growth parameter. The highest plant height may be due to the positive effects of potassium and micronutrients on the vegetative growth and accumulation of metabolic materials. Patil and Dhonde (2009) showed that the maximum height was obtained with the application of 50 kg K_2O ha^{-1} in green gram respectively. Similar findings were obtained by Sahay *et al.*, (2013) in lentil, Billore *et al*., (2009) in soybean.

4.3.2 Effect of levels of potassium on leaf area.

Leaf area is one of the important attributes that influences the growth and development of crop. Therefore, the measurement of leaf area was carried out in all observations during growth cycle of green gram. The data pertaining to this observation are presented Table 4.4.

Table 4.4 Effect of levels of potassium on leaf area.

Treatments	**Leaf area(cm^2)**		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (No fertilizer)	74.44	85.67	78.97
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	81.13	106.00	89.30
T_3 RDF + 25 kg K_2O ha^{-1}	82.42	124.66	116.15
T_4 RDF + 50 kg K_2O ha^{-1}	87.93	133.66	125.32
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient.	84.37	127.65	119.99
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient.	88.80	138.34	128.39
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient.	86.26	128.88	120.65
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient.	90.50	141.16	129.65
Grand Mean	84.11	123.25	113.55
SEm±	3.16	5.71	5.319
CD at 5%	9.58	17.32	16.13
CV %	6.51	8.03	8.11

In this table it was clearly indicated that leaf area showed increasing tendency up to pod development stage and thereafter it was declining. Application of all the treatments recorded significantly higher leaf area over control (T_1) at flowering stage except RDF (T_2) and RDF + 25 kg K_2O ha^{-1}(T_3). Whereas, application of all the treatments significantly increased leaf area over control (T_1) and RDF (T_2) i.e. without K at pod development and harvesting stage. The application of RDF + 50 K_2O kg ha^{-1} + Grade II (0.5%) micronutrient (T_8) showed the maximum leaf area in flowering stage (90.50 cm^2), pod development stage (141.16 cm^2) and at harvest (129.65 cm^2).These result opined that the inclusion of potassium in recommended dose (N and P) has synergistic effects.

4.3.3 Effect of levels of potassium on number of flowers and pods of per plant

The Table 4.5 represents the effects of potassium levels on number of flowers and pods per plant.

Table 4.5 Effect of levels of potassium on number of flowers and pods per plant.

Treatments	**Number of flowers and pods per plant**		
	Flowering (Flowers)	**Pod development (Pods)**	**Harvest (Pods)**
T_1 Absolute control (No fertilizer)	6.60	5.53	5.50
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1}	11.30	9.93	8.48
T_3 RDF + 25 kg K_2O kg ha^{-1}	12.50	10.60	10.85
T_4 RDF + 50 kg K_2O kg ha^{-1}	13.68	10.39	11.60
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	15.49	11.26	11.05
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	16.32	12.54	12.10
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	14.36	11.02	10.90
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	15.82	11.33	11.20
Grand mean	12.38	10.33	10.19
SEm±	1.02	0.66	0.595
CD at 5%	3.12	2.00	1.80
CV %	13.33	11.07	10.66

The application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) (16.32, 12.54, 12.10) recorded the highest number of flowers and pods at all the stages followed by application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_8) (15.82, 11.33, 11.20) at flowering, pod development and harvest. Improvement of pod bearing capacity of crop could be possibly be because of improved N and P fertilization efficiency in the presence of K. Increase rate of photosynthetic and symbiotic activity following balanced application of NPK stimulated better vegetative and reproductive growth of the crop resulting in higher green pod yield. Thenua *et al.*, (2010) reported that application of 40 kg K_2O ha^{-1} recorded higher pod yield in soybean. Similar observation was reported by Thesiya *et al.*, (2013) in black gram, Kushwala (2001) in field pea and Asghar *et al*., (1994) in blackgram.

4.3.4 Effect of levels of potassium on number of nodules per plant

The data on number of nodules per plant under graded levels of potassium presented in Table No 4.6.

Table 4.6 Effect of levels of potassium on number of nodules per plant

Treatments	Number of nodules per plant		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (No fertilizer)	54.00	35.27	28.79
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	67.00	47.46	48.10
T_3 RDF + 25 kg K_2O ha^{-1}	74.66	50.15	49.97
T_4 RDF + 50 kg K_2O ha^{-1}	85.00	67.48	57.25
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	82.97	65.19	54.16
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	88.33	73.05	60.33
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	82.67	64.14	52.73
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	84	72.92	59.85
Grand mean	77.32	59.46	51.38
SEm±	3.64	2.86	2.49
CD at 5%	11.05	8.64	7.56
CV %	8.16	8.34	8.4

The data on nodulation of green gram revealed that there was significant variation in nodule number at all the stages. Results showed that treatment at RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient produced highest number of nodules (88.33, 73.05, 60.33) per plant followed by treatment RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (84, 72.92, 59.85) and treatment RDF + 50 kg K_2O ha^{-1} (85.00, 67.48, 57.25) at flowering, pod development and harvesting stage respectively. This may be due to the application of potassium in various levels. Potassium is required by adenosine S-triphosphate phosphohydrolase (ATP ase) for the movement of sugars from the apoplast between the cells of the phloem. In depth scrutiny of data influenced by growth stages showed that there was continuous decrease in number of nodules per plant from flowering (77.32) to harvest (51.38). The study by Collins and Duke (1981) on composition of the effects of K and N_2 fixation and photosynthesis in a legume found that potassium was found to have large effect on nodulation and N_2 fixation. Highest number of nodules was observed at 45 kg K_2O ha^{-1} in groundnut by Salve and Gunjal (2011). Similar findings reported by Patra *et al.,* (1999) in groundnut.

4.3.5 Effect of levels of potassium on fresh weight of nodules per plant

Periodical observations recorded for nodules weight on various dates under different potassium level treatments are presented in Table 4.7.

It was observed that there was continuous decrease in nodules weight throughout growth period of crop (0.708 g to 0.359 g). Over all significant variations were observed for nodules weight at all growth stages. Combination of recommended dose of fertilizer along with 50 kg K_2O and Grade I micronutrient (T_6) recorded highest fresh nodule weight $plant^{-1}$ (0.93, 0.70, 0.55 g $plant^{-1}$) in flowering, pod development and harvesting stages, respectively. Similar observations were found by Balai *et al.,* (2005) in cowpea, Kushwala (2001) in field pea.

Table 4.7 Effect of levels of potassium on fresh weight of nodules per plant

Treatments	Fresh weight of nodules(g plant $^{-1}$)		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (No fertilizer)	0.43	0.31	0.13
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	0.53	0.36	0.24
T_3 RDF + 25 kg K_2O ha^{-1}	0.62	0.42	0.30
T_4 RDF + 50 kg K_2O ha^{-1}	0.84	0.65	0.46
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	0.76	0.46	0.38
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	0.89	0.70	0.55
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	0.72	0.44	0.36
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	0.87	0.68	0.44
Mean	0.708	0.501	0.359
SEm±	0.045	0.028	0.022
CD at 5%	0.141	0.08	0.068
CV %	11.38	9.79	10.9

4.3.6 Effect of levels of potassium on total biomass production (g plant $^{-1}$)

The data of total biomass yield per plant of green gram under various potassium levels are presented in Table 4.8. The data indicated the periodical increase in total biomass of green gram. The average increase in biomass recovery was from 2.58 g plant^{-1} to 9.61 g plant^{-1} from flowering to harvesting stages of the crop. The accumulation of biomass was relatively more at the later part of the crop. This may be attributed to the productive phases of green gram. Results indicate, that the significant increase of biomass was recorded with the application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6; 3.57, 7.47, 15.32 g plant^{-1}) followed by application RDF + 50 kg K_2O ha^{-1} + Grade II micronutrient (T_8; 3.32, 7.38, 12.40 g plant $^{-1}$) in flowering, pod development, harvesting respectively which were found to be statistically at par with only at flowering and pod development stages with treatment. This may be due to the effect of both potassium and micronutrients. Potassium plays a major role in growth as it is involved in assimilation, transport, and storage tissue development (Cakmak 2005). Balai *et al.*, (2005) found that highest dry matter accumulation g plant^{-1} was obtained by 40 kg K_20 ha^{-1} in Cowpea and Salve and Gunjal (2011) found the similar result in groundnut.

Table 4.8 Effect of levels of potassium on total biomass production (g plant^{-1})

Treatments	Biomass production (g plant $^{-1}$)		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (No fertilizer)	1.49	2.78	4.21
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	2.02	4.50	7.18
T_3 RDF + 25 kg K_2O kg ha^{-1}	2.10	4.67	7.72
T_4 RDF + 50 kg K_2O kg ha^{-1}	2.99	6.34	11.57
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	2.76	6.31	9.38
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	3.57	7.47	15.32
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	2.42	6.09	9.11
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	3.32	7.38	12.40
Grand mean	2.58	5.69	9.61
SEm±	0.15	0.35	0.61
CD at 5%	0.48	1.06	1.86
CV %	10.63	10.69	10.92

4.3.7 Effect of levels of potassium on dry matter (kg ha^{-1}) production

The data on dry matter production (kg ha^{-1}) at different critical growth stages are presented in Table 4.9 and Fig 4.1. The results revealed that various levels of potassium application resulted in increase in mean dry matter yield with advancement in crop growth stages i.e. from flowering (1462.19 kg ha^{-1}) to harvest (3292.78 kg ha^{-1}). The mean dry matter was found to be highest due to application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) (1980.36, 3029.27, 3994.37 kg ha^{-1}) which was significantly higher than other treatments at all growth stages .At these stages, RDF + 50 kg K_2O kg ha^{-1} + Grade I micronutrient (T_6) and RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient (T_8) were found to be at par. This is due to effect of K nutrition on cell elongation, turger potential in leaves. Such results were also observed in soybean plants as by Mengal and Arneke (1982). Patil and Dhonde (2009) observed that highest dry matter kg ha^{-1} with the application of 50 kg K_2O ha^{-1} in green gram.

Table 4.9 Effect of levels of potassium on dry matter (kg ha^{-1}) production

Treatments	Dry matter (kg ha^{-1})		
	Flowering	Pod development	Harvest
T_1 Absolute control (No fertilizer)	755.64	1070.98	1750.83
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	1161.92	2041.74	3123.54
T_3 RDF + 25 kg K_2O ha^{-1}	1205.07	2369.44	3429.81
T_4 RDF + 50 kg K_2O ha^{-1}	1715.50	2746.47	3641.70
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	1585.94	3244.28	3385.45
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	1980.36	3029.27	3994.37
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	1388.16	2479.75	3480.29
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	1904.95	2841.75	3521.24
Grand mean	1462.19	2477.96	3290.90
SEm±	82.31	143.23	179.67
CD at 5%	249.71	434.49	545.03
CV %	9.75	10.01	9.45

4.3.8 Effect of levels of potassium on Economic yield of green gram

Application of RDF + 50 K_2O kg ha^{-1} + Grade I (0.5%) micronutrient (T_6) was recorded highest seed yield per plant (2.26 g $plant^{-1}$) which was significant higher over control (T_1; 1.08 g $plant^{-1}$) and application of RDF (T_2; 1.65 g $plant^{-1}$). Similarly followed by treatment receiving RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8; 2.25 g $plant^{-1}$) and RDF + 50 kg K_2O ha^{-1} (T_4; 2.08 g $plant^{-1}$) also had higher grain yield per plant.

The data on economic yield of green gram (grain yield) under various graded levels of potassium are presented in Table 4.10 and Fig 4.2. The grain yield was lowest (550.50 kg ha^{-1}) in unfertilized plot (T_1) while yield was improved in nutrient added plots. Potassium application showed significant increase in grain yield of green gram in all the treatments over control (T_1) and RDF (T_2). The highest yield was obtained by the application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6: 1210.22 kg ha^{-1}) followed by RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient ($T_{8;}$ 1160 kg ha^{-1}), and RDF + 50 kg K_2O ha^{-1} ($T_{4\,;}$ 1110.10 kg ha^{-1}) which are at par with each other. It was observed that, the application of potassium (50 kg K_2O ha^{-1} + Grade I micronutrient) increased the grain yield of green gram over control (no application of any fertilizer) by 119.84% and grain yield was increased over RDF (no application of K) by 42.68%. The one year data showed that application of 25 kg and 50 kg K_2O recorded statistically on par grain yield. The positive effect of K on crop yield might also be due to its requirement in carbohydrate synthesis and translocation of photosynthesis and also may be due to improved yield attributing characters, shoot growth and nodulation. Billore *et al.,* (2009) observed seed yield of soybean increase 35.6 % over control with the application of 49.8 kg K ha^{-1}.Similar findings were observed by Thesiya *et al.,* (2013) in lentil, Patil and Dhonde (2009) in green gram, Salve and Gunjal (2011) in groundnut, Balai *et al*., (2005).

Table 4.10 Effect of levels of potassium on economic yield of green gram

Treatments	**Economic yield**	
	g plant $^{-1}$	**kg ha^{-1}**
T_1 Absolute control (No fertilizer)	1.08	550.50
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	1.65	848.48
T_3 RDF + 25 kg K_2O ha^{-1}	2.13	1110.10
T_4 RDF + 50 kg K_2O ha^{-1}	2.08	1102.80
T_5RDF +25 kg K_2O ha^{-1} + Grade I micronutrient	2.01	1060.61
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	2.26	1210.22
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	2.02	1090.76
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	2.25	1160.50
Grand Mean	1.93	1016.74
SEm±	0.11	59.54
CD at 5%	0.34	180.64
CV %	10.15	10.14

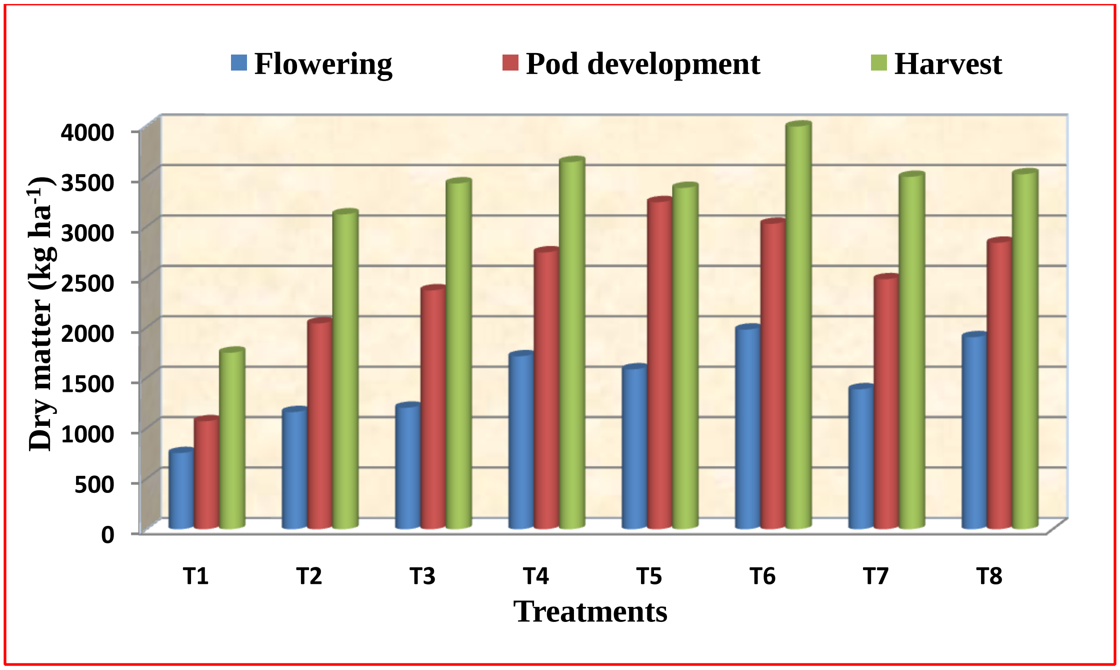


Fig 4.1 Effect of levels of potassium on dry matter (kg ha^{-1}) production.

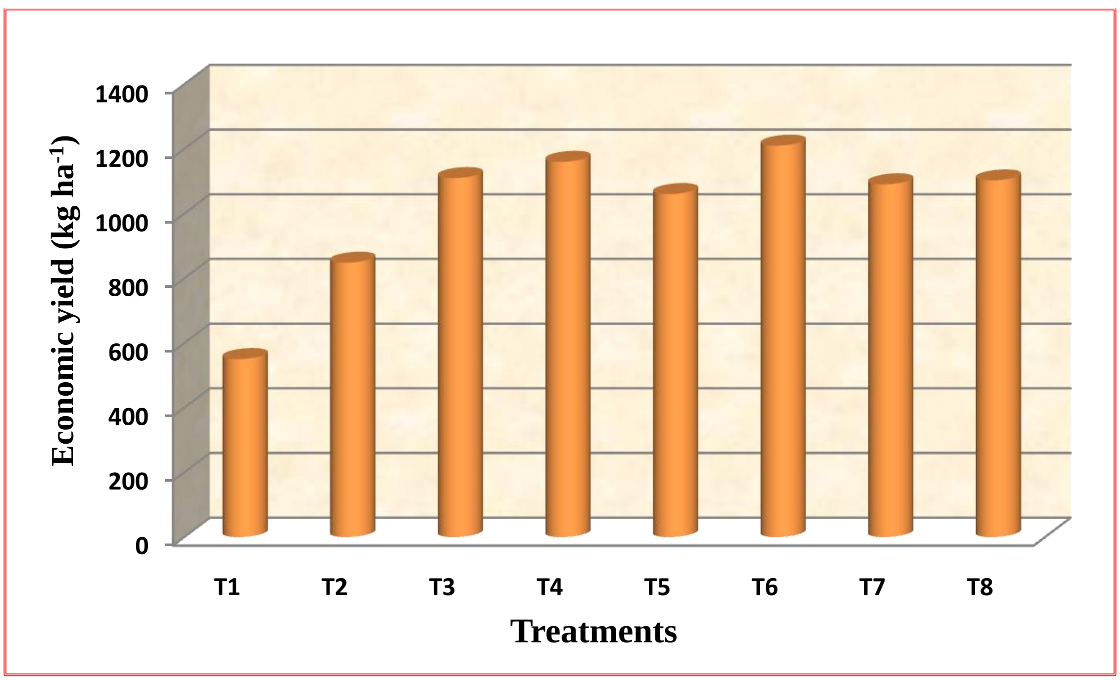


Fig 4.2 Effect of levels of potassium on Economic yield (kg ha^{-1}) of green gram.

(T_1) Absolute control

(T_2) RDF (20:50 N and P_2O_5 kg ha^{-1})

(T_3) RDF + 25 kg K_2O ha^{-1}

(T_4) RDF + 50 kg K_2O ha^{-1}

(T_5) RDF + 25 kg ha^{-1} K_2O + Grade I micronutrient

(T_6) RDF + 50 kg ha^{-1} K_2O + Grade I micronutrient

(T_7) RDF + 25 kg ha^{-1} K_2O + Grade II 0.5% foliar spray

(T_8) RDF + 50 kg ha^{-1} K_2O + Grade II 0.5% foliar spray

Plate IV. Effects of potassium on various treatments

4.3.9 Effect of levels of potassium on leghemoglobin (mg g^{-1}) content of green gram

Leghemoglobin content of legumes suggest the health of nodule or health of crop. In present study the leghemoglobin content of green gram was determined and data are presented in Table 4.11. From the table it was observed that leghemoglobin content was varied from 0.66 mg g^{-1} to 0.71 mg g^{-1} with an average of 0.69 mg g^{-1}. There was increase of leghemoglobin content from 0.66 mg g^{-1} to 0.71 mg g^{-1} due to K application. Even though, no significant variation was observed due to potassium application.

Table 4.11 Effect of levels of potassium on leghemoglobin (mg g^{-1}) content

Treatments	**Lb (mg g^{-1})**
T_1 Absolute control (No fertilizer)	0.66
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	0.68
T_3 RDF + 25 kg K_2O ha^{-1}	0.70
T_4 RDF + 50 kg K_2O ha^{-1}	0.71
T_5RDF +25 kg K_2O ha^{-1}+Grade I micronutrient	0.70
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	0.70
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	0.71
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	0.71
Grand mean	0.69
SEm±	0.015
CD at 5%	NS

4.4 Effect of graded levels of potassium on quality parameters of green gram

4.4.1 Effect of levels of potassium levels on protein and seed index

The protein content and seed index of green gram under various potassium levels are presented in Table 4.11. The data revealed that protein content showed some amount of variation among different treatments. The highest protein content 19.21% was recorded by application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8) (19.21%), followed by RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6, 19.16 %) and

RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient ($T_{7;}$ 19.09 %). Potassium involved in physiological and biochemical functions of plant growth i.e. enzyme activation and protein synthesis and its application in legumes might have improved the nitrogen use efficiency which leads to increase the protein content of the crop. Similar findings were obtained by *Farad et al.*, (2010), and Salve and Gunjal (2011).

Table 4.12 Effect of levels of potassium on protein and seed index

Treatments	Quality parameters	
	Seed Index (gm)	**Protein (%)**
T_1 Absolute control (No fertilizer)	4.44	17.27
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	4.70	18.13
T_3 RDF + 25 kg K_2O ha^{-1}	4.80	18.18
T_4 RDF + 50 kg K_2O ha^{-1}	5.04	19.00
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	4.83	18.79
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	4.63	19.16
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	5.05	19.09
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	5.19	19.21
Grand mean	4.83	18.06
SEm±	0.13	0.39
CD at 5%	0.40	1.19
CV %	4.82	3.67

The significant increase in seed index was observed due to application of various levels of potassium. The highest seed index was obtained (5.19 g) by the application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8) which is significantly higher over control (T_1 ; 4.44 g), RDF ($T_{2;}$ 4.70 g) and RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient(T_6 , 4.63 g) while, rest of the treatments were at par with each other. The higher level of K supplied sufficient K to plants which initiated maximum translocation of photosynthatse to fruiting zone. Similar findings were obtained by Thesiya *et al*., (2013) in lentil and Thenua *et al*., (2010) in soybean.

The data presented on growth parameters and grain yield and quality parameters of green gram under various graded levels of potassium presented in Table 4.2 to 4.12 and interpreted in above paragraphs showed that in general , that application of graded levels of potassium with recommended dose of N and P_2O_5 (25 : 50 kg ha^{-1}) recorded increase in yield. Treatment T_6 comprises recommended dose of N (25 kg N ha^{-1}) and P (50 kg P_2O_5 ha^{-1}) with 50 kg K_2O and Grade I micronutrient fertilizer application produced 1210.22 kg ha^{-1} grain yield and found at par with all the treatments receiving potassium. However, it is significantly superior over absolute control and recommended dose 25 : 50 kg N and P_2O_5 (without K application). Addition of potassium either 25 or 50 kg ha^{-1} recorded significant improvement in yield and all parameters contributing grain yield ,biomass yield and quality. The grain yield of green gram further increased with addition of micronutrient grade I fertilizer and foliar spraying of Grade II micronutrient fertilizer.

It is also reported that application of potassium increase the absorption of nitrogen and the N use efficiency. This results in to improvement in growth, yield and quality of crop.

4.5 Effect of graded levels of potassium on plant nutrient concentration at critical growth stages

4.5.1 Effect of levels of potassium on nitrogen concentration at critical growth stages

From the data presented in Table 4.12 and Fig 4.3 it was revealed that application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) significantly increased the N concentration in plant and seed. Significant differences in N concentration in plants were noticed with application graded doses of K at all the critical growth stages. N concentration was found to be highest in (T_6) RDF + 50 kg K_2O ha^{-1} + Grade I micronutrients at flowering, pod development, harvest and in seed (2.89, 2.80, 2.56, 3.87% respectively) followed by T_8 RDF + 50 kg K_2O ha^{-1} + Grade II micronutrient (2.86, 2.78, 2.52, 3.85% N) which was significantly superior over control (T_1) and RDF (T_2) at respective growth stages.

The nitrogen concentration in green gram plant was highest at flowering stage and decline at harvest of the crop but the concentration was higher in grain. This trend may be due to high mobility of the nitrogen from vegetative tissues to reproductive organs after flowering stages. Similar results were observed by Kherawat *et al.,* (2013) in clusterbean, Ramswaroop meena, (2013) in green gram and Laxminarayana (2001) in groundnut.

Table 4.13 Effect of levels of potassium on nitrogen concentration at critical growth stages

Treatments	N concentration (%)			
	Flowering	**Pod development**	**Harvesting**	**Seed**
T_1 Absolute control (No fertilizer)	1.85	1.83	1.13	2.78
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	2.05	1.61	1.54	3.38
T_3 RDF + 25 kg K_2O ha^{-1}	2.38	2.27	1.84	3.42
T_4 RDF + 50 kg K_2O ha^{-1}	2.76	2.53	2.49	3.65
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrients	2.48	2.37	2.09	3.58
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	2.89	2.80	2.56	3.87
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	2.82	2.42	2.25	3.61
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	2.86	2.78	2.52	3.85
Grand mean	2.51	2.33	2.05	3.51
SEm ±	0.058	0.053	0.047	0.06
CD at 5%	0.18	0.16	0.14	0.19
CV %	3.12	4.11	4.02	3.18

4.5.2 Effect of levels of potassium on phosphorous concentration at critical growth stage

The data on phosphorous in plant concentration are presented in Table 4.13 and Fig 4.4. There was increase in P content in different plant parts with increasing levels of potassium application. Maximum phosphorous content was found in RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient at flowering and pod development stages. Further, phosphorous concentration was highest in application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrients (T_6) in plant at harvesting stages in plant (0.39%) and in seed

(0.63%). However, treatment differences could not reach to the level of significance. Similar results were observed by Kherawat *et al.*, (2013) in clusterbean, Ramswaroop meena, (2013) in green gram.

Table 4.14 Effect of levels of potassium on phosphorous concentration at critical growth stages

Treatments	**P concentration (%)**			
	Flowering	**Pod development**	**Harvesting**	**Seed**
T_1 Absolute control (No fertilizer)	0.38	0.36	0.28	0.52
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	0.40	0.42	0.30	0.57
T_3 RDF + 25 kg K_2O ha^{-1}	0.40	0.41	0.31	0.51
T_4 RDF + 50 kg K_2O ha^{-1}	0.46	0.40	0.35	0.59
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	0.42	0.36	0.33	0.58
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	0.48	0.42	0.39	0.63
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	0.43	0.39	0.34	0.54
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	0.49	0.45	0.36	0.61
Grand mean	0.43	0.40	0.33	0.57
SEm ±	0.03	0.02	0.02	0.007
CD at 5%	0.12	0.09	0.09	0.024
CV %	3.45	4.27	5.31	3.02

4.5.3 Effect of levels of potassium on potassium concentration at critical growth stages

The data on potassium concentration in plant due to application of different graded levels of K are presented in Table 4.14 and Fig 4.5. The maximum potassium concentration was recorded with the application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8) followed by application RDF + 50 kg K_2O ha^{-1} + Grade I micronutrients (T_6) at flowering, pod development and harvesting in plant and seed which was significantly higher than control (T_1) and RDF (T_2) at flowering and pod development stage. This may be due to the synergistic effects of potassium with other nutrients. Similar results were observed by Ramswaroop meena, (2013) in green gram and Laxminarayana (2001) in groundnut.

Table 4.15 Effect of levels of potassium on potassium concentration at critical growth stages

Treatments	**K concentration (%)**			
	Flowering	**Pod development**	**Harvesting**	**Seed**
T_1 Absolute control (No fertilizer)	1.80	1.21	1.15	2.43
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	1.90	1.23	1.19	2.54
T_3 RDF + 25 kg K_2O ha^{-1}	2.13	1.49	1.27	2.56
T_4 RDF + 50 kg K_2O ha^{-1}	2.41	1.83	1.49	2.65
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	2.32	1.59	1.83	2.59
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	2.60	1.98	1.59	2.68
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	2.36	1.66	1.98	2.64
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	2.62	2.11	1.66	2.71
Grand mean	2.26	1.638	1.39	2.60
SEm ±	0.04	0.03	0.03	0.03
CD at 5%	0.12	0.11	0.09	0.09
CV %	3.13	3.99	3.84	3.35

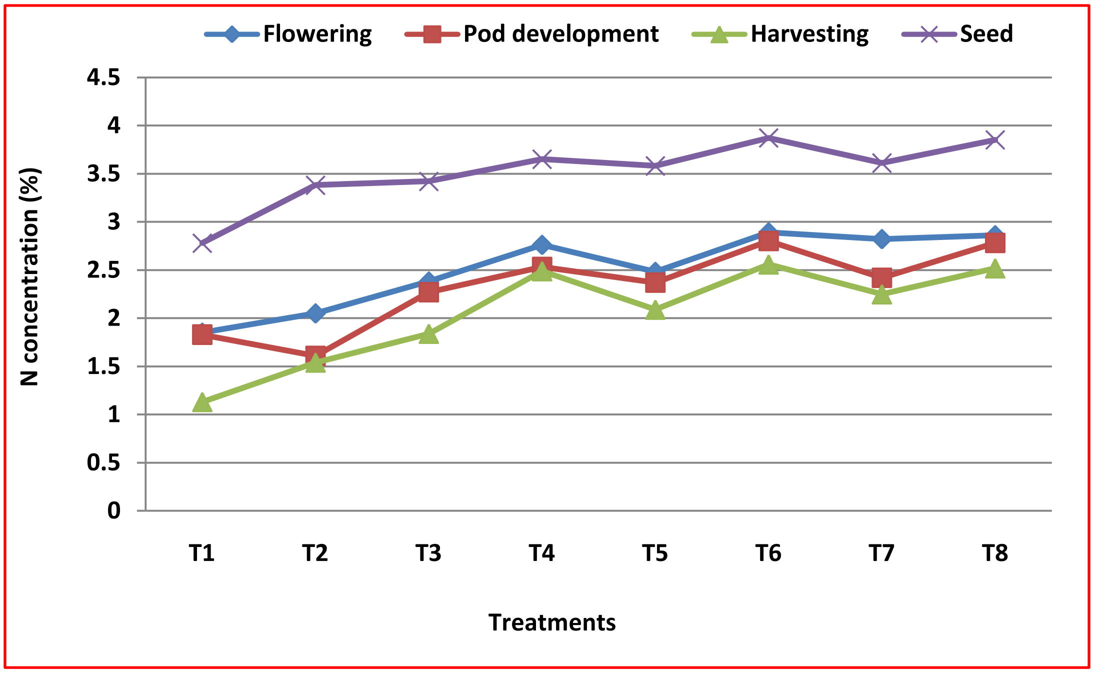


Fig 4.3 Effect of various treatments on N (%) concentration in plant at different growth stages.

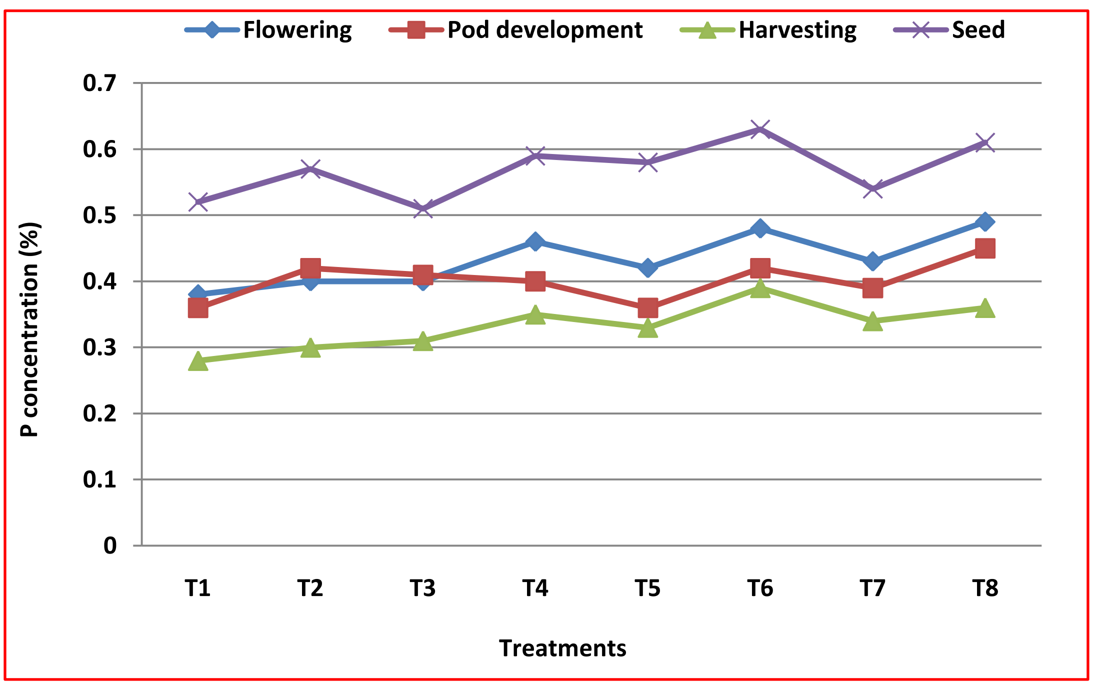


Fig 4.4 Effect of various treatments on P (%) concentration in plant at different growth stages.

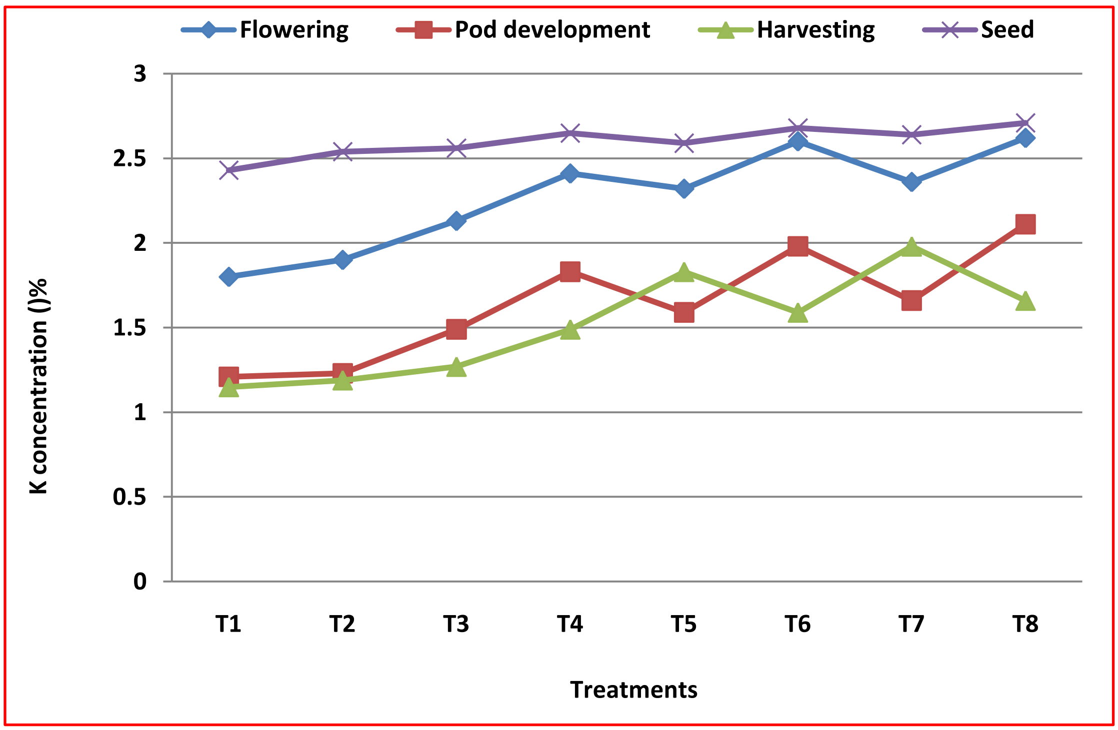


Fig 4.5 Effect of various treatments on K (%) concentration in plant at different growth stages.

4.5.4 Effect of levels of potassium on micronutrients (Fe, Zn, Cu, Mn) concentration at critical growth stages

The data in respect iron zinc, copper and manganese in plant and seed are presented in Table 4.15 to 4.18 and Fig 4.6 to 4.9. The concentration of these micronutrient in plant and grain did not influence significantly due to application of potassium. However, there was significant increase in these concentration due to inclusion of micronutrients Grade I and Grade II fertilizers in fertilizer schedules. The results also showed that concentration of Fe, Zn, Cu, and Mn was more in seed as compared to plant. The concentration was reduced with advancement of crop growth. Further it was very clear that there was no significant variation in nutrient concentration due to micronutrient fertilizer application either through soil and foliar. It was also noted that there was no antagonistic effect of potassium application on micronutrient concentration in plant during varied growth stages.

Table 4.16 Effect of levels of potassium on iron concentration at critical growth stages

Treatments	**Fe concentration (mg kg^{-1})**			
	Flowering	**Pod development**	**Harvesting**	**Seed**
T_1 Absolute control (No fertilizer)	315.65	155.00	166.32	356.87
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	326.42	156.65	167.33	377.84
T_3 RDF + 25 kg K_2O ha^{-1}	335.63	156.43	171.59	373.80
T_4 RDF + 50 kg K_2O ha^{-1}	334.35	157.84	176.53	378.00
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	357.35	196.37	198.56	405.35
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	362.33	198.70	213.68	408.91
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	394.71	204.67	213.33	402.69
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	397.68	207.99	216.63	404.72
Grand mean	353.02	179.02	190.49	388.52
SEm ±	7.24	3.77	4.68	6.59
CD at 5%	21.88	11.84	14.69	20.00
CV %	3.52	3.35	3.6	3.01

Table 4.17 Effect of levels of potassium on zinc concentration at critical growth stages

Treatments	Zn concentration (mg kg^{-1})			
	Flowering	**Pod development**	**Harvesting**	**Seed**
T_1 Absolute control (No fertilizer)	40.31	21.73	35.33	50.67
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	40.61	22.72	36.59	53.89
T_3 RDF + 25 kg K_2O ha^{-1}	41.49	21.49	37.90	50.48
T_4 RDF + 50 kg K_2O ha^{-1}	41.91	22.74	41.11	55.22
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	43.82	26.40	43.09	65.73
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	45.81	27.55	43.56	68.74
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	45.82	28.66	44.43	64.93
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	47.02	29.91	45.77	68.03
Grand mean	43.34	25.15	40.97	59.71
SEm ±	1.26	0.90	1.05	0.97
CD at 5%	4.02	3.01	3.19	3.16
CV %	4.03	4.54	4.49	3.07

Table 4.18. Effect of levels of potassium on copper concentration at critical growth stages

Treatments	Cu concentration (mg kg^{-1})			
	Flowering	**Pod development**	**Harvest plant**	**Seed**
T_1 Absolute control (No fertilizer)	15.87	10.93	12.13	17.17
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	15.82	10.40	12.33	17.40
T_3 RDF + 25 kg K_2O ha^{-1}	15.20	11.13	12.33	17.28
T_4 RDF + 50 kg K_2O ha^{-1}	15.60	11.47	12.80	18.82
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	17.90	12.80	16.13	21.76
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	18.21	12.83	17.13	22.82
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	20.55	13.51	20.57	19.58
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	19.59	13.73	21.87	20.82
Grand mean	17.34	12.10	15.66	19.46
SEm ±	0.96	0.73	1.10	0.43
CD at 5%	2.40	2.26	3.21	1.39
CV %	4.93	4.55	4.83	3.33

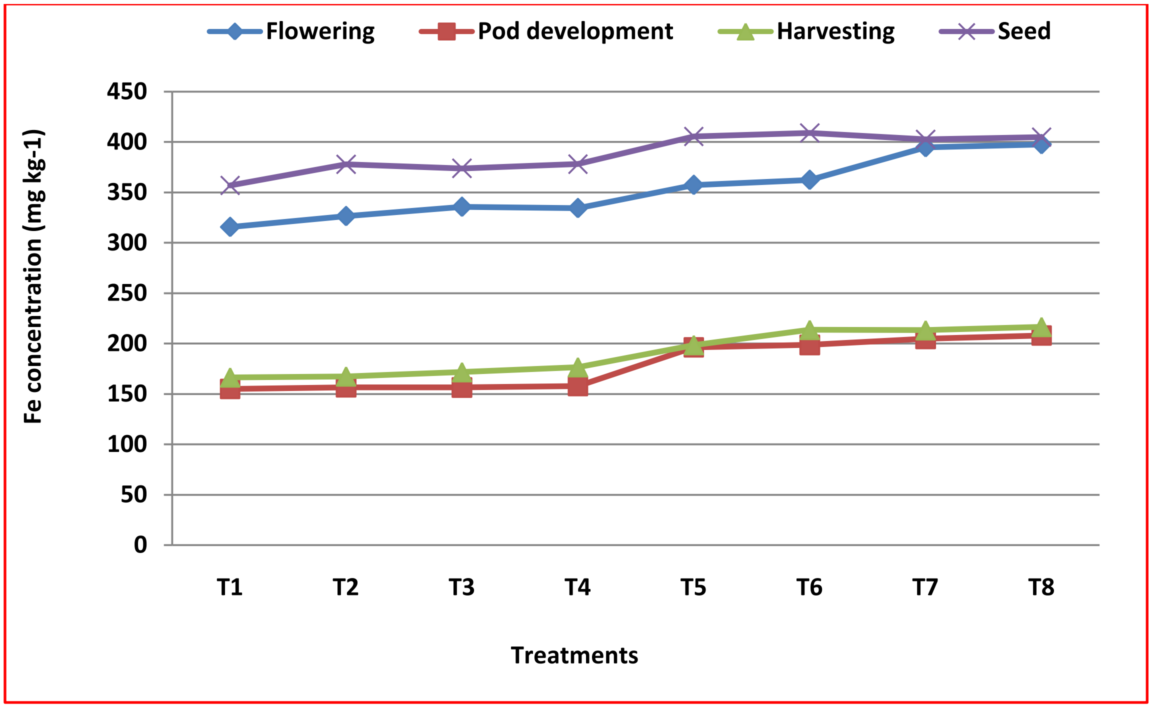


Fig4.6 Effect of various treatments on Fe (mg kg^{-1}) concentration in plant at different growth stages**.**

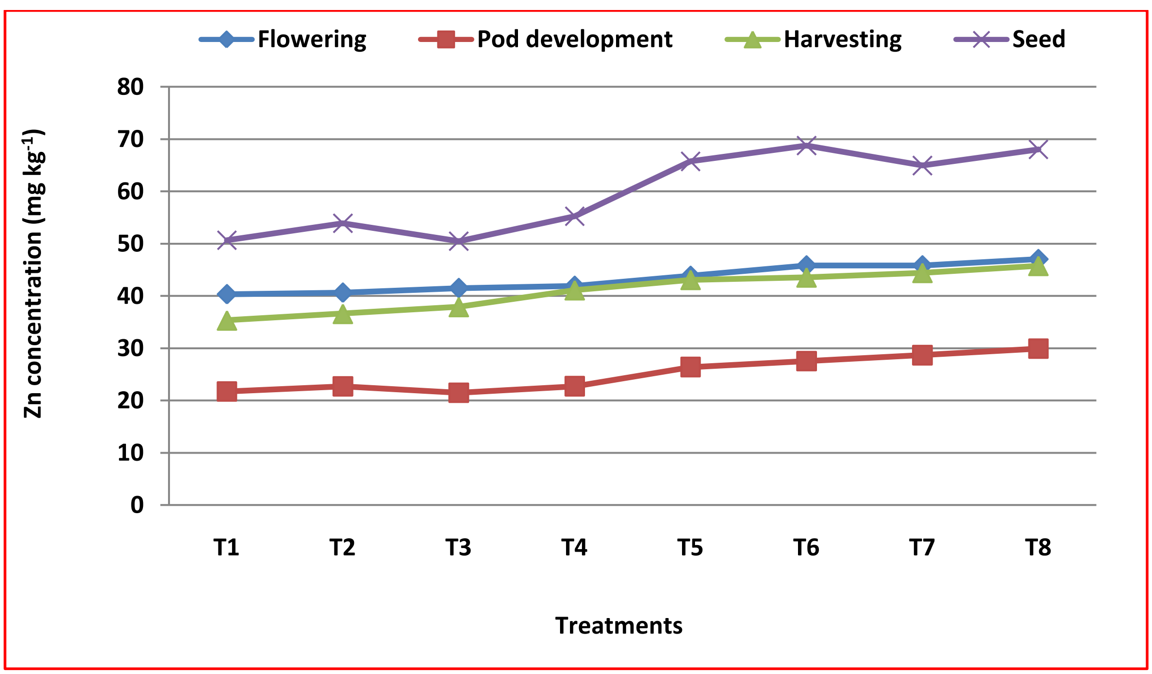


Fig 4.7 Effect of various treatments on Zn (mg kg^{-1}) concentration in plant at different growth stages.

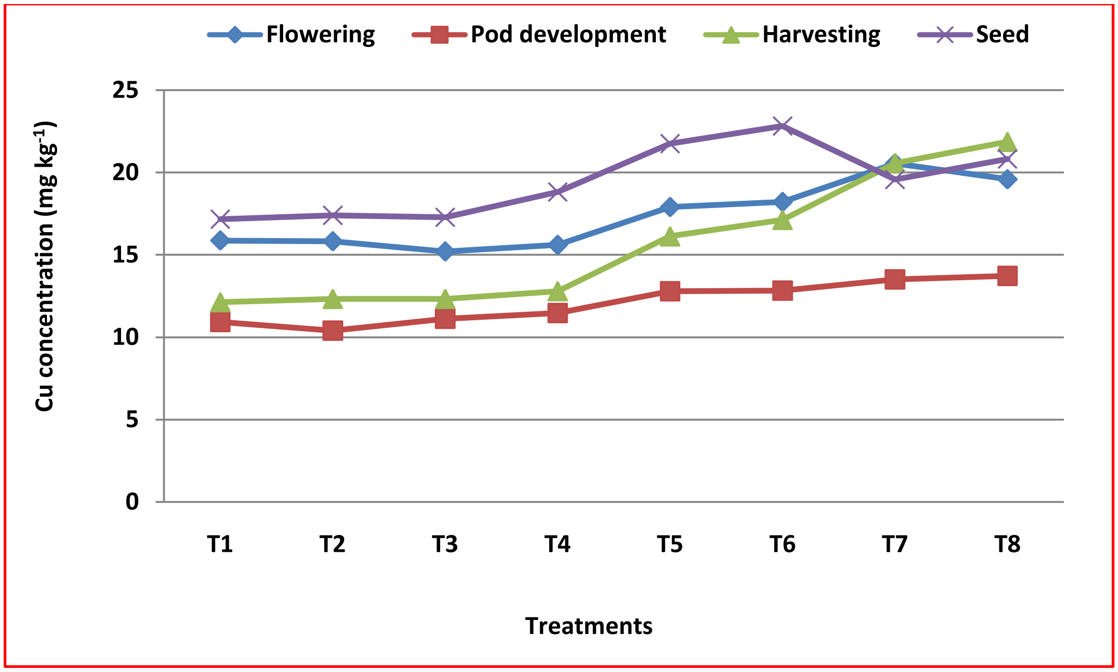


Fig 4.8 Effect of various treatments on Cu (mg kg^{-1}) concentration in plant at different growth stages.

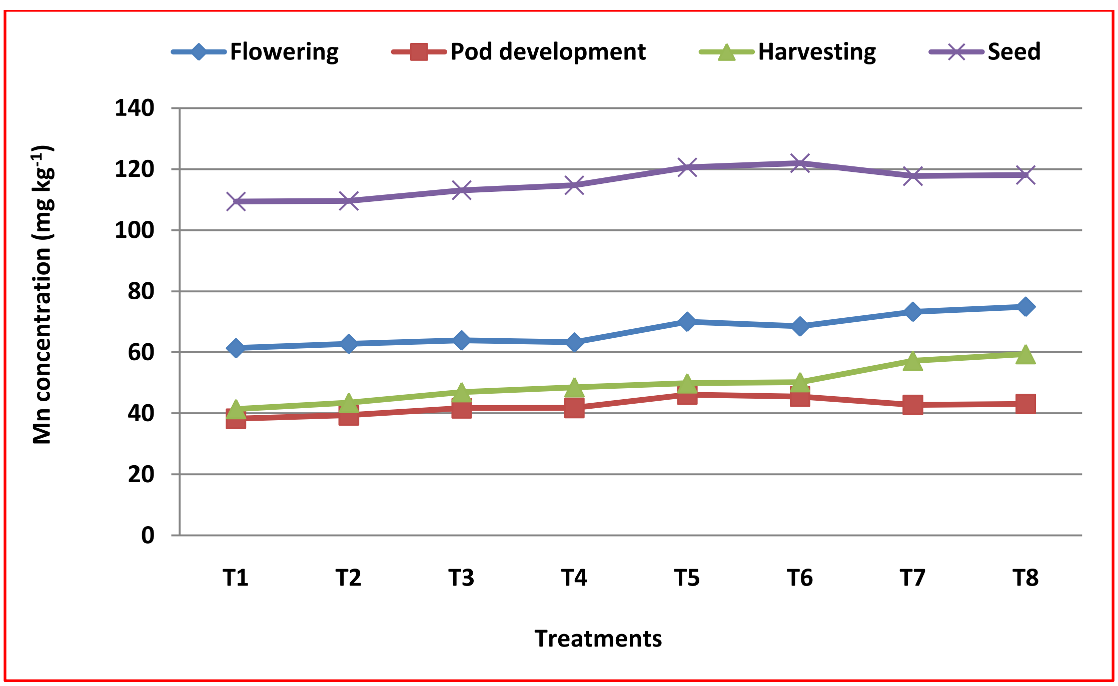


Fig 4.9 Effect of various treatments on Mn (mg kg^{-1}) concentration in plant at different growth stages.

Table 4.19 Effect of levels of potassium on Mn concentration at critical growth stages

Treatments	Mn concentration (mg kg^{-1})			
	Flowering	Pod development	Harvesting	Seed
T_1 Absolute control (No fertilizer)	61.35	38.20	41.43	109.41
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	62.76	39.34	43.50	109.60
T_3 RDF + 25 kg K_2O ha^{-1}	63.91	41.67	46.97	113.11
T_4 RDF + 50 kg K_2O ha^{-1}	63.22	41.78	48.59	114.75
T_5 RDF + 25 kg K_2O ha^{-1} + Grade I micronutrient	70.02	46.15	49.87	120.60
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	68.49	45.48	50.25	121.94
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	73.27	42.74	57.26	117.73
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	74.94	43.05	59.43	118.10
Grand mean	67.25	42.30	49.66	115.66
SEm ±	1.47	0.98	1.05	2.12
CD at 5%	4.47	2.97	3.19	6.46
CV %	3.27	3.61	3.49	3.29

4.6 Nutrient status of the experimental soil at various crop growth stages

The available nutrient status of the experimental soil was presented in Appendix I-VII.

4.7 Effect of graded levels of potassium on nutrient uptake by green gram

4.7.1 Effect of graded levels of potassium on N uptake

The data regarding the nitrogen uptake in green gram with respect to various graded level of potassium are presented in Table 4.20 and Fig 4.10.

Table 4.20 Effect of graded levels of potassium on N uptake

Treatments	Uptake N (kg ha^{-1})				
	Flowering	Pod development	Harvest		
			Plant	Seed	Total
T_1 Absolute control (No fertilizer)	20.01	19.51	13.41	15.32	28.73
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	35.40	32.89	35.09	28.64	63.73
T_3 RDF + 25 kg K_2O ha^{-1}	37.13	53.80	42.68	37.86	80.54
T_4 RDF + 50 kg K_2O ha^{-1}	61.64	69.56	61.86	42.36	104.22
T_5 RDF + 25kg K_2O ha^{-1} + Grade I micronutrient	52.55	76.53	48.65	37.99	86.64
T_6 RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient	72.07	84.95	71.41	46.78	118.19
T_7 RDF +25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	47.57	60.14	54.13	39.37	93.5
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	65.93	79.13	60.89	42.49	103.38
Grand mean	49.04	59.56	48.51	36.35	84.86
SEm ±	3.17	3.51	3.25	2.15	-
CD at 5%	9.26	10.65	9.88	6.54	-
CV %	11.2	10.22	11.64	10.27	-

Among the treatments, application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) recoded significantly higher uptake in flowering (72.07 kg ha^{-1}), pod development (84.95 kg ha^{-1}), plant at harvest (71.41 kg ha^{-1}) and seed (46.78 kg ha^{-1}). This was followed by RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8) and RDF + 50 kg K_2O ha^{-1} $^{(}T_4$). T_6 treatment were at par with T_8 in flowering and pod development stage and while, it was at par with T_8 and $T_{.4}$ at harvesting stage. In presence of potassium, the increase in N uptake could be attributed to enhanced vigour of crop growth with increased utilization and translocation of N in to plant and synergy between N and K in soil system resulting in the enhancement of yield. Similar trend was also reported by Sahay *et al.*, (2013).

4.7.2 Effect of levels of potassium on P uptake

Table 4.20 and Fig 4.11 represent the data on uptake of P under various treatments administered. The significantly maximum enhancement in phosphorous uptake by green gram crop was recorded at highest level of potassium (50 kg K_2O ha^{-1}) application along with RDF and micronutrient (T_6) in flowering (9.80 kg ha^{-1}), pod development (12.62 kg ha^{-1}) and harvest in plant (18.54 kg ha^{-1}) and seed (6.41 kg ha^{-1}) as compared to control (T_1) and RDF (T_2) and (T_3).However, RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) found at par with RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient (T_8) and RDF + 50 kg K_2O ha^{-1} (T_4) in flowering, pod development and in seed. Similar, results was observed by Verma and Nandram (2003).

Table 4.21 Effect of levels of potassium on P uptake

Treatments	Uptake P (kg ha^{-1})				
	Flowering	Pod development	Harvest		
			Plant	Seed	Total
T_1 Absolute control (No fertilizer)	2.81	3.29	2.96	1.60	4.56
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	4.36	6.33	6.43	2.87	9.3
T_3 RDF + 25 kg K_2O ha^{-1}	4.85	8.49	7.12	4.25	11.37
T_4 RDF + 50 kg K_2O ha^{-1}	7.94	10.83	8.73	5.69	14.42
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	6.64	11.65	7.65	5.05	12.7
T_6 RDF + 50 kg K_2O ha^{-1} +Grade I micronutrient	9.80	12.62	18.54	6.41	24.95
T_7 RDF +25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	6.02	9.57	8.15	4.80	12.95
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	9.48	12.61	9.50	5.59	15.09
Grand mean	6.48	9.42	8.63	4.53	13.16
SEm ±	0.59	0.68	0.67	0.34	-
CD at 5%	1.79	2.06	2.04	1.04	-
CV %	15.76	12.53	13.5	13.6	-

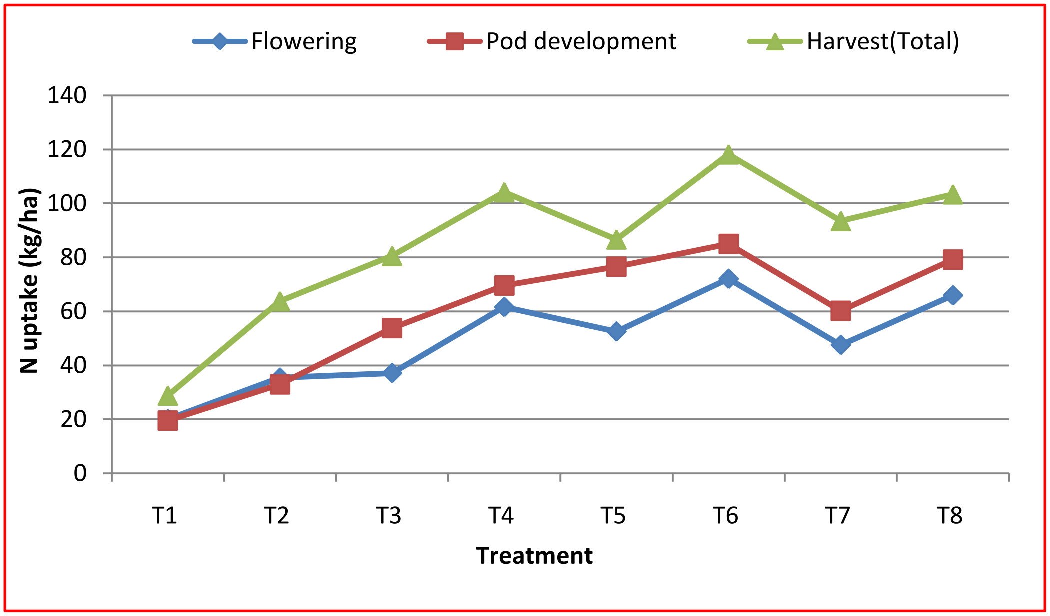


Fig 4.10 Effect of various treatments on N uptake (kg ha^{-1}) at different growth stages.

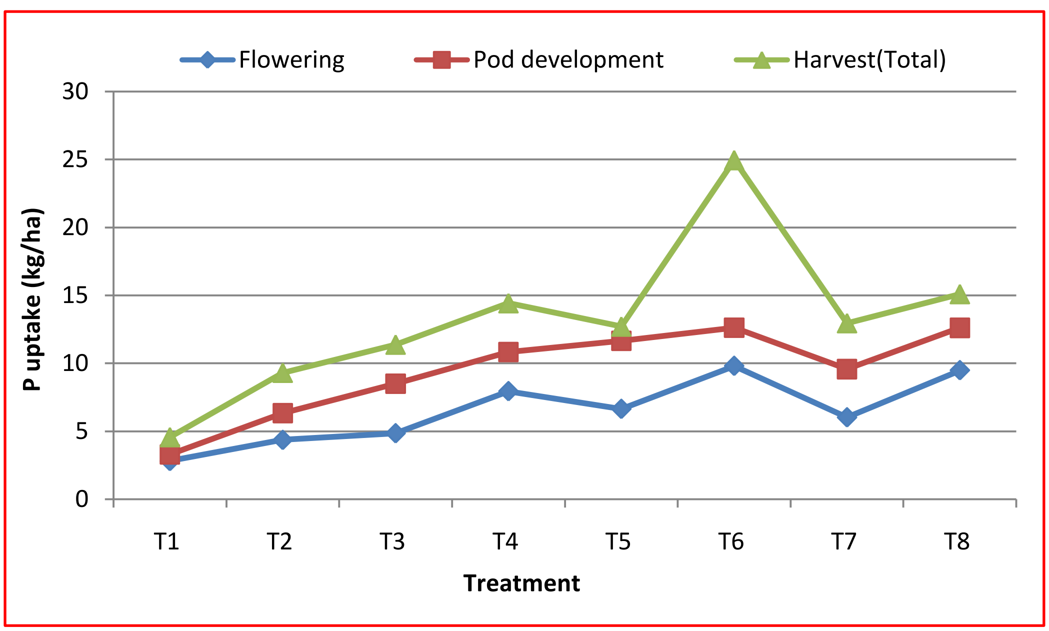


Fig 4.11 Effect of various treatments on P uptake (kg ha^{-1}) at different growth stages.

4.7.3 Effect of levels of potassium on K uptake.

The data regarding the K uptake in green gram with respect to potassium levels are presented in Table 4.21 and Fig 4.12. Data indicated that application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrients (T_6) significantly increased the uptake of K in green gram plant and grain which was statistically at par with the application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrients (T_8) at flowering, pod development and harvesting stages, respectively. This might be due to application of higher doses of mineral K with micronutrients favored higher root and shoot development which might have also increased the K uptake. Similar, result was observed by Kherawat *et al.*, (2013) in clusterbean.

Table 4.22 Effect of levels of potassium on K uptake

Treatments	**Uptake K (kg ha^{-1})**				
	Flowering	**Pod development**	**Harvest**		
			Plant	**Seed**	**Total**
T_1 Absolute control (No fertilizer)	13.59	12.96	13.89	7.87	21.76
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	22.11	25.07	27.08	13.08	40.16
T_3 RDF + 25 kg K_2O ha^{-1}	25.80	35.50	29.39	17.35	46.74
T_4 RDF + 50 kg K_2O ha^{-1}	41.34	50.19	37.09	19.11	56.2
T_5 RDF + 25 kg K_2O ha^{-1} +Grade I micronutrient	36.75	51.68	30.70	16.84	47.54
T_6 RDF + 50 kg K_2O ha^{-1} +Grade I micronutrient	51.28	60.05	46.59	20.35	66.94
T_7 RDF +25 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	32.77	41.16	32.60	17.85	50.45
T_8 RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	49.89	59.91	40.66	18.89	59.55
Grand mean	34.19	42.06	32.24	16.41	48.65
SEm ±	1.84	2.75	1.96	1.03	-
CD at 5%	5.60	8.34	5.94	3.14	-
CV %	9.36	11.32	10.53	10.94	-

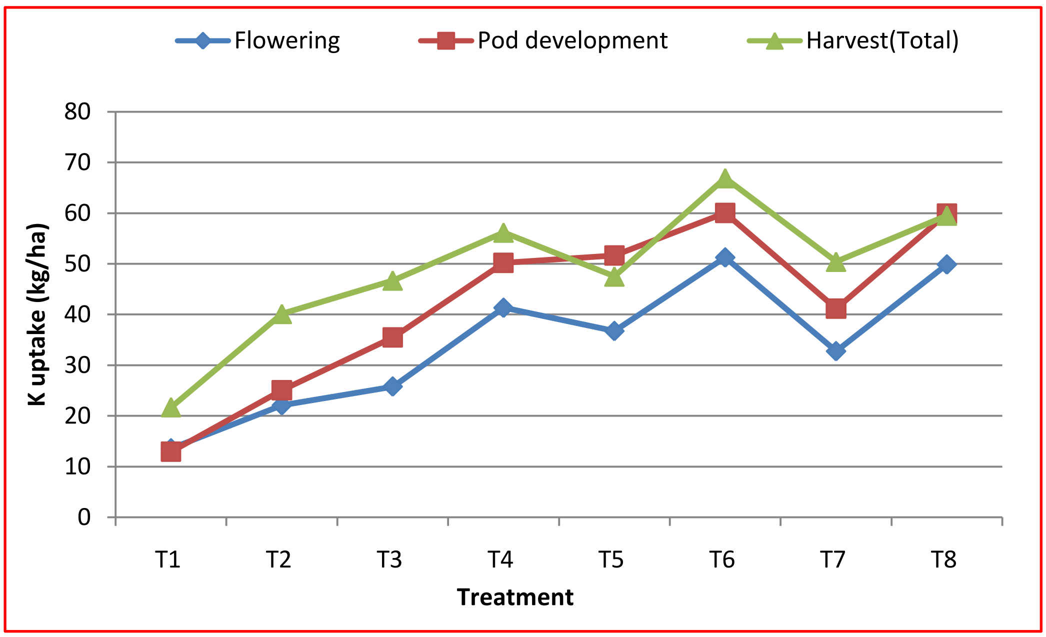


Fig 4.12 Effect of various treatments on K uptake (kg ha^{-1}) at different growth stages.

4.7.4 Effect of graded levels of potassium on Fe uptake

The data as presented in tabular form (Table 4.22 and Fig 4.13) indicated that increasing levels of K produced significant effect on Fe uptake by plant and grain in all the growth stages. The Fe uptake by plant and grain increased from 365.67 to 639.01 g ha^{-1} in flowering, 531.52 to 999.23 g ha^{-1} in pod development and 370.47 to 781.03 g ha^{-1} in harvesting stage with the application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) over control. The increasing Fe uptake may also be attributed due to concentration of Fe in plant and seed. Significant increase in biomass production is also one of the reasons for better nutrient uptake. Similar trend was observed by Chaturvedi *et al.*, (2010) in soybean.

Table 4.23. Effect of levels of potassium on Fe uptake

Treatments	Uptake Fe (g ha^{-1})				
	Flowering	Pod development	Harvest		
			Plant	Seed	Total
T_1 Absolute control (No fertilizer)	365.67	531.52	280.52	89.95	370.47
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	415.19	666.40	456.96	143.47	600.43
T_3 RDF + 25 kg K_2O ha^{-1}	450.01	795.15	462.47	212.73	675.2
T_4 RDF + 50 kg K_2O ha^{-1}	468.83	868.78	466.52	228.09	694.61
T_5 RDF + 25 kg K_2O ha^{-1} +Grade I micronutrient	543.35	954.50	444.39	210.66	655.05
T_6 RDF + 50 kg K_2O ha^{-1} +Grade I micronutrient	639.01	999.23	535.62	245.41	781.03
T_7 RDF +25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	628.07	919.15	498.47	265.48	763.95
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	629.22	998.03	496.90	271.98	768.89
Grand mean	517.42	841.59	455.23	208.47	663.7
SEm ±	32.77	55.00	33.21	15.31	-
CD at 5%	99.43	166.85	100.76	46.45	-
CV %	10.12	10.7	13.49	12.72	-

4.7.5. Effect of levels of potassium on Zn uptake

The data in Table 4.23 and Fig 4.14 as presented indicated that increasing the potassium level up to 50 kg ha^{-1} with RDF and integration with Grade I and Grade II micronutrient resulted in higher uptake of Zn. The application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient (T_6) recorded significantly higher uptake in flowering, harvesting and seed. The increased grain yield and higher nutrient content in the crop by K application, thereby activating more absorption of nutrients from the soil, resulted in higher uptake of nutrients.

Table 4.24 Effect of levels of potassium on Zn uptake

Treatments	**Uptake Zn (g ha^{-1})**				
	Flowering	**Pod development**	**Harvest**		
			Plant	**Seed**	**Total**
T_1 Absolute control (No fertilizer)	40.79	45.65	33.95	38.91	72.86
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	56.88	80.47	51.74	41.08	92.82
T_3 RDF + 25 kg K_2O ha^{-1}	60.77	96.02	49.88	42.04	91.92
T_4 RDF + 50 kg K_2O ha^{-1}	61.47	98.51	53.61	42.71	96.32
T_5 RDF +25 kg K_2O ha^{-1} +Grade I micronutrient	94.24	111.69	84.64	45.61	130.25
T_6 RDF +50 kg K_2O ha^{-1} +Grade I micronutrient	96.01	118.84	104.52	51.49	156.01
T_7 RDF +25 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	96.25	118.01	92.52	50.46	142.98
T_8 RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	110.59	122.02	96.65	50.48	147.13
Grand mean	77.12	98.90	70.94	45.34	116.28
SEm ±	4.81	6.57	4.63	2.28	-
CD at 5%	14.60	19.93	14.05	6.92	-
CV %	9.94	10.1	11.1	9.42	-

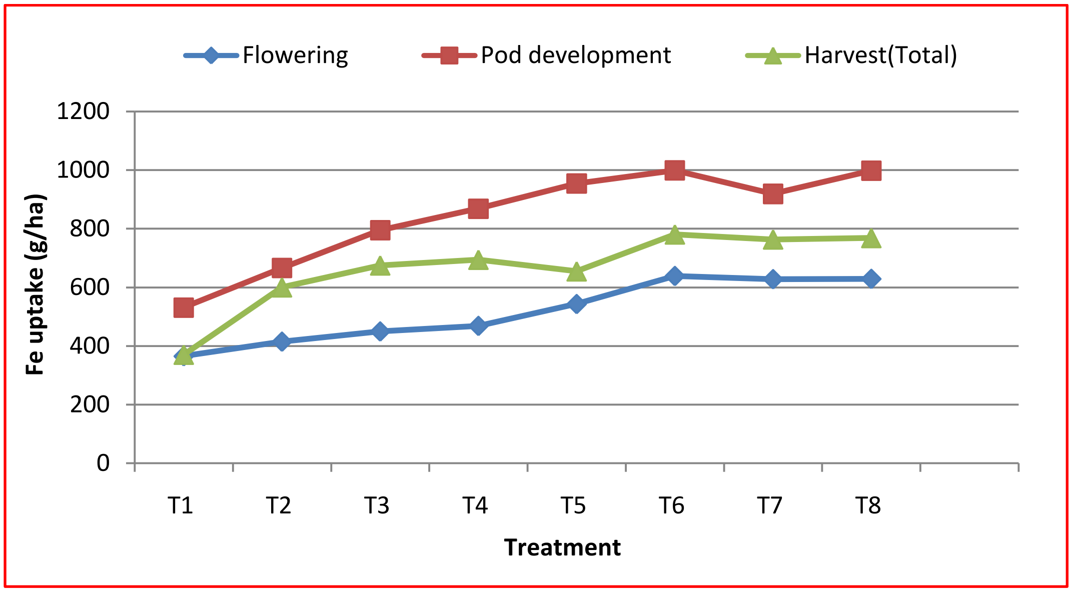


Fig 4.13 Effect of various treatments on Fe uptake (g ha^{-1}) at different growth stages.

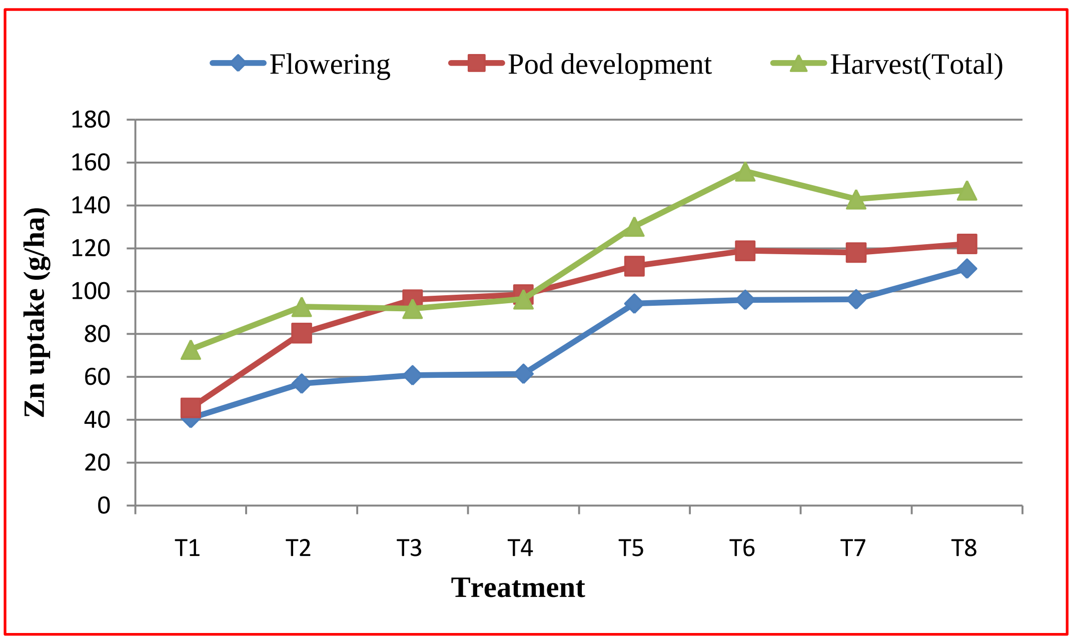


Fig 4.14 Effect of various treatment on Zn uptake (g/ha) by green gram at different growth stages.

4.7.6. Effect of levels of potassium on Cu uptake

Table 4.24 and Fig 4.15 represent the data on Cu uptake under various treatments administered. Increasing level of K produced significant effect on Cu uptake by plant and grain of green gram. Significantly higher uptake was obtained by the application of RDF + 50 kg K_2O ha^{-1} or 25 kg K_2O amended with micronutrient soil application or foliar spraying. The potassium helped to enhance the dry matter accumulation which also contributed in higher Cu uptake by green gram.

Table 4.25 Effect of levels of potassium on Cu uptake

Treatments	Uptake Cu (g ha^{-1})				
	Flowering	Pod development	Harvest		
			Plant	Seed	Total
T_1 Absolute control (No fertilizer)	10.68	11.50	8.02	4.26	12.28
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	17.85	23.99	16.85	7.09	23.94
T_3 RDF + 25 kg K_2O ha^{-1}	20.81	33.54	23.49	11.48	34.97
T_4 RDF + 50 kg K_2O ha^{-1}	22.31	46.02	28.37	14.85	43.22
T_5 RDF +25 kg K_2O ha^{-1} +Grade I micronutrient	24.48	58.10	27.38	17.05	44.43
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	35.16	55.07	35.29	22.44	56.07
T_7 RDF + 25 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	31.19	50.79	37.30	20.78	59.74
T_8 RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient	39.64	55.64	37.92	24.11	62.03
Grand mean	25.26	41.83	26.82	15.25	42.07
SEm ±	1.64	3.11	1.68	0.89	-
CD at 5%	4.98	9.44	5.11	2.70	-
CV %	9.98	12.9	10.88	10.11	-

4.7.4 Effect of levels of potassium on Mn uptake

The data as presented in tabular form (Table 4.26 and Fig 4.16) indicated that increasing levels of K produced significant effect on Mn uptake by plant and grain in all the growth stages. The Mn uptake by plant and grain increased from 69.27 to 241.48 g ha^{-1} in flowering, 54.58 to 355.20 g ha^{-1} in pod development, 66.11 to 229.11 g ha^{-1} in harvesting stage. It was noted that application of RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrients had produced maximum uptake of Mn in pod development (355.20 g ha^{-1}), plant at harvesting (152.54 g ha^{-1}) and seed (76.57g ha^{-1}).

Table 4.26 Effect of levels of potassium on Mn uptake

Treatments	**Uptake Mn (g ha^{-1})**				
	Flowering	**Pod development**	**Harvest**		
			Plant	**Seed**	**Total**
T_1 Absolute control (No fertilizer)	69.27	54.58	43.27	22.84	66.11
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1}	114.54	114.04	85.96	36.67	122.63
T_3 RDF + 25 kg K_2O ha^{-1}	136.48	156.45	96.63	52.10	145.73
T_4 RDF + 50 kg K_2O ha^{-1}	197.11	181.54	109.18	56.39	165.567
T_5 RDF +25 kg K_2O ha^{-1} +Grade I micronutrient	191.26	227.15	107.29	52.87	166.16
T_6 RDF +50 kg K_2O ha^{-1} + Grade I micronutrient	241.48	207.46	126.60	60.81	187.41
T_7 RDF + 25 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	163.62	305.48	151.20	73.38	224.58
T_8 RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	224.87	355.20	152.54	76.57	229.11
Grand mean	167.32	200.23	109.08	53.95	163.03
SEm±	10.69	10.54	7.52	3.21	-
CD at 5%	32.45	31.98	22.81	9.76	-
CV %	11.07	9.12	11.94	10.34	-

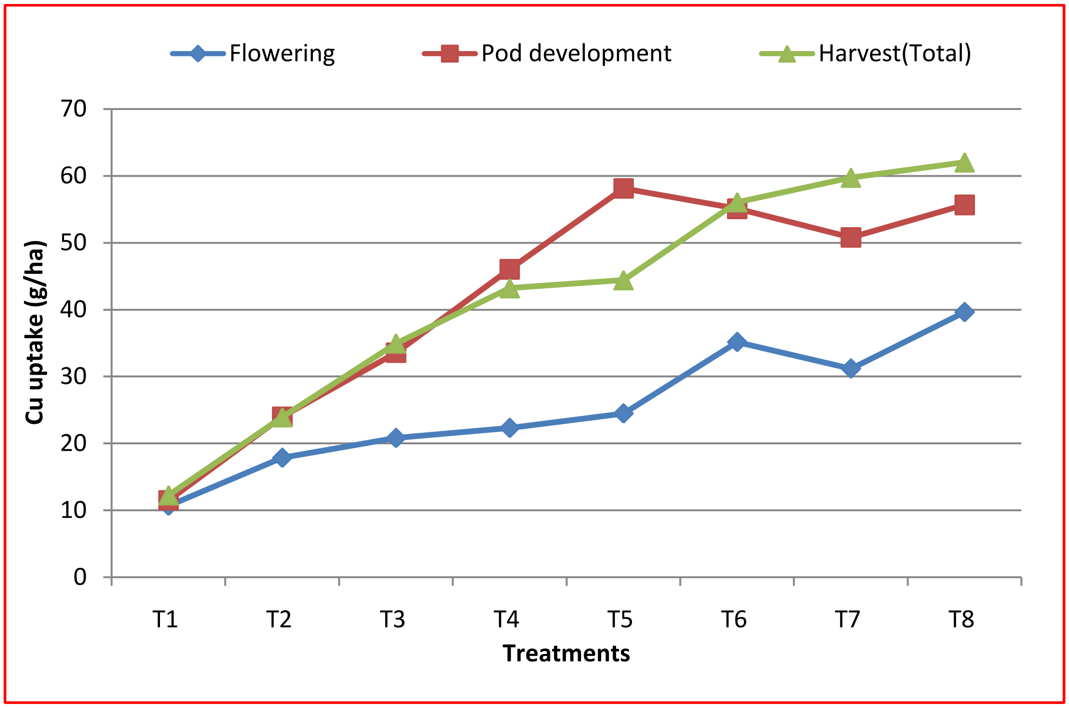


Fig 4.15 Effect of various treatments on Cu uptake (g ha^{-1}) by green gram at different growth stages.

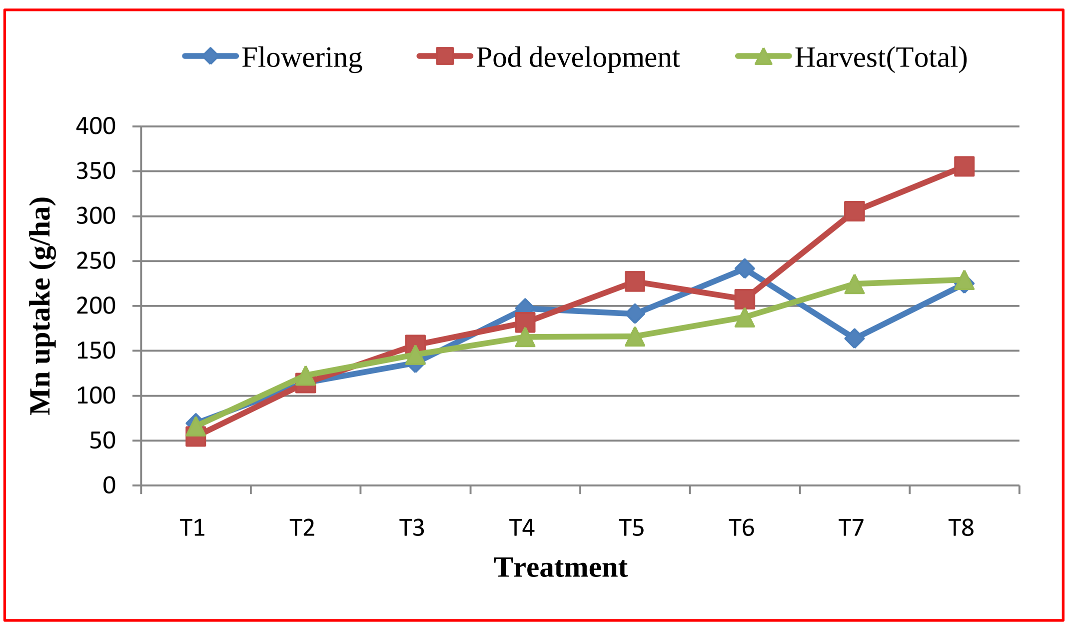


Fig 4.16 Effect of various treatments on Mn uptake (g ha^{-1}) by green gram at different growth stages.

4.8 Economics of green gram

The economic in respect of green gram production with the selected prescribed treatment schedule was computed considered the cost of cultivation, gross monetary return, net monetary return and cost benefit ratio. The prevailing market results for inputs and market prices of sale of product were used for calculating of cost of cultivation. The data thereof are presented in Table 4.27. It was recorded that GMR and NMR was maximum when green gram received RDF + 50 kg K_2O + Grade I micronutrient (T_6) application followed by RDF + 50 kg K_2O + Grade II micronutrient (0.5 %) (T_8). However, the C: B ratio was higher in treatment RDF + 25 kg K_2O (T_3) followed by RDF + 50 kg K_2O + Grade I micronutrient (T_6).

Table 4.27 GMR, NMR and C:B ratio as influenced by various treatments

Treatments	Cost of cultivation (Rs ha^{-1})	Gross monetary return (Rs ha^{-1})	Net monetary return (Rs ha^{-1})	C:B
T_1 Absolute control (No fertilizer)	11193.01	28321.12	17128.11	1:1.53
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1}	17466.69	43586.77	26120.08	1:1.49
T_3 RDF + 25 kg K_2O ha^{-1}	20420.29	56642.2	36221.91	1:1.77
T_4 RDF + 50 kg K_2O ha^{-1}	21265.89	57053.44	35787.55	1:1.68
T_5 RDF +25 kg K_2O ha^{-1} + Grade I micronutrient	20620.05	54483.47	33863.42	1:1.64
T_6 RDF +50 kg K_2O ha^{-1} + Grade I micronutrient	22681.35	62193.39	39512.04	1:1.74
T_7 RDF + 25 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	20907.11	56025.45	35118.34	1:1.67
T_8 RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5%) micronutrient	22341.12	59623.42	37283.3	1.1:66

Rate of nutrients: N= Rs 27.55/kg, P= Rs 40 /kg, K= 25 /kg,

Selling price 1 Qtn=5139.95

CHAPTER –V

SUMMARY AND CONCLUSION

A project entitled "Studies on Effect of potassium on growth, yield and uptake of nutrients by green gram" was carried out at Department of Soil Science and Agricultural Chemistry, VNMKV, Parbhani during 2012-2013. The result presented, interpreted, and discussed in previous chapter are summarized in following paragraphs.

The experimental soil was fine, smectitic calcareous, iso-hyperthermic Typic Haplusterts. The soil was slightly alkaline in reaction (pH $_{2.5}$, 7.84), safe in soluble salt concentration (EC $_{2.5}$ 0.206 dSm^{-1}) and high in organic content (7.7 g kg^{-1}). The free $CaCO_3$ content was 48 g per kg. After harvest of the crop, pH, EC, and $CaCO_3$ were not influenced significantly due to administration of various levels of graded potassium treatments. However, there was numerical increase in organic carbon content in all the treatments.

The effect of different levels of graded potassium recorded non significant effect on germination count and final plant stand. Growth parameter like plant height showed significant increases with the application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient at pod development and harvest. While, in flowering, maximum height was recorded with the application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient. The application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient showed the maximum leaf area at flowering stage, pod development stage.

The other growth parameters like number of pods (per plant), number of nodules(per plant), fresh weight of nodules (per plant), total biomass production (g $plant^{-1}$), and dry matter (kg ha^{-1}) were at higher magnitude when green gram received RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient followed by application of RDF + 50 kg K_2O ha^{-1} + Grade II foliar spray.

Application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient had recorded highest seed yield per plant which was significantly higher over control and application of RDF i.e. only N and P.

The highest grain yield of was 1210.22 kg ha^{-1} obtained by the application of RDF +50 kg K_2O ha^{-1} + Grade I micronutrient followed by application of RDF + 50 kg K_2O kg ha^{-1} + Grade II (0.5 %) foliar spray which were statistically at par with each other. It can be observed that, the application of potassium (50 kg K_2O ha^{-1} + Grade I micronutrient) increased the grain yield of green gram over control (no application of any fertilizer) by 119.84% over RDF (no application of K) by 42.68%.

The highest protein content (19.21%) and seed index (5.19) was recorded by application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient followed by application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient.

The highest N, P, K, concentration in plant was recorded by application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient followed by RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient.

Micronutrients i.e. Fe, Zn, Cu and Mn concentrations in plant were found highest with the application of application of RDF + 50 kg K_2O ha^{-1} with either Grade I or Grade II micronutrient fertilizer application. The application of potassium level showed no significant increase in these nutrient concentrations in plant/seed. The N, P_2O_5 and K_2O and micronutrient availability in soil was found increased with the application of RDF + 25 or 50 kg K_2O ha^{-1} + Grade I or Grade II micronutrient at all the growth stages.

Application of RDF + 50 kg K_2O ha^{-1} + Grade I micronutrient showed maximum uptake of N, P, K , and micronutrients in green gram plant and grain and followed by RDF + 50 kg K_2O ha^{-1}+Grade II micronutrient foliar spray. The uptake of Cu, Mn was more with application of RDF + 50 kg K_2O ha^{-1} + Grade II (0.5%) micronutrient at pod development stage. While, application of RDF + 50 kg K_2O kg ha^{-1}+Grade I micronutrient recorded significantly higher uptake of Cu, Mn at flowering stage.

GMR and NMR was maximum when green gram received RDF + 50 kg K_2O + Grade I micronutrient (T_6) application followed by RDF + 50 kg K_2O + Grade II micronutrient (0.5 %) (T_8). However, the C: B ratio was higher in treatment RDF + 25 kg K_2O (T_3) followed by RDF + 50 kg K_2O + Grade I micronutrient (T_6).

CONCLUSIONS

1. Inclusion of 25 or 50 kg potassium in recommended dose of green gram (25: 50 kg N: P_2O_5 ha^{-1}) enhanced the growth parameters, yield and quality of green gram.
2. Potassium application showed synergic effects on other nutrient uptake.
3. The application of micronutrients either through soil or foliar improved the growth and yield of green gram.
4. The soil fertility was improved due to application of potassium and micronutrients to the green gram.

Application of 25 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 25 kg or 5O kg K_2O ha^{-1} + Grade I micronutrient (10 kg ha^{-1}) or Grade II foliar spray (0.5%) found superior over only N and P application in green gram.

FUTURE LINE OF WORK

Very few reports are available on K effects on green gram production in India and there is a lot of scope to take up studies on K nutrition in pulse production for getting and sustained production and productivity. Further other important areas of research would be.

1. Characterization of soil K in different pulse –growing agro-ecological regions.
2. Working out K needs of pulses in cropping systems on different soil types and its critical limits.
3. Interaction of K with other nutrients and management factors.
4. Residual effects of K in various cereal-pulse cropping system.
5. Contribution of pulse residues/litter towards K status of soil and its uptake by succeeding cereal crops.
6. Potassium effects on drought tolerance of various pulse crops.

LITERATURE CITED

Ali.M. and Srinivasarao.Ch. (2001). Role of potassium fertilization in improving productivity of pulse crop. Potassium in Indian Agriculture. International symposium on importance of potassium in nutrient management for sustainable crop production in India. N.S Pasricha and S.K. Bansal (Eds).pp:261-275

Annadurai, K., Seshardri, P. and Palaniappan, S.P. (1994). Response of soybean (*Glycine max*) to phosphorous and residual potassium. *Indian J. Agron*., **39**(2): 320-322.

Anuradha, K. and Sharma, P. S. (1995). Effect of moisture stress applied potassium on yield and biochemical parameters of soybean in Vertisols. *J. Oilseed Res.*, **12**(2): 275-278.

AOAC (1975). Association of Official Analytical Chemistry. Washington D.C. USA.

Asghar, A.U., Asghar, M. Mauk. Rehmat A. A., Tahir, M. and Arif, H. (1994). Effect of potassium on yield and yield components of Black gram. *Pak. J. Agri.Sa* ., **31** (3): 275-278.

Ayub, M., Nadeem, M.A., Naeem, M., Tahir, M., Tariq, M., and Ahmad, W. (2012). Effect of different levels of P and K on growth, forage yield and quality of cluster bean (*Cyamopsis tetragonolobus* L.). *The Journal of Animal and Plant Sciences.*, **22**(2): 479-483.

Balai, C. M. and Majumdar, S. P. (2007). Metabolites content and Water Relations of Cowpea (*Vigna unguiculata* (L.) WALP) as influenced by different levels of compaction, potassium and Cobalt. *Curr. Agric*., **31**(1-2): 47-53.

Balai, C. M., Majumdar, S. P. and Kumawat, B. L. (2005). Effect of Soil Compaction , Potassium and Cobalt Growth and Yield of Cowpea. *Indian J. Pulses Res.*, **18**(1): 38-39.

Balasubramanian, P. and Palaniappan, S. P. (1996). Time of NK application and its effect on irrigated groundnut. *Madras Agric. J.*, **83**(12): 750-753.

Banik, N.C. and Sengupta, K. (2013). Increased production in mungbean (*Vigna radiata*) through nutrient management and utilization of residual soil productivity for raising succeeding crop. *Indian J. Agron.*, **58** (4) 560- 563.

Bansal, K.N. (1992). Potassium balance in multiple cropping system in Vertisols at Jubalpur. *J. Potassium Res*., **8**(1):52-58.

Bansal, S.K. and Umar, S. (1998). Balanced fertilization. An Overview In: *Balanced Fertilization in Punjab Agriculture*, M.S Brar, and S.K. Bansal (eds), Punjab Agricultural University, Ludhiana. 53-63.

Basith, M. A., Satyanarayana, V., Latchan, A. and Vara Prasad, P.V. (1995). Response of groundnut genotypes to levels of potassium and plant stands in rainy seasons. *J. Potassium Res.*, **11**(3 &4):385-388.

Bhattacharyya, R., Prakash, V., Kundu, S., Ghosh, B.N., Srivastva, A. K. and Gupta, H.S. (2008). Potassium availability as influenced by Farmyard Manure application under continuous Soybean-Wheat cropping in a Typic Haplaquept. *J. Indian Soc. Soil Sci.*, **56** (2): 182-185

Bhuma, M. and Selavakumari T. (2003). Studies on the effect of greengram to potassium humate on soil fertility. *Madras Agric. J.*, **90** (7-9):444-449.

Billore, S.D., Ramesh, A., Vyas, A. K. and Joshi, O. P. (2009). Potassium use efficiencies and economic optimization as influenced by levels of potassium and Soybean (*Glycine max*) genotypes under staggered planting. *Indian J. Agric. Sci.*, **79**(7):510-514.

Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *Journal of Plant Nutrition and Plant Science*, **168**: 521–530.

Chatterjee, B.N., and Mandal, S.S. (1996). Potassium nutrition under intensive cropping. *J. Potassium Res*, **12**: 358-364.

Chaturvedi, S., Chandel, A.S., Dhyani, V.C. and Singh, A.P. (2010). Productivity, profitability and quality of soybean (*Glycine max*) and residual soil fertility as influenced by integrated nutrient management. *Indian J. Agron*, 55 (2) :133-137.

Chitdeshwari, T., Selvaraj, P. K. and Shanmugam P. M. (2007). Influence of levels and split application of fertilizers on the yield and nutrient uptake by groundnut. *Agricultural Science Digest*, **27**(2): 91-94

Collins, M. and Duke, S.H. (1981). Influence of potassium –fertilization rate and form on photosynthesis and N_2 fixation on Alfa. *Crop Sci*. **21**:481-485.

Deshmukh, V.N., Atre, A.H., Rangacharaya, R.P. and Rewatkar, S.S. (1993). Effect of phosphorous and potassium application on growth, yield, quality and nutrient uptake by groundnut. *J. Potassium Res*., **9**(1): 72-75.

Deshmukh, V.N., Rangacharya, R.P., Rewatkar, S.S. and Solanke, B.U. (1994). Response of soybean to phosphorous and potassium application in Vertisols. *J. Potassium Res.*, **10** (4): 332-337.

Deshmukh, V. N., Warokar, R. T. and Kanakpure, B.T. (1992). Yield, quality and nutrient uptake by groundnut as influenced by potash fertilization and time of application. *J. Potassium Res*., **8**(4): 367-370

Deshmukh, V. N., Warokar. R. T. and Kanakpure, B .T. (1993). Yield, quality and nutrient uptake by groundnut as influenced by potash fertilization and time of application. *J. Potassium Res*., **8** (4):367-370.

Dev, G. (1995). Potassium-An essential element. *In: Proc. Use of potassium in Panjab agriculture*.PAU, Ludhiana, July 5, 1994.pp.17-23.

Dutta, R., Gogoi, P.K. and Deka, N.C. (2003). Effect of levels of lime and potassium on nutrient uptake and residual soil fertility in groundnut. *Crop Res*., **26**(3): 420-423.

Egilla, J.N., Davies, F. T. and Drew, M.C. (2001). Effect of potassium on drought resistance of *Hibiscus rosa sinensis*. cv. Leprechaun: Plant growth, leaf macro and micronutrient content, and root longevity. *Plant and Soil*, **229**: 213–224.

Farhad, I.S. M., Islam, M.N., Hoque, S. and Bhuiyan, M.S.I. (2010). Role of potassium and sulphur on the growth, yield and oil content of soybean (*Glycine max* L.). *Academic Journal of Plant Sciences*, **3**(2) : 99-103.

Geetha, V. and Varughese, K. (2001). Response of vegetable cowpea to nitrogen and Potassium under varying methods of irrigation. *Journal of Tropical Agriculture*., **39** :111-113.

Golakiya, B.A. (1999). Potassium Fertilization of Groundnut in Saurashtra region, India. *Proceedings of workshop organized by the International Potash Institute at the 16 th world congress of soil science*, Montpellier , France,20-26 August 1998, pp : 57-69.

Golakiya, B.A. and Patel, M.S. (1988). Role of potassium in counteracting the effect of cyclic drought on groundnut. *J. Potassium Res.,* **4**: 163-167.

Gopalan, C., Rama Sastri, B.V. and Balasabramananian, S.C. (2002). Nutritive value of *Indian Foods*. NIN, Hyderabad.

Grewal, H. S., Kolar, J. S. and Singh, D. (1994). Effect of potassium and nitrogen growth and yield of soybean (*Glycine max*. L) Merr. *J. Potassium Res*., **10** (2): 173-179.

Gupta, B. R., Tiwari, R., Tiwari, T. P. and Tiwari, K. N. (2007). Maximizing yield, nutrient use efficiency, and profit in summer black gram. *Better Crops.*, **91**(3): 22-23.

Hameed Ansari, A., Qayym, S. M., Usman, M. and Usmani, K. (1993). Impact of row spacing and NPK fertilizer levels on the growth, seed yield and oil content in pea nut. *Oil Crops Newsletter.*, **10**: 50-53.

Hoeft, R. G, Nafaziger, E. D., Jhonson, R. R. and Aldrich, R. (2000). Modern corn and soybean production, *MCSP publication*, USA., 353.

Hsiao, T. C. and Lauchli, A. (1986). Role of potassium in plant–water relations. *In Advances in plant nutrition*, ed. B. Tinker and A. Lauchli, 281–312. New York: Praeger Scientific.

Jackson, M.L. (1973). Soil Chemical Analysis. Prentice, Hall of Indian Private Ltd., New Delhi.498.

Jadhav, A.S. (1992). Effect of fertilizer management on nutrient uptake by sorghum and groundnut under double cropping system. *Madras Agric. J.,* **79**(2): 66-71.

Jamadagni, B.N. and Birar, S. P. (1994). Yeild response of cowpea to varying levels of potassium and phosphorous on lateritic soils of Konkan region. *J. Potassium Res*., **10**(2): 192-195.

Joshi, M. and Rudraradhya, M. (1993). Effect of differential doses of potassium on yield of soybean. *J. Potassium Res.,* **9**(4): 388-391.

Kabir, M. E., Karim, M. A. and Azad, M. A. K. (2004). Effect of potassium on salinity Tolerance of Mungbean. (*Vigana radiate* L. Wilczek). *Journal of Biological Sciences*, **4**(2): 103-110.

Kalaichelvi, K. and Chinnusamy, C. (2005). Influence of potassium humate on residual fertility of cotton-black gram cropping system. *Intern. J. Trop. Agric*, **23**(1-4): 79-90.

Karunakaran, V., Rammohan, J., Chellamuthu, V. and Poonghuzhalan, N. (2010). Effect of integrated nutrient management on the growth and yield of groundnut (*Arachis hypogaea*) in costal region of Karaikal. *Indian. J. Agron.*, **55**(2):128-132.

Kherawat, B.S., Munna lal, AgarwaL, M., Yadav, H. K. and Kumar, S. (2013). Effect of applied potassium and manganese on yield and uptake of nutrients by clusterbean. (*Cyanosis teragonoloba*). *Journal of Agricultural Physics*., **13**(1): 22-26**.**

Kumar, K., Sinha, K. K. and Roy Sharma, R. P. (2004). Effect of organic manure, NPK and boron application on the productivity of French bean in sandy loam soil of north Bihar. *Indian J. Pulses Res*., **17**(1): 42-44.

Kumar, P., Singh, A.K. and Meena, R.S. (2014). Response of potassium application on growth parameters of mung bean (*Vigna radiata* (L) Wilczek) under Custard Apple (Annona squamosa L.) based Agri-horti system. *Journal of Agri Search*., **9**(2): 265-267

Kundu, S., Bhatnagar, V.K., Vedprakash., Joshi, H.C. and Koranne, K.D. (1990). Yield response of soybean-wheat rotations to K application in a long term field experiment. *J. Potassium Res.*, **6**(2):70-78.

Kushwala, B.L. (2001). Effect of nitrogen and potash on growth and yield of dwarf field pea. *Indian J. Pulses Res*., **14** (1):44-47.

Lakhshmanna, P. J., Shivaraj, A. and Rao, L. (1996). Effect of cobalt, phosphorous and potassium and nutrient uptake in groundnut. *Ann. Agric. Res.,* **17**(3): 335-336.

Laximinarayana, K. (2001). Effect of hybridization of sandy soil with black soil and potassium on yield attributes and nutrient composition in groundnut. *J. Res. ANGRAU* ., **29** (4) 36-42.

Laxminarayana, K., and Subbaiah, G. V. (1995). Effect of mixing of sandy soil with clay Vertisols and potassium on yield and nutrient uptake by groundnut. *J . Indian Soc. Soil Sci*., **43** (4): 694-696.

Leigh, R.A., Jones R.G.W. (1984). A hypothesis relating critical potassium concentrations for growth, distribution and functions of this ion in the plant-cell. *New Phytol.,* **97**:12-13.

Lindsay, W. L. and Norvell, W. A. (1978). Development of DTPA soil testing for Zn, Fe, Mn and Cu. *Soil Sci. Amer. Proc. J.*, (**42**):421-423.

Mandal, K. G., Ghosh, P. K., Wanjari, R. H., Hati, K. M., Bandyopadhyay K. K. and Misra, A. K. (2002). Practical implication of nutrient x nutrient interaction to boost oilseeds productivity in India. *Fert. Res*., **47**(7): 13-18 & 21-26.

Mandal, S. S. and Goswami, S. B. (1991). Effect of split application of potassium on rainfed groundnut. *J .Potassium Res*., **7** (4): 304-308.

Mandal, S. S. and Pramanik, C. K. (1996). Integrated fertilizer management with potassium in soybean and sesame under different cropping systems. *J. Potassium Res*., **12** (3):298-304.

Maniyar, V.G. (1979). Physio–chemical properties of normal and salt affected soils of Parbhani district. M.Sc. (Agri.) Thesis, Marathwada Agricultural University, Parbhani.

Marschner, H. (2002). *Mineral nutrition of higher plants*. London: Academic Press.

Meena, M. C., Dwiveda, B. S., Singh, D., Sharma, B. M., Kumar, K., Singh, R.V., Kumar, P. and Rana, D. S. (2012). Effect of integrated nutrient management on productivity and soil health in pigeonpea (*Cajanus cajan*)

– wheat (*Triticum aestivum*) cropping system. *Indian J. Agron*., **57** (4): 333-337.

Mengal, K. and Arneke, W. W. (1982). Effect of potassium on the water potential osmotic potential pressure potential osmotic potential and cell elongation in the leaves of *Phaseolus vulgaris*. *Physiological plantarum*., 6: 70-78.

Mengel, K. (1997). Impact of potassium on crop yield and quality with regard to economical and ecological aspects. In *Food security in the WANA region: The essential need for balanced fertilization*, ed. A. E. Johnston, 157–174. Basel, Switzerland: International Potash Institute.

Mengel, K. and Kirkby, E. A. (2001). *Principles of plant nutrition*. Dordrecht, the Netherlands: Kluwer Academic Publishers.

Mitra, G. N. and Sahoo, D. (1998) Nitrogen –potassium interaction on yield and quality development for rice –legume sequence in Orissa. *Final report. IPI/PRII sponsored research project* . Department of Agril. Chemistry, Soil Science and Bio chemistry. OUAT.

Mitra, G. N., Sahoo, D. and Raou, K.K. (2001). Effect of N-K interaction on yield, nutrient uptake and grain quality of rice groundnut cropping sequence in the alluvial soils of Orissa. *J. Potassium Res.*, **17** (1): 71-78.

Mitra, G. N., Sahoo, D., Sahu, S. K. and Dev, G. (1993). Potassium-iron and potassium-sulphur interaction in rice and rice based cropping system grown on lateritic soils. *International symposium on decade of Potassium Research.* Nov -18-22, 1993, PRII, New Delhi.

Mona, A. M., Sabah, M. A. and Rehab, A. M. (2011). Influence of potassium sulphate on Faba bean yield and quality. *Australian Journal of Basic and Applied Sciences*, **5** (3): 87-95.

Mpelasoka, B. P., Schachtman, D. P., Treeby, M. T. and Thomas, M. R. (2003). A review of potassium nutrition in grapevines with special emphasis on berry accumulation. *Australian Journal of Grape and Wine Research*, **9**:154–168.

Munda, G.C., Patel, D.P. and Islam, M. (2004). Effect of macro and micronutrients on growth and yield of groundnut. *Ann. Plant Physiol*., **18** (1): 9-12.

Nagre, K. T., Deshmukh, S. B., Bhalerao, P. D. and Thorve, P.V. (1991). Effect of sowing date and fertilization on growth, yield and quality of soybean varieties. *PKV: Res J.,* **15** (1): 82-84.

Oad, F.C., Naqi Shah, A., Jamro, G. H. and Ghaloo, S. H. (2003). Phosphorous and potassium requirements of Mungbean (*Vigna radiata*). *Pakistan Journal of Applied Sciences*, **3**(6): 428-431.

Olsen, S. R., Cole, G. V., Watanable, F. S. and Dean, L. A. (1954). Estimation of available P in soils by extraction with sodium bicarbonate USDA. CRIC. 939.

Panda, P. K., Sen, H., Mukherjee, A. and Satapathy, M. R. (2003). Studies on the effect of NK fertilization on the performance of Yambean-pigeonpea intercropping system and its residual effect on the succeeding Mung. *Legume Res*., **26** (4): 235-241.

Pande, M., Mudlagiri, B. G. and Bellaloui, Nacer (2014). Effect of foliar and soil application of potassium fertilizer on soybean seed protein, oil, fatty acids, and minerals. *American Journal of Plant Sciences*, 5, 541-548.

Panse, U.G. and Sukhatme, P.V. (1985). Statistical methods for agricultural workers, Publ. by ICAR, New Delhi.

Pasricha, N.S. (2000). Opening remarks, balanced nutrition of groundnut and other field crops grown in calcareous soils of India. Proceedings of National Symposium (N.S. Pasricha, S.K. Bansal, B.A. Golakiya, Eds) pp-1-2.Potash research Institute of India. Gurgaon.

Patel, M. S., Gundalia, J. D., Golakiya, B. A. and Hadvani, G. J. (1993). Dynamics of soil potassium in medium black soils of Saurashtra semi-arid region. pp-32-35. *In: Potassium in Gujarat Agriculture.* Gujarat Agricultural university. Dantiwada Campus, Sardar Krushinagar.

Patil, R.B., More, A. D., Kalyankar, M., and Wadje, S.S. (2011). Effect of potassium humate on nutrients uptake of *Glycine max*, *Phaseolous mungo* and *Triticum aestivum*. *Plant Sciences Feed*, **1**(10): 174-178.

Patil, S. D., Dabke, D.J. and Nigade, P.M. (2011). Effect of different levels of N and K with and without bio-fertilizers on yield, nutrient uptake by cowpea and their correlation in lateritic soil of Konkan. *Green Farming*., **2** (3): 316-318.

Patil, S. M. and Dhonde, M. B. (2009). Effect of potash levels and foliar spray of cowurine on growth and yield of summer green gram. *J. Maharashtra Agric. Univ*., **34**(1): 106-107.

Patil, V. D., Pholane, L.P. and Adsul, P. B. (2001). Plant nutrient mining in different agro-climatic zones of Maharashtra. *Fertilizer News*, July 2001, Vol. **46** (7) PP. 43-48 and 51-54.

Patra, A. K., Samui, R.C. and Tripthy .S.K., (1996). Response of summer groundnut varieties to potassium and planting method. *J. Oilseeds Res*., **13** (1): 26-31.

Patra, A. K., Tripathy, S. K. and Samui, R. C. (1995). Yield and nutrient uptake of groundnut (*Arachis hypogaea* L.) as influenced by potash fertilization and methods of planting. *J. Potassium Res*., **11**(3 &4) : 332-337.

Patra, A.K., Tripathy, S.K. and Samui, R.C. (1999). Effect of K and planting method on nodulation, shoot and pod yield of summer groundnut. *J. Potassium Res*., **15**(1-4): 103-108.

Pettigrew, W. T. (2000). Potassium deficiency increased specific leaf weights and leaf glucose levels in field grown cotton. *Agronomy Journal*., **91**: 962–968.

Piper, C.S. (1966). Soil plant Analysis. Hans Publishers, Mumbai. Proceedings of the air borne imaging spectroscopy workshop .Bruges.

Ponnuswamy, K., Balakrishnan, V. K. and Santhi, P. (1996). Exploiting the production potential of groundnut by improved nutrient management in the lower Bhavani project area, Tamil Nadu, India. *International Arachis Newsletter*., **16**: 50-52

PRII (1999). Annual Report 1999-2000, All India Coordinated Research Project on MULLaRP (Rabi), *Indian Institute of Pulses Research* (*PRII*), Gurgaon. 261-278.

Rajagopal, A. and Velu, G. (1995). Effect of irrigation and agronomic management practice for water use efficiency in soybean. *Madras Agric. J*., **82**(4): 274-278.

Ram, B., Punia, S.S., Tetarwal, J.P., Meena, D.S. and Tomar S.S. (2013). Effect of organic and inorganic sources of nutrients productivity, profitability and soil health in lentil (Lens culanaris) under Vertisols. *Indian J. Agron.,* **58** (4): 564-569.

Ramswaroop Meena, Ramawatar, Kamalesh, Vijay Singh Meena and Kalu Ram. (2013). Effect of organic and inorganic source of nutrients on yield, nutrient uptake and nutrient status of soil after harvest of green gram. *An Asian Journal of Soil Science.*, **8**(1): 80-83.

Rao, N. K., and Kameshwar Rao, B. V. (2004). Effect of potash levels and topping on leaf potassium, yield and quality in flue cured tobacco. *Indian J. of plant physiol.,* **9**: 283-293.

RaoSrinivasa, Ch. (2012). Impacts of participatory site specific potassium management in several crops in rainfed regions of Andhra Pradesh, India. *International Potash Institute. e-ifc* (*Electronic International Fertilizer Correspondent*)., **30**: 7-25.

Rao Srinivasa. Ch., Benzioni, A., Eshel, A. and Waisel, Y. (2012). Potassium uptake by Fababean roots : Effect of roots type, plant age and salinity. *J. Indian Soc. Soil Sci.,* **50** (3): 264-268**.**

Ravankar, H. M., Patil, D. M., Mahood, N. B. and Deshmukh, P. W. (2000). Effects of organics and inorganics on yield and nutrient availability under soybean wheat sequence in Vertisols. *PKV Res. J*., **24**(2):75-79.

Read, J.J., Raja Reddy, K. and Jenkins, J.J. (2006). Yield and fiber quality of upland cotton as influenced by nitrogen and potassium nutrition. *European Journal of Agronomy*, **24**: 282–290.

Rupa, T. R., Srivastava, S., Swarup, A., Sahoo, D. and Tembhare, B. R. (2003). The availability of potassium in Aeric Haplaquept and Typic Haplustert as affected by long term cropping, fertilization and manuring. *Nutrient Cycling in Agroecosystems*, 65:1-11.

Sahay, N., Singh, S. P. and Sharma, V. K. (2013). Effect of Cobalt and Potassium application on growth, yield, and nutrient uptake in lentil (*Lens culinaris* L). *Legume Res.*, **36**(3): 259-262.

Sahu, S. K., Dev, G. and Mitra, G. N. (1996). Potassium and Sulphur requirements for groundnut and rice on a Leterite soil. *J. Potassium Res.*, **12** (4):365-369.

Salve, Y.V. and Gunjal, B.S. (2011). Effect of different levels of phosphorous and potassium on summer groundnut (*Arachis hypogaea* L.). *Intern. J. Agril Sci*, **17**(2): 352-355.

Sawarkar, S. D., Khamparia, N. K., Thakur, R., Dewda, M. S. and Singh, M. (2013). Effect of long term application of inorganic fertilizers and organic manure on yield, potassium uptake and profile distribution of potassium fractions in Vertisol under Soybean-wheat cropping system. *J. Indian Soc. Soil Sci.*, **61**(2): 94-98.

Sepehya, S., Bharadwaj, S. K., Dixit, S. P. and Dhiman, S. (2012). Effect of integrated nutrient management on yields attributes, yield and NPK uptake in garden pea (Pisum sativum L.) in acid alfisol. *Journal of Food Legumes*., **25**(3) : 246-248.

Shankar, M.A., MaruthiSankar, G.R., Sharma, K.L., Sharma, K.L., Muniswamappa, M.V., Srinivasarao Ch. and Suma Chandrika. D. (2013). Effect of Micronutrient based integrated use of nutrients on crop productivity, Nutrient uptake, and soil fertility in greengram and fingermillet sequence under semi arid tropical conditions. *Communications in Soil Science and Plant Analysis*, (**44**): 2771-2787.

Sharma, G. L. and Agarawal, R. M. (2002). Potassium induced changes in nitrate reductive activity in *Cicer arietinum* L. *Indian J. Plant Physiol.*, **7**(3): 221-226.

Sharma, P. K. and Dixit, S. P. (1994).Effect of lime and potassium on the yields of crops and different forms of K in soil under wheat –soybean-linseed cropping sequence. *J. Potassium Res.*, **10**(2): 178-183.

Singh, N., Chhonkar, V. Sharma, K.D. and Kuhad, M.S. (1997). Effect of potassium on water relations, $C0_2$ exchange and plant growth under quantified water stress in chickpea. *Indian J. Plant physiol.*, **2**. 202-206.

Singh, A.B. and Prasad, J. (1997). Relative response of Chickpea cultivars to potash fertilization. *Legumes Res.*, **20** (3 & 4): 233-235.

Singh, A.K., Chandra, A., Singh, R.K. and Singh, M.K. (2009). Integrated nutrient management in black gram. (*Vigna munga*) under rainfed condition. *Intern. J. Trop. Agric.*, **27**(3-4): 541-544.

Singh, A. K., Singh. K., Singh, U. N., Raju, M. S. and Singh, N. P. (1995). Effect of potassium, zinc and iron on yield protein harvest and nutrient uptake in french bean (*Phaseolus vulgaris* L.). *J. Potassium Res*., **11**(1): 75-80.

Singh, A.L. and Chaudhari, V. (1996). Interaction of sulphur with phosphorus and potassium in groundnut nutrition in calcareous soil. *Indian J. Plant Physiol*., New series, 1 : 21-27.

Singh, D. and Singh, V. (1994). Response of soybean to K, Zn and S application on yield and K uptake. *Fert. News*., **39** (2) :53-55.

Singh, H. and Singh, G. (2013). Effect of potassium and split application of nitrogen on yield attributes and yield of soybean [*Glycine max* (L.) Merrill]. *Agric. Sci. Digest.,* **33** (4): 264- 268.

Singh, J., Sharma, H.L. and Singh, C.M. (1993). Response of soybean to potassium nutrition in different agro-climatic zone of H.P. *J. Potassium Res*., **9**(1): 38-43.

Singh, R., Sharma, H. B., Kumar, P., Paliwal, D. K. and Kumar, P. (2013). Effect of integrated nutrient management on growth, yield, and nutrient uptake by soybean (*Glycine max*) cultivars. *Indian J. Agron.*, **58** (3) : 379-383.

Singh, S., Gangwar, M.S., Singh, H.P. and Singh, S., (1999). Nodulation and biomass production in soybean as influenced by the application of nutrients. *J. Potassium Res.*, **15** (1-4).

Sood, R.D., Thakur, R.C. and Bhargava, M. (1996). Response of chick pea and urd bean to N, P and K application on farmers fields under rainfed conditions. *Indian J. Pulses Res*., **9**(2): 117- 119.

Srinivasasarao, Ch., Ganeshamurthy, A.N., Ali, M. Singh, R.N. and Singh, K.K. (2001). Potassium availability in different soil types of major pulse growing regions of India. In: *Proceedings of International Symposium on Importance of Potassium in Nutrient Management for Sustainable Crop*

Production in India. (N. S. Pasricha and S.K. Bansal, Eds.) pp 52, Potash Research Institute of India, Gurgaon.

Subbaiah, B.V. and Asija, G.E. (1956). A rapid procedure for estimation of available nitrogen in soil. *Curr. S*ci., **25**: 259.

Subbulakshmi, S., Saravanan, N., Sivaprakash, M. and Harisudan, C. (2009). nutrition management for pulses. *J. Pulses Research*, **7**(8) : 48.

Subrahmaniyan, K., Kalaiselvan, P. and Arulmozhi, N. (2000). Studies on the effect of nutrient spray and graded level of NPK fertilizers on the growth and yield of groundnut. *Intern. J. Trop. Agric*., **18**(3): 287-290.

Swaminathan, M.S. (1981). Improving pulse production and productivity challenges aheads. *Pulse Crops Newsletter.*, **1**(2): 25.

Swarup, A., Reddy, K.S. and Tripathi, A.K. (2001). Nutrient mining in agro-climatic zones of Madhya Pradesh. *Fertilizer News.,* **46**(4) : 33-38 and 41-45.

Tandon, H.L.S. and Sekhon, G.S. (1988). Potassium Research and Agricultural Production in India. Fertilizer Development and Consultation Organization, New Delhi. pp 144.

Thenua, O.V.S., Singh, K. and Shivakumar, B.G. (2010). Studies on rizhobium inoculation and nitrogen and potassium levels on the performance of soybean (*Glycine max* L.). *Ann. Agric. Res.*, **31**(1&2) :1-4.

Thesiya, N.M., Chovatia, P.K. and Kikani, V.L. (2013). Effect of potassium and sulphur on growth and yield of black gram (*Vigna Mungo* .L) under rainfed Condition. *Legume Res.,* **36** (3): 255-258.

Tiwari, D.D., Pandey, S.B. and Dubey, M.K. (2012). Effect of potassium application on yield and quality characteristics of pigeon pea (*Cajanus cajan*) and mustard (*Brassica juncea* L. Czern) crops in Central Plain Zone of Uttar Pradesh. *International Potash Institute. e-ifc* (*Electronic International Fertilizer Correspondent*)., **3**: 16-24.

Tiwari, H.S., Agarwal, R.M. and Bhatt, R.K. (1998). Photosynthesis, stomatal resistance and related characteristics as influenced by potassium under normal water supply and water stress condition in rice (*Oryza sativa L*). *Indian J. Plant Physiol.*, **3**:314-316.

Tiwari, V.N. and Tiwari, K.N. (1999). Role of potassium in biological nitrogen fixation . *In : Use of Potassium in U.P. Agriculture* (Eds. Tiwari, K.N. and Modgal, S.C.). 79-87.

Tomar, V.S. (1998). Role of potassium in water stress management in soybean. *Farmer and Parliament,* **33**:15-26.

Trolldenier, G. (1987). Rhizosphere organisms potassium interaction with emphasis on methodology, proceedings of 20th colloquim *International Potash Institute*, Badenbci, wein lanstria PP. 283-297.

Umar, S. (1997). Influence of Potassium on solar energy harvesting efficiency of groundnut under different soil moisture stress.). *Indian J. Plant Physiol*., **2** :315-317

Usherwood, N.R. (1985). The role of potassium in crop quality. In *Potassium in agriculture*, ed. R.D. Munson, 489–514. Madison.

Ved prakash, Kundu, S., Ghosh, B.N., Singh, R.D., and Gupta, H.S. (2001). Yield response patterns of soybean and wheat to K application and changes in K status in soil profile after 27 years of cropping in mid –hills of northern Himalays. In: Proceedings of international Symposium on importance of potassium in nutrient management for sustainable Crop production in India. Vol 1. Potash Research Institute of India., Gurgaon, pp-362-365.

Verma, R.K. and Nandram, S.U. (2003). Response of wheat to long term NPK fertilization. *Ann. Pl. Soil Res*., **5**(1): 9-11.

Viradiya, M.B., Golakiya, B.A. and Kikani, V.L. (2008). Effect of potassium and salinity levels on nutrient concentration of groundnut (*Arachis hypogeae L*.). *Legume Res.*, **31**(3): 196-198.

Vyas, S.P., Garg, B.K., Kathju, S., and Lahiri, A.N. (2001). Influence of potassium on water relations, photosynthesis, nitrogen metabolism and yield of cluster bean under soil moisture stress. *Indian J. Plant Physiol.,* **6**: 30-37.

Wan-Tai Yu., Zi –Shao Jiang., Hua Zhou and Qiang Ma. (2009). Effects of nutrient cycling on grains yields and potassium balance. *Nutr Cycl Agroecosyst*, **84**: 203-213.

William, T.P. (1999). Potassium deficiency increase specific leaf weights and leaf glucose levels in field grown cotton. *Agronomy Journal*, 91:962-968.

www.agropedia.iitk.ac.in

Yadav, D. S., Alok Kumar and Singh, V. K. (1993). Response of different Crops to potassium on cultivators' fields in Uttar Pradesh under irrigated and rainfed conditions. *J. Potassium Res*., **9**: 253-261.

Yadav, R.L., Sen, N.L. and Yadav, B.L. (2003). Response of onion to nitrogen and potassium fertilization under semi-arid condition of Rajasthan. *Indian Journal of Horticulture*, **60**:176–178.

Zharare G.E. (1996.) Research priorities for groundnut (*Arachis hypogaea* L.) nutrition- A scientific basis for manipulating soil fertility to optimize groundnut yields. *Agronomy Institute Annual Review and Planning Workshop.* 6–7 August 1996. Department of Research and Specialist Services, Harare, Zimbabwe.

APPENDIX – I

Nitrogen status of the experimental soil at critical growth stages.

Treatments	**Available N (kg ha^{-1})**			
	Flowering	**Pod development**	**Harvest**	**Mean**
T_1 Absolute control (no fertilizer)	177.33	174.56	180.93	177.6
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	180.35	177.09	182.10	179.84
T_3 RDF + 25 kg K_2O ha^{-1}	184.50	178.35	185.84	182.89
T_4 RDF + 50 kg K_2O ha^{-1}	194.18	184.58	196.68	191.81
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	187.27	182.51	188.70	186.16
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	196.91	191.27	199.22	195.8
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	183.78	185.50	187.68	185.65
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	195.69	190.45	193.88	193.34
Grand mean	187.50	183.03	189.37	-
SEm±	3.13	3.34	3.39	-
CD at 5%	10.06	10.15	10.28	-
CV %	3.07	3.17	3.10	-

Initial available N 159.58 kg ha^{-1}

APPENDIX - II

Phosphorous status of the experimental soil at critical growth stages.

Treatments	**P_2O_5 (kg ha^{-1})**		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (no fertilizer)	6.84	7.57	7.31
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	9.42	7.75	10.37
T_3 RDF + 25 kg K_2O ha^{-1}	12.91	11.63	15.01
T_4 RDF + 50 kg K_2O ha^{-1}	19.71	20.44	19.49
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	18.10	15.63	18.49
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	20.10	17.96	20.35
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	17.14	18.69	19.68
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	18.73	15.26	21.38
Grand mean	15.36	14.36	16.51
SEm±	0.43	0.99	0.41
CD at 5%	1.31	3.01	1.27
CV %	4.9	4.97	4.39

Initial available phosphorous 7.01 kg ha^{-1}

APPENDIX - III

Potassium status of the experimental soil at critical growth stages.

Treatments	**K_2O(kg ha^{-1})**		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (no fertilizer)	797.70	761.70	735.26
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	837.88	771.84	744.20
T_3 RDF + 25 kg K_2O ha^{-1}	849.03	778.78	759.02
T_4 RDF + 50 kg K_2O ha^{-1}	869.79	820.61	793.12
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrients	850.93	781.71	762.12
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	873.00	824.10	796.24
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	853.35	780.10	760.55
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	871.03	822.43	795.33
Grand mean	850.34	792.58	768.23
SEm±	13.10	13.94	13.76
CD at 5%	39.76	42.30	41.74
CV %	2.67	3.05	3.10

Initial available K_2O 841.71 kg ha^{-1}

APPENDIX - IV

Iron status of the experimental soil at critical growth stages.

Treatments	Available Fe (mg kg^{-1})		
	Flowering	Pod development	Harvest
T_1 Absolute control (no fertilizer)	3.33	3.14	3.44
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	3.40	3.19	3.55
T_3 RDF + 25 kg K_2O ha^{-1}	3.56	3.26	3.72
T_4 RDF + 50 kg K_2O ha^{-1}	3.70	3.31	3.88
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	3.58	3.47	3.75
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	3.73	3.56	3.91
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	3.60	3.33	3.78
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	3.61	3.35	3.80
Grand mean	3.56	3.33	3.72
SEm±	0.06	0.05	0.08
CD at 5%	0.20	0.17	0.26
CV %	3.24	3.03	4.06

Initial available Fe 3.36 mg kg^{-1}

APPENDIX - V

Zinc status of the experimental soil at critical growth stages.

Treatments	**Available Zn (mg kg^{-1})**			
	Flowering	**Pod development**	**Harvest**	**Mean**
T_1 Absolute control (no fertilizer)	0.58	0.45	0.66	0.56
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	0.62	0.50	0.74	0.62
T_3 RDF + 25 kg K_2O ha^{-1}	0.67	0.53	0.79	0.66
T_4 RDF + 50 kg K_2O ha^{-1}	0.72	0.57	0.85	0.71
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	0.86	0.75	0.92	0.84
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	0.88	0.78	0.95	0.87
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	0.70	0.60	0.84	0.71
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	0.69	0.62	0.86	0.72
Grand mean	0.71	0.60	0.82	-
SEm±	0.01	0.013	0.019	-
CD at 5%	0.02	0.04	0.05	-
CV %	4.39	3.96	4.1	-

Initial soil 0.60 mg kg^{-1}

APPENDIX - VI

Copper status of the experimental soil at critical growth stages.

Treatments	**Cu (mg kg^{-1})**		
	Flowering	**Pod development**	**Harvest**
T_1 Absolute control (no fertilizer)	1.96	1.95	1.74
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	2.03	1.97	1.70
T_3 RDF + 25 kg K_2O ha^{-1}	2.14	2.03	1.78
T_4 RDF + 50 kg K_2O ha^{-1}	2.17	2.08	1.81
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	2.38	2.21	1.91
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrient	2.40	2.25	1.93
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	2.19	2.13	1.77
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	2.21	2.17	1.80
Grand mean	2.18	2.10	1.80
SEm±	0.04	0.03	0.03
CD at 5%	0.12	0.11	0.10
CV %	3.19	3.00	3.37

Initial value 1.98 mg kg^{-1}

APPENDIX - VII

Manganese status of the experimental soil at critical growth stages

Treatments	**Mn (mg kg^{-1})**			
	Flowering	**Pod development**	**Harvest**	**Mean**
T_1 Absolute control (no fertilizer)	8.06	8.01	7.97	8.01
T_2 RDF (20:50 N and P_2O_5 kg ha^{-1})	8.27	8.18	8.08	8.17
T_3 RDF + 25 kg K_2O kg ha^{-1}	8.24	8.16	8.05	8.15
T_4 RDF + 50 kg K_2O ha^{-1}	8.29	8.19	8.03	8.17
T_5 RDF + 25 kg K_2O ha^{-1}+Grade I micronutrient	8.73	8.65	8.31	8.56
T_6 RDF + 50 kg K_2O ha^{-1}+Grade I micronutrients	8.88	8.67	8.33	8.62
T_7 RDF + 25 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	8.31	8.28	8.13	8.24
T_8 RDF + 50 kg K_2O ha^{-1}+Grade II (0.5%) micronutrient	8.44	8.40	8.18	8.34
Grand mean	8.40	8.32	8.13	-
SEm±	0.15	0.13	0.014	-
CD at 5%	0.45	0.39	NS	-
CV %	3.12	2.73	3.07	-

Initail 8.10 mg kg^{-1}