Effect of ethylene on growth, nodulation, early flower induction and yield in mungbean

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Abstract

Late flowers induction, less number of flowers and pods per plant, improper use of fertilizer and not exogenous application of plant hormones are the major limiting factors of low average yield of mungbean at farmer field than potential yield. Mungbean yield is enhanced by application of plant growth regulator ethylene along with fertilizers. Ethylene is unsaturated hydrocarbon phyto-hormone which regulates and co-ordinate many metabolic and developmental processes within plant body. Ethylene regulates growth, yield, root development, nodulation, seed germination, flowering initiation, fruit set up, fruit ripening and seed dormancy. A pot experiment was conducted to evaluate the effect of ethylene on growth, yield, nodulation and early flower induction in mungbean. The experiment was comprised of five treatments (control, 6.25 ppm, 12.5 ppm, 18.75 ppm and 25 ppm) and three replications. L-Methionine (L-MET) was used as the source of ethylene and was applied foliarly, with hand sprayer. The N, P, and K fertilizers were applied in the form of Urea, DAP and SOP, respectively. Data was collected by standard procedures and subjected to statistical analysis. Results showed that ethylene promoted early flowers induction, number of flowers, pods per plant, 1000 grains weight, shoot fresh and dry weight, photosynthesis and N in grains and shoot as compared with control. While, plant height, nodulation, stomatal conductance, transpiration rate and N concentration in root decreased as concentration level of ethylene increased. Application L-Methionine (L-MET) with NPK fertilizer improved the yield contributing factors that resulted in significant increase in mungbean yield.

KEY WORDS: L-methionine, plant growth regulators, precursors and yield

Introduction

Mungbean (*Vigna radiata* L.) average yield is very low at farmer field than potential yield i.e. 2650 kg per hectare [1]. This low yield may be due to low soil fertility, imbalance use of fertilizers, disease and insect attack, weeds and lack use of plant growth regulators. The low yield of mungbean is due to lack of knowledge about nutrition and modern production technology [2]. If seed quality and germination is up to mark then availability of applied nutrients to crop plants have significant effects on crop yield. While, present situation demands urgent steps to improve crop production and quality of cultivars produce by using the non-conventional approaches like biotechnology, genetic modification of cultivars and use of plant growth regulators to narrow down the gap between potential and farmer obtains yield. Plant growth regulators (PGRs) behave as wonder chemicals because PGRs can change physiological growth patterns of crop, thus increase yield of horticulture and agronomic crops [3].

Plant growth regulators are organic compounds which are produced in plant body which regulates and co-ordinate plant growth and development. Major classes of PGRs are auxins, gibberellins, cytokinins, abscisic acid and ethylene [4]. Ethylene is unsaturated hydrocarbon phyto-hormone which regulates and co-ordinates many metabolic and developmental processes within plant body. It plays important role in embryogenesis, germination, senescence, leaf abscission, flowers induction and fruit maturity [5]. It involves in all growth and development stages of plants such as germination, ripening and senescence of plant tissues [6]. Ethylene involves in promoting the transcription and translation of ripening-related genes. These genes involve in cell wall breakdown and carotenoid biosynthesis [7].

There are several precursors of ethylene (C_2H_4) but L-methionine (L-MET) is one of the precursors of ethylene (C_2H_4) in plants. The conversion of methionine to ethylene in plant system is now well known with S-adenosylmethionine (SAM) and 1-aminocyclopropane-1-carboxylic acid (ACC), serving as intermediates [8]. Ethylene (C_2H_4) is a potent phytohormone that can affect many phases of plant growth and development. Its concentrations as low as 10 ppm can evoke plant response and concentrations of 25 ppm results in decrease fruits and flowers development [9]. The microorganism in soil can produced ethylene from various compounds including amino acids, carbohydrates, alcohols and proteins. The ethylene production in soil is highly substrate dependent. The addition of L-MET in soil stimulates ethylene production [10] and a significant growth and yield response in soybean was noticed by the application of L-MET to soil. [11] observed the response of sarsoon (*Brassica carinata*) and lentil (*Lens culinaris*) to C_2H_4 precursors added to the rhizosphere and reported that the treatments had significant effects on growth and yield parameters of the tested plants.

When ethylene was applied to mustard photosynthetic rate (PN), stomata conductance (gS) and carbonic anhydrase (CA) increased at 1.5 mM concentration. When concentration increased above 1.5 mM, it decreased these physiological parameters [12]. Exogenous application of ethylene leads to morphological and physiological changes such as higher root/shoot ratio and a decrease in stomata conductance which could alleviate the water deficit [13,14,15]. While, Ethylene application (source was calcium carbide) on cucumber promoted female flower production and increased yield as compared with untreated controls, depending on soil type and crop type [16]. The application of ethylene also stimulates root growth and early onset of flowering in agronomic and vegetable crops [17]. Similarly, ethylene application to tomato also increased the early onset of flowers and number of flowers per plant [18].

Treatment of ethephon (2-chloroethyl phosphoric acid), it is ethylene releasing compound, increased cotton yield up to 29% and leads to early harvesting of crop. The ethephon also increased the flax yield at the rate of 900 g ha^{-1} during first year [19]. Similarly, application of ethephon at 0.28 – 0.84 kg $ha^{-1,}$ significantly reduced the lodging in barley and increased the 100 grains weight [20].

This paper focuses on the use and selection of best dose of ethylene for improving growth, yield, nodulation and early flowers induction in mungbean.

Materials and methods

A pot experiment was conducted to evaluate the effect of ethylene on growth, yield, nodulation and early flowers induction in mungbean. The soil used was sandy clay loam in texture. The some other chemical properties of testing soil were as follows: ECe 1.16 dS m^{-1}; pH 7.7; organic matter contents 0.88%; and total N contents 0.05%. Soil was mixed thoroughly, ground, passed through 2 mm sieve and added in polythene lined earthen pots @ 10 kg per pot. Pots were placed according to completely randomized design in 3 replicates. The experiment was comprised of five treatments (control, 6.25 ppm, 12.5 ppm, 18.75 ppm and 25 ppm) and three replications. L-Methionine (L-MET) was used as the source of ethylene and was applied foliarly, with hand sprayer. The N, P, and K fertilizers were applied at sowing time in the form of Urea, DAP and SOP at the rate of 20, 60, and 25 kg ha^{-1}, respectively.

Application of treatment: Mungbean (NM 2006) was used as test crop. Three plants were maintained in each pot after two weeks. The uprooted seedlings were incorporated in the same pots. Nitrogen as urea, phosphorous as DAP and potassium as muriate of sulphate were applied by dissolving in water. While L-Met 1 g was first dissolved in 1L water for stock solution of 1000 ppm, after this made substock solution ranging 6.25, 12.5, 18.75 and 25 ppm then applied after 20 days of germination. For irrigation tape water was used throughout the growth period. Data regarding flowers induction day, number of flowers and pods per plant, 1000 grains weight, shoot fresh and dry weight, N in grains, shoot and root, plant height, nodulation, photosynthesis, stomatal conductance and transpiration rate were collected.

Plant analysis: Root, shoot and grains samples were dried and ground to determine nitrogen concentration (%) by [21] method of Sulphuric acid digestion and distillation on Kjeldhal's apparatus [22].

Statistical analysis: Data collected for various characteristics were analyzed statistically using Fisher's analysis of variance technique [23]. The treatment means were compared by least significant difference test at 5% probability level.

Results

Agronomic parameters

The maximum flowers induction days (40) was observed in treatment T_1 at which only recommended dose of N, P and K fertilizers were applied. The minimum flowers induction days (32.67) was noticed in treatment T_2 at which 6.25 ppm L-methionine along with NPK was applied (Fig.1). Number of flowers plant^{-1} was significantly enhanced with the application of L- methionine. Maximum number of flowers observed where L- methionine plus NPK fertilizers were applied (Fig. 2). Reduction in number of flowers was observed where alone NPK fertilizers were applied. While similar behaviour was observed regarding number of pods per plant (Fig 3). Quantitative data regarding shoot fresh weight was shown in fig. 4. Statistical analysis showed that shoot fresh weight promoted where 6 ppm L- methionine plus NPK fertilizers were applied. Similarly, shoot fresh weight was also promoted where 6 ppm L- methionine plus NPK fertilizers were applied as compared with control (fig.5). Statistical data regarding 1000 grains weight shown in (Fig.6). Maximum 1000 grains weight was observed where 6 ppm L-methionine plus NPK fertilizers were applied as compared with control. The statistical analysis showed (Fig. 7) that highest increase in plant height was observed in treatment T_1 (47.161 cm) at which only recommended dose of N, P and K fertilizer was applied. The minimum value of mean was noticed in treatment T_5 (30 cm) at which 25 ppm L-methionine along with NPK was applied. The quantitative statistical data regarding nodule formation showed (Fig. 8) that highest increase in nodule formation was observed in treatment T_1 (14.33) at which only recommended dose of N, P and K fertilizer was applied. The minimum value of mean (10.66) was noticed in treatment T_5 at which 25 ppm L-methionine along with NPK was applied.

Physiological parameters:

Results in Figure (9) showed the behaviour of photosynthesis rate when different concentrations of L-MET were applied to mungbean plant. The minimum photosynthesis rate (1.23) was observed in treatment T_5 at which only recommended dose of N, P and K fertilizers and 25 ppm L-MET was applied. The maximum photosynthesis rate (2.90) was noticed in treatment T_2 at which 6.25 ppm L-methionine was applied. While, statistical data regarding transpiration rate when different concentrations of L-MET were applied to mungbean plants, was represented in (Fig. 10). The minimum transpiration rate (1.03) was observed in treatment T_5 at which only recommended dose of N, P and K fertilizers and 25 ppm L-MET was applied. The maximum transpiration rate (1.93) was noticed in treatment T_1 at which N, P and K was applied. However, similar trend regarding stomatal conductance was observed which was showed in (Fig.11). The minimum stomatal conductance (0.2267) was observed in treatment T_5. The maximum stomatal conductance (0.7600) was noticed in treatment T_1 at which N, P and K was applied.

Chemical parameter

Nitrogen concentration in grains (Fig. 12) enhanced with the application of ethylene plus N fertilizer compared to control. Nitrogen was applied @ 20 kg ha^{-1} via urea. Addition of precursor with fertilizer helped to conserve the nutrient in soil that is why more N concentration in grain was observed in the treatments where ethylene was applied with NPK fertilizers. However, maximum increase in N concentration was observed where 6 ppm ethylene plus NPK fertilizers were applied compared to all other treatments. Data in Fig. 13 explained that treatment where L-methionine along NPK fertilizers were applied, significantly enhanced N concentration in shoot over control. Treatment where L- Met plus NPK fertilizers were applied also showed significant increase in N concentration compared to NPK fertilizers alone. While, statistical Data in Fig. 14 demonstrated that treatment where alone NPK fertilizers were applied, significantly increased N concentration in root over all other treatments. Addition of ethylene decreased nodule formation by inhibition of cortical cell division.

Discussion

Plant growth regulator (ethylene) is unsaturated hydrocarbon phyto-hormone which regulates and co-ordinates many metabolic and developmental processes within plant body. It plays important role in embryogenesis, germination, senescence, leaf abscission, flowers induction and fruit maturity [5]. It involves in all growth and development stages of plants such as germination, ripening and senescence of plant tissues [6].

Results showed significant improvement in early flower induction, number of flowers, number of pods, 1000 grains weight, shoot fresh and dry weight while plant height and nodule formation decreased of mungbean with application ethylene the presence of recommended doses of NPK fertilizers. This is due to ethylene involves activation of floral meristem identity genes which promoted early flower induction and number of flowers per plant [24] and ethylene changes the cellulose microfibral arrangement and inhibits auxin movement in plant body by which plant height and root length decreases and root hair formation is enhanced, it leads to more soil proliferation and more nutrient up take and better yield [6,25].

Photosynthesis is the main driving force for biomass accumulation. Different intrinsic and extrinsic factors at both cellular and organ levels controls photosynthesis. Among these various factors PGR (ethylene) is influenced the photosynthesis. It enhanced photosynthesis. The reason for increase in photosynthesis due to changes in activity of ribulose 1,5-bisphosphate carboxylase (Rubisco) and carboxylation efficiency (CE) which are directly mediated by ethylene and indirectly by regulating stomatal opening and closing of stomata. When ethylene oxidized into carbon dioxide, it increases the water potential by which water moves from guard cell to subsidiary cell then stomata becomes close [6] that is why as concentration of ethylene increases transpiration and stomatal conductance decrease. However, ethylene blocks cortical cell division [26] and it inhibits infection in legumes [27]. Ethylene blocks the formation of nodule primodia [26]. That is why nodule formation and N concentration in root reduced as concentration of ethylene increased in mungbean.

Conclusion

Application L-Methionine (L-MET) with NPK fertilizer improved the yield contributing factors that resulted in significant increase in mungbean yield. So these results suggest the application of 6 ppm L-Methionine (L-MET) in a better formulation could be recommended by general use on farmer's field.

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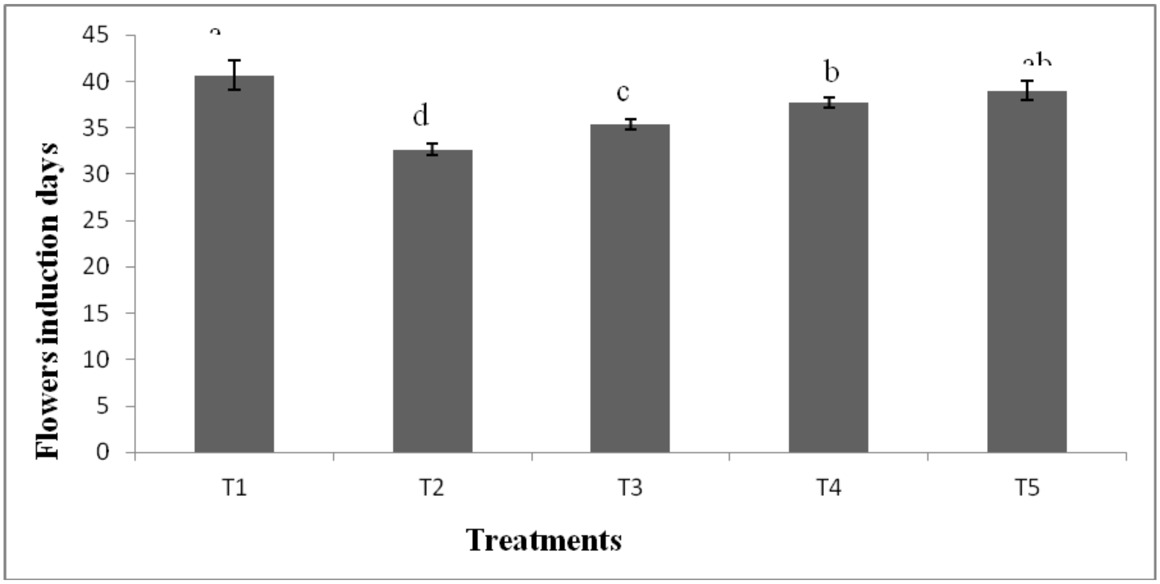

Fig: 1. Effect of foliar application of L-MET on flower induction days in mungbean. Treatments sharing same letters are statistically non-significant at p< 0.05. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

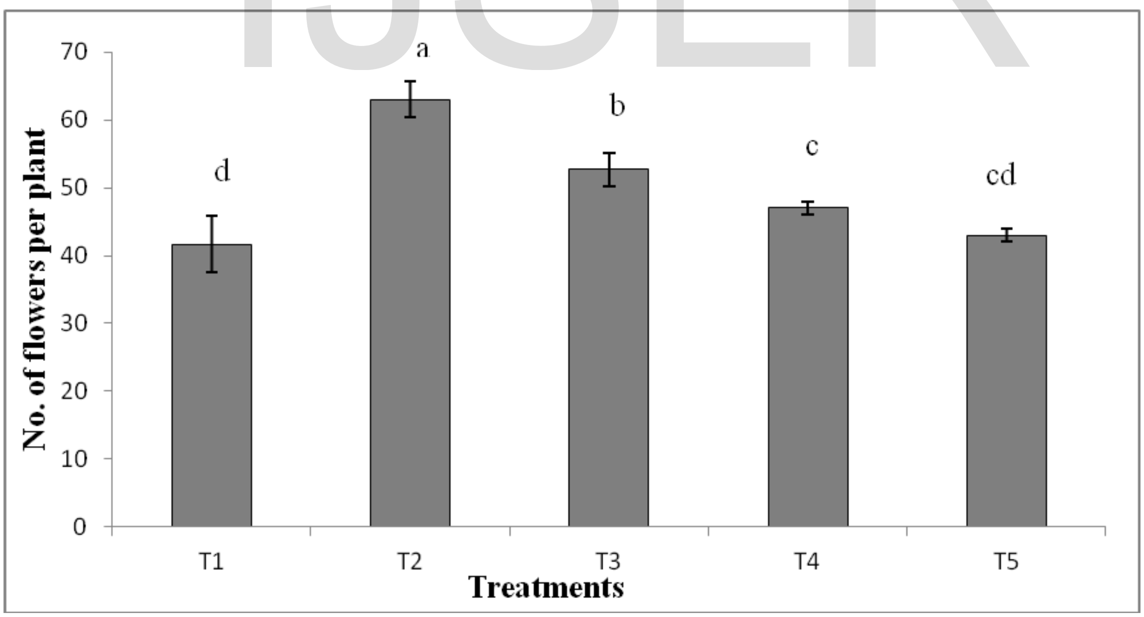

Fig: 2. Effect of foliar application of L-MET on number of flowers per plant in mungbean. Treatments sharing same letters are statistically non-significant at p< 0.05. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

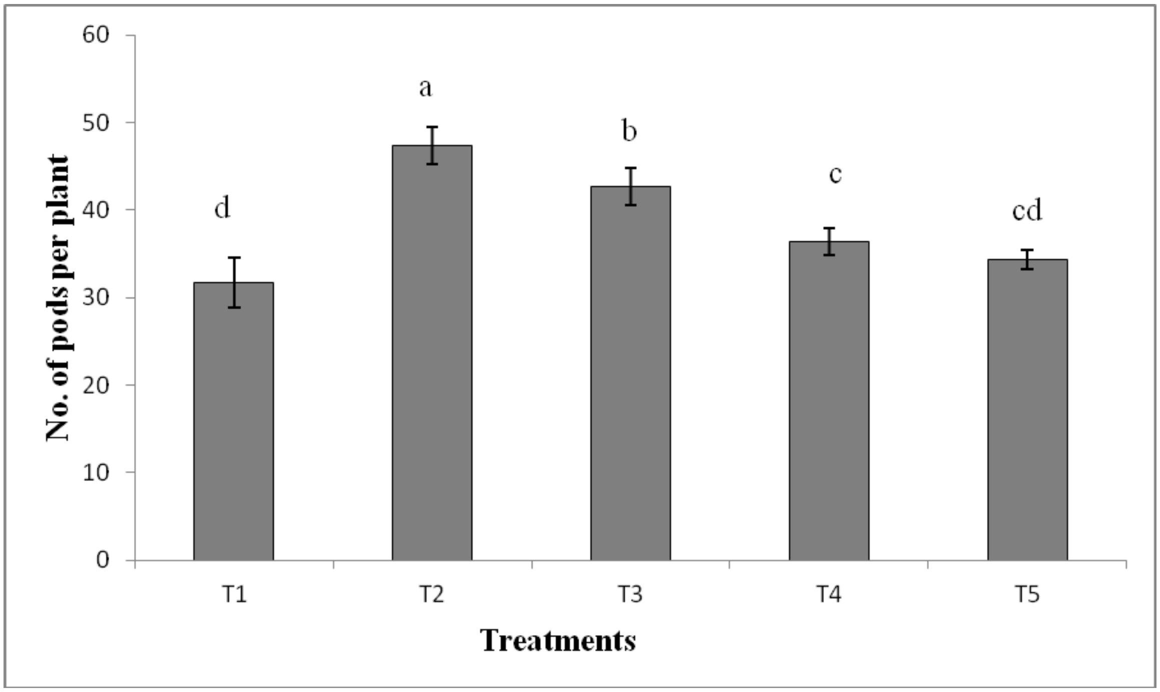

Fig: 3. Effect of foliar application of L-MET on number of pods per plant in mungbean. Treatments sharing same letters are statistically non-significant at $p< 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

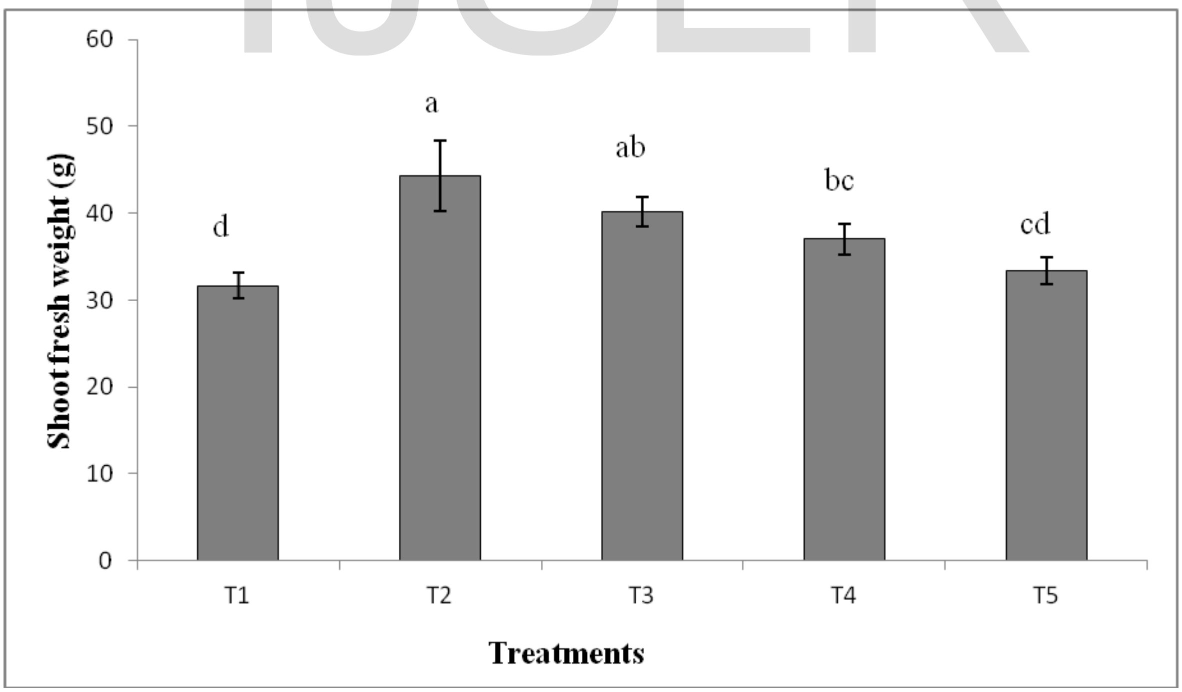

Fig: 4. Effect of foliar application of L-MET on shoot fresh weight in mungbean. Treatments sharing same letters are statistically non-significant at p< 0.05. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

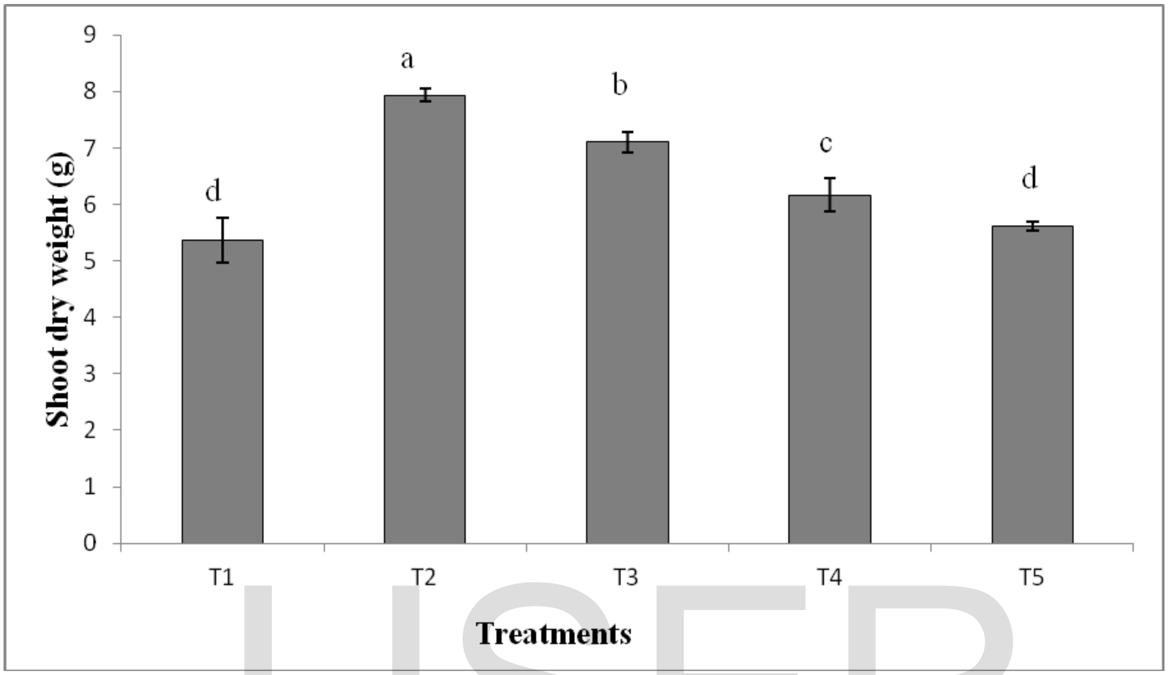

Fig: 5. Effect of foliar application of L-MET on shoot dry weight in mungbean. Treatments sharing same letters are statistically non-significant at p< 0.05. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

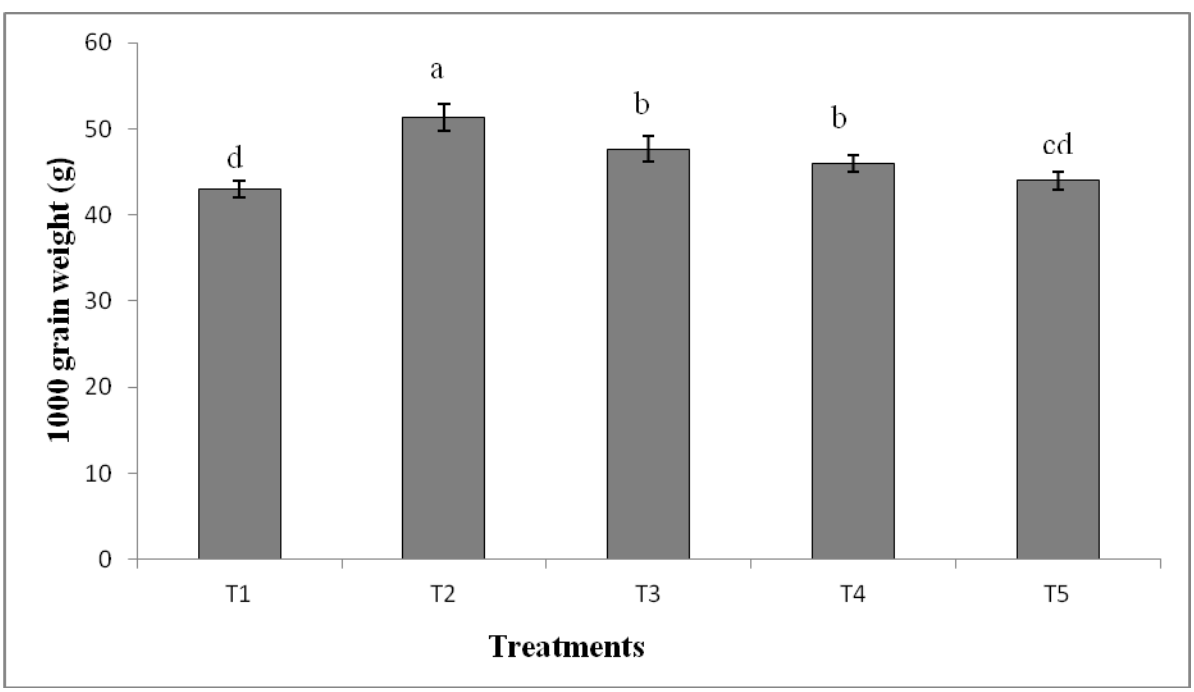

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Fig: 6. Effect of foliar application of L-MET on graings weight in mungbean. Treatments sharing same letters are statistically non-significant at p< 0.05. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

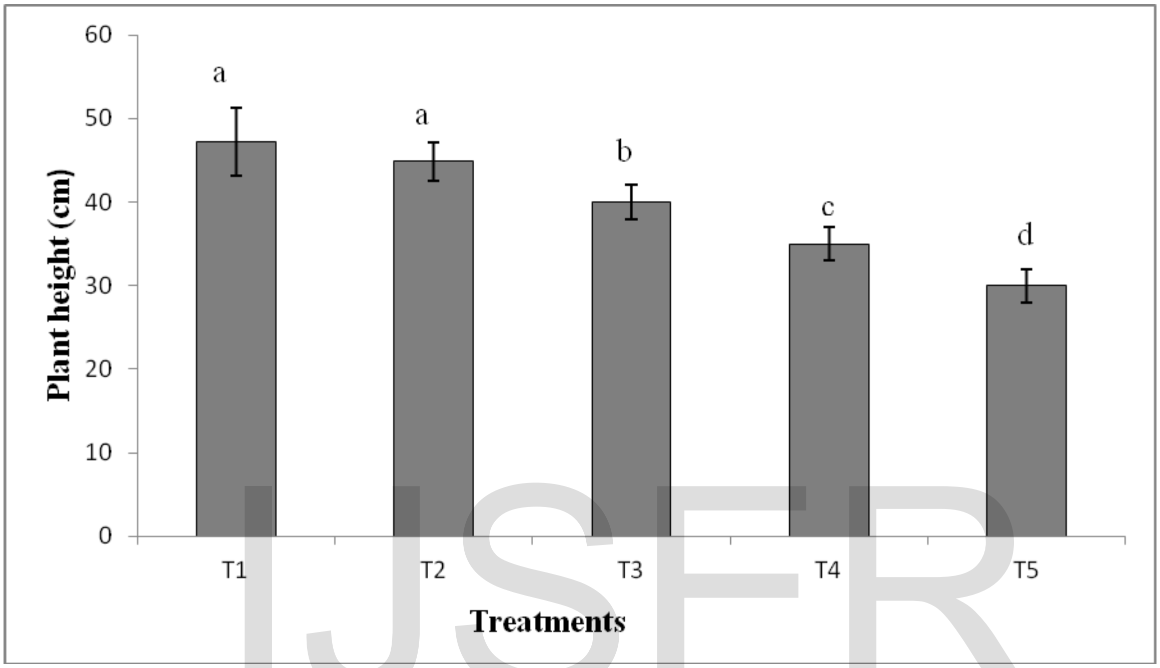

Fig: 7. Effect of foliar application of L-MET on graings weight in mungbean. Treatments sharing same letters are statistically non-significant at p< 0.05. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

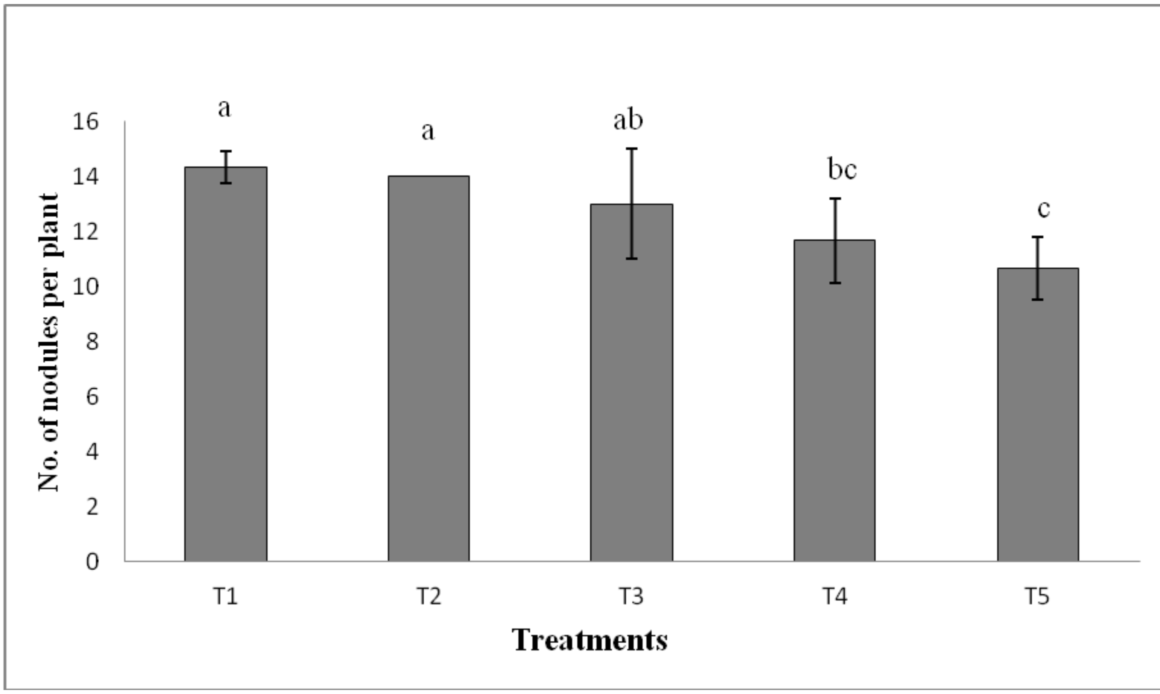

Fig: 8. Effect of foliar application of L-MET on grains weight in mungbean. Treatments sharing same letters are statistically non-significant at $p< 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

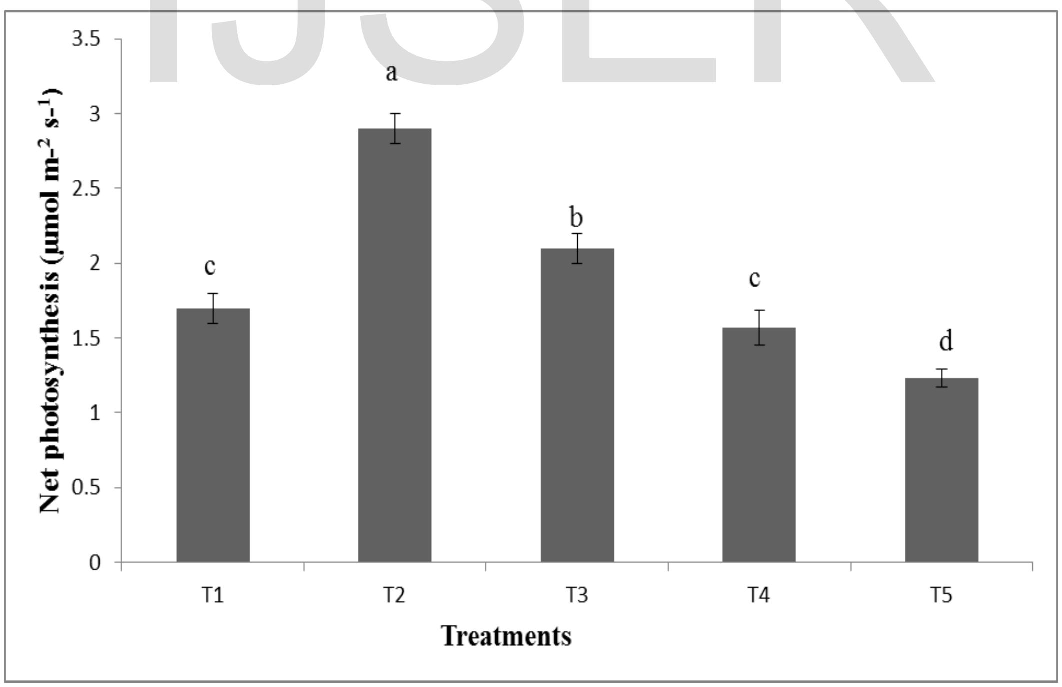

Fig: 9. Effect of foliar application of L-MET on net photosynthesis in mungbean. Treatments sharing same letters are statistically non-significant at $p < 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

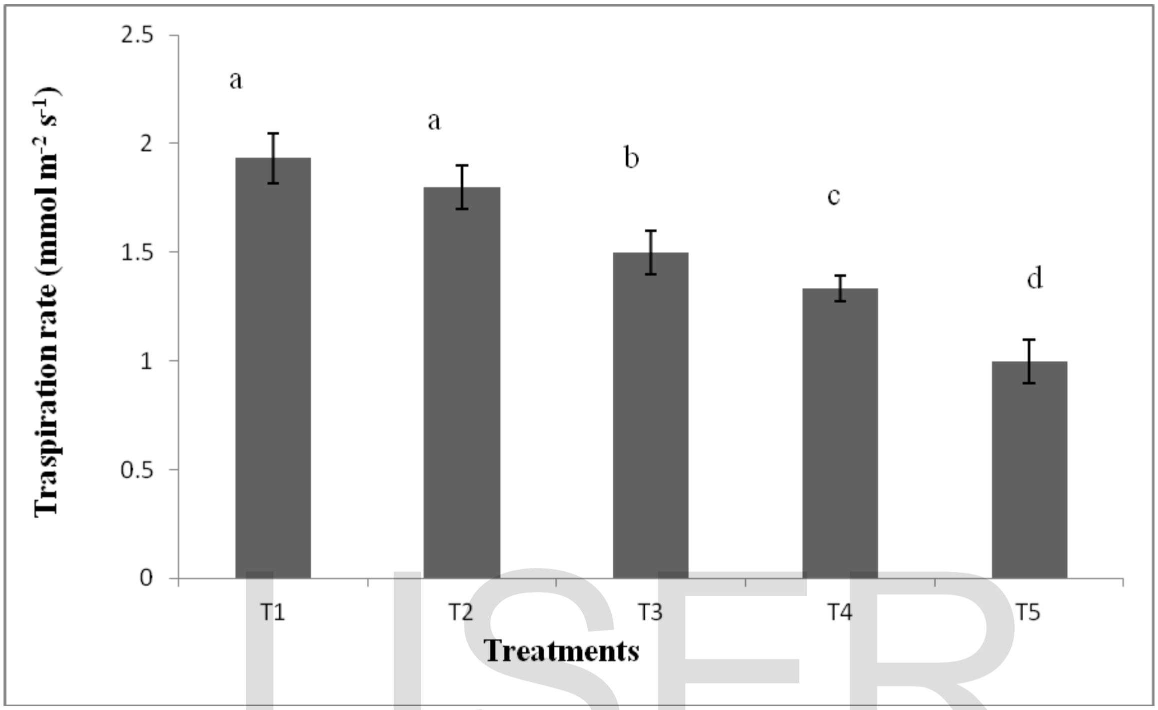

Fig: 10. Effect of foliar application of L-MET on transpiration rate in mungbean. Treatments sharing same letters are statistically non-significant at $p < 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

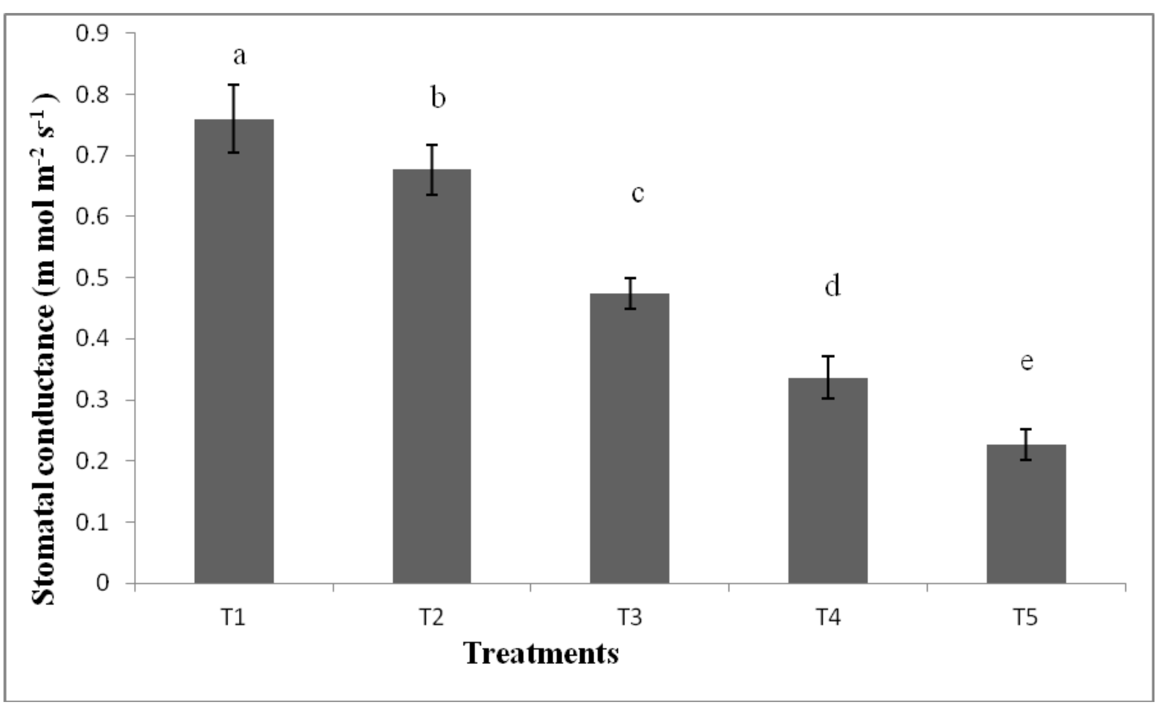

Fig: 11. Effect of foliar application of L-MET on stomatal conductance in mungbean. Treatments sharing same letters are statistically non-significant at $p < 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-M

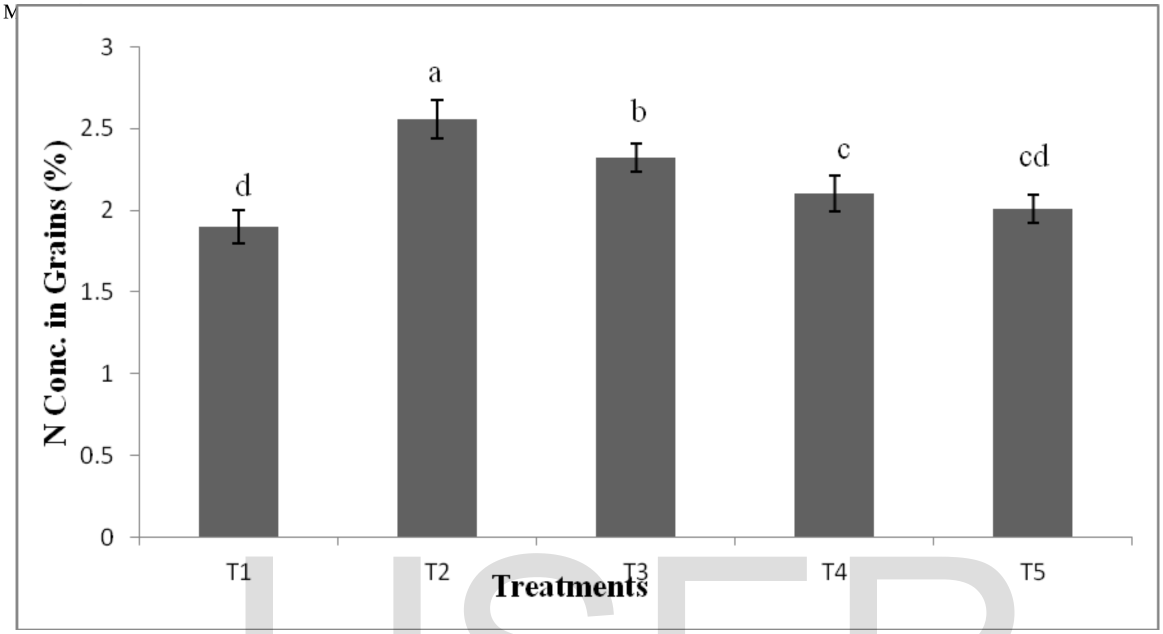

Fig: 12. Effect of foliar application of L-MET on N concentration in grains in mungbean. Treatments sharing same letters are statistically non-significant at $p < 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

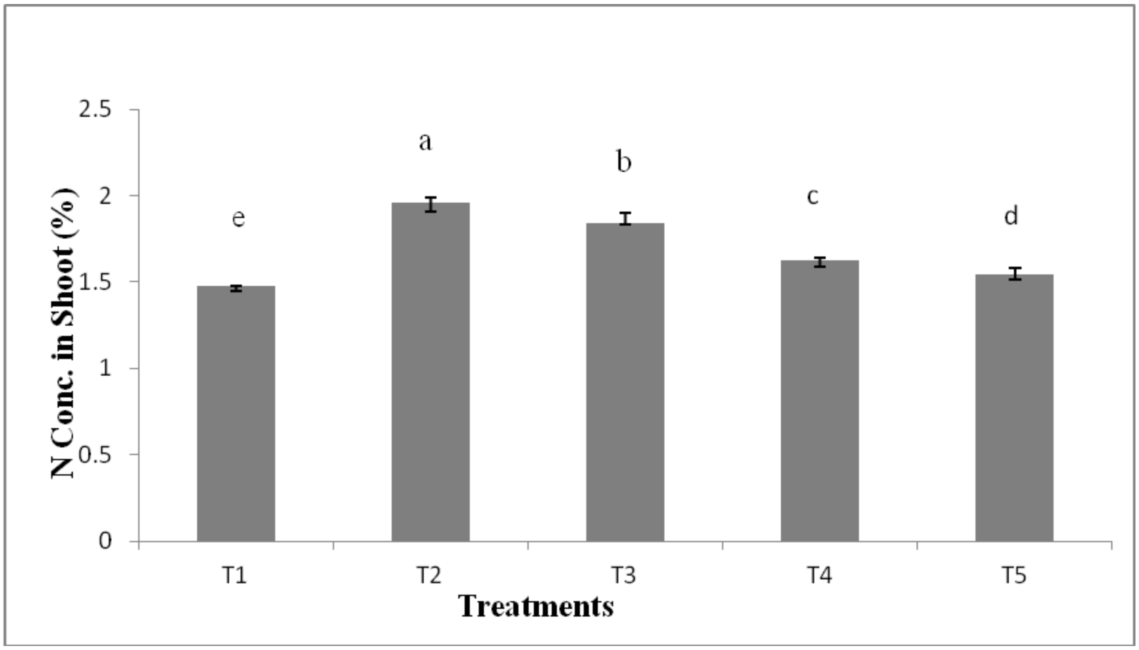

Fig: 13. Effect of foliar application of L-MET on N concentration in shoot in mungbean. Treatments sharing same letters are statistically non-significant at $p < 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.

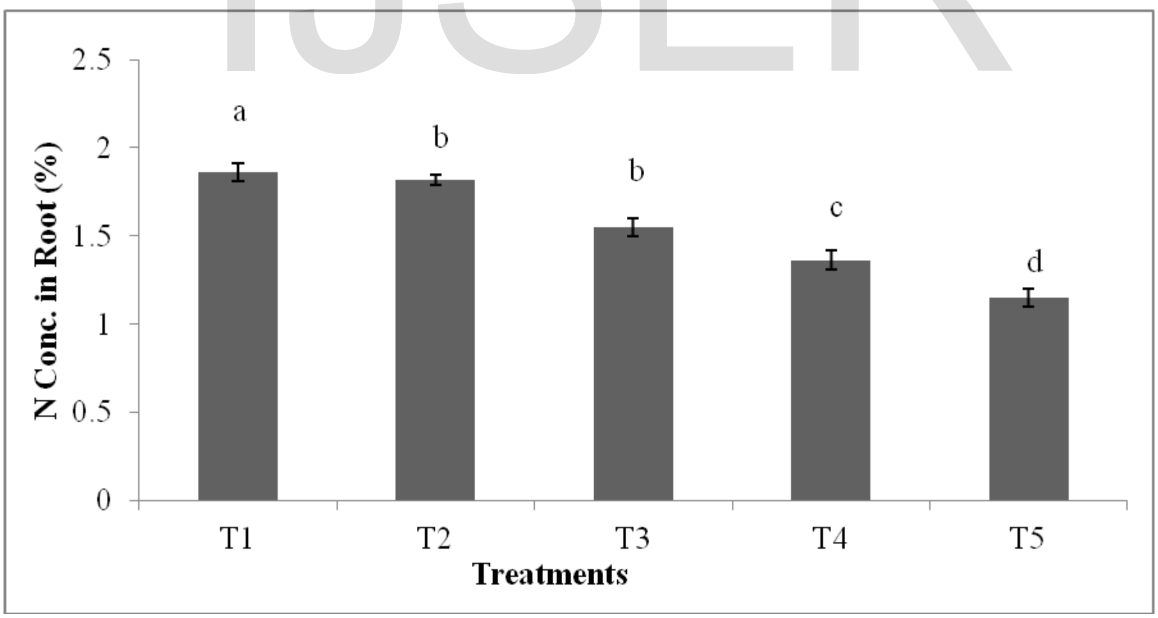

Fig: 14. Effect of foliar application of L-MET on N concentration in root in mungbean. Treatments sharing same letters are statistically non-significant at $p < 0.05$. T1: control NPK + 0 ppm L-MET, T2: NPK + 6.25 ppm L-MET, T3: NPK + 12.5 ppm L-MET, T4: NPK + 18.75 ppm L-MET and T5: NPK + 25 ppm L-MET.