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GROWTH AND YIELD RESPONSE OF TOMATO (*LYCOPERSICON ESCULENTUM* MILL.) TO SOIL APPLIED CALCIUM CARBIDE AND L-METHIONINE

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Abstract

A pot experiment was conducted in the wirehouse to compare the effects of 2 precursors (Calcium carbide and L-methionine) of ethylene on growth and yield of tomato. L-methonine @ 1 mg kg $^{-1}$soil in the form of solution and Calcium carbide @ 15 mg kg^{-1}soil in medical capsules were applied. Encapsulated Calcium carbide was applied 6 cm deep into soil. Recommended doses of N, P and K fertilizers @ 100-90-60 kg ha^{-1}, respectively were applied alone and in combination with precursors. Half dose of N and full dose of P and K was applied after one week of nursery transplantation and the remaining dose after 3 weeks of nursery transplantation. Encapsulated Calcium carbide was applied after 10 days of transplantation while L-methonine was dissolved in water and then applied after 10 days of transplanting. A completely randomized design was followed with 6 treatments and 3 replications. Results regarding number of flowers, number of fruits, shoot dry weight, fruit weight, root weight, N concentration and uptake in shoot and fruit were significantly affected by both precursors in combination with fertilizers compared to control and alone fertilizer. Application of Calcium carbide with NPK fertilizer improved the yield contributing factors that resulted in significant increase in tomato fruit yield.

Introduction

Tomato (*Lycopersicon enculentum* Mill.) is one of the most important vegetable crops and covers annually an area of 28.9 thousands hectares in the Punjab with a total production of 313 thousand tones (Anon., 2006-07). Ethylene (C_2H_4) is an important gaseous plant hormone involved in almost all phases of growth and development of plants (Abeles *et al*., 1992; Reid, 1995; Arshad & Frankenberger, 2002). There are certain compounds, which are known to release ethylene. Application of these ethylene-releasing compounds could be much easier than the gaseous form of ethylene.

Calcium carbide (CaC_2) releases acetylene (C_2H_2), therefore CaC_2 is considered a powerful nitrification inhibitor because it inhibits the *Nitrosomonas* activity that converts NH_4^+ in to NO_3^- (Banerjee *et al*., 1990; Freney *et al*., 1990; Keerthisinghe *et al*., 1996; Sharma & Yadav, 1996; Randall *et al*., 2001; Ahmad *et al*., 2004; Yaseen *et al*., 2005, 2006; Rashid *et al*., 2007). Moreover acetylene released from CaC_2 is converted into plant hormone ethylene (C_2H_4) by soil microorganisms (Muromtsev *et al*., 1988; Lurssen 1991; Arshad & Frankenberger, 2002). C_2H_4 plays major role in growth and development processes of plants by stimulating seed germination, shoot and root growth and early crop maturity (Arshad & Frankenberger, 2002). Muromtsev *et al*., (1990) conducted field trail with a CaC_2 –based Retprol. They reported that its addition to soil @ 120 kg ha^{-1} in a dry form during growth stage of 3-4 true leaves of tomatoes (Lebyazhinski variety) increased the yield by 30-50% alongwith accelerated ripening and improved quality. L-methionine is an established precursor of ethylene and its application to soil has shown positive effect on plant growth (Arshad & Frankenberger, 2002, Akhtar *et al*., 2005). Addition of L-methionine (L-MET) has been shown to increase C_2H_4 accumulation in the soil atmosphere (Frankenberger & Phelan, 1985 a, b; Arshad & Frankenberger, 1990 a, b). Arshad & Frankenberger (1990 a) found that soil application of L-MET @ 0.0185 to 1.85 mg kg^{-1} soil affected vegetative growth and resistance to stem lodging of cultivars of corn. Highest rate of L-MET (1.85 mg kg^{-1}) significantly increased shoot height, stem diameter, shoot fresh and dry weights and resistance to stem breaking in corn (cv. Kandycorn and Miracle). In another experiment, Arshad *et al*., (1994) observed a significant growth and yield response in soybean when exposed to L-MET applied to soil. They reported that plant height, plant dry weight, root weight and total biomass, pods/plant and grain yield of soybean were significantly increased in response to various levels (2x 10^{-4} to 20 mg kg^{-1} soil) of L-MET application. Zahir & Arshad (1998) investigated 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. The soil application of L-MET @ 0.1 to 6 mg kg^{-1} caused a significant increase in plant height, pod length, number of seeds per pod, straw and grain yield of sarsoon compared to untreated controls while the 1000-grain weight was maximum with the highest dose of L-MET applied to soil.

This paper focuses on the use and selection of precursor of Ethylene for improving growth and yield of tomato.

Materials and Methods

A pot experiment was conducted to test the response of tomato to substrates dependent biosynthesis of Ethylene. The soil used was sandy clay loam in texture. Some other properties of this soil were as follows: pH 7.7; EC_e 1.16 dS m^{-1}; 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 @ 14 kg per pot. Pots were placed according to completely randomized design in 3 replicates. The set of treatments were as follows: control; NPK fertilizers @ 100-90-60 kg ha^{-1}; L-methionine (L-Met) @ 1 mg kg^{-1} soil; Calcium carbide @ 15 mg kg^{-1} soil; NPK + L-Met @ 1 mg kg^{-1} soil and NPK + Calcium carbide@ 15 mg kg^{-1} soil.

Encapsulation of calcium carbide: Stones of Calcium carbide was ground in pestle and mortal. The required weight of Calcium carbide was filled in medical capsules. The objective of encapsulation was just to place Calcium carbide safely in soil at required soil depth.

Application of treatment: Tomato cv "Moneymaker" was used as test crop. Four seedlings from 30 days old nursery were transplanted into pots and one plant was maintained in each pot after two weeks. The uprooted seedlings were incorporated in the same pots. Nitrogen as urea, phosphorous as single super phosphate and potassium as muriate of potash were applied by dissolving in water. Half N and full P and K were applied after one week of nursery transplantation and other half N was applied after 3 weeks of nursery transplantation. Calcium carbide was encapsulated @ 15 mg kg^{-1} soil and was applied after 10 days of nursery transplantation. Capsules were placed in the root zone 6 cm deep followed by immediate irrigation. While L-Met @ 1.0 mg kg^{-1} soil was first dissolved in water and then applied after 10 days of transplantation. For irrigation canal water was used through out the growth period. Data regarding number of flowers, number of fruits and fruit weight were collected during crop growth while shoot dry mass, root weight, N concentration and N uptake were noted after harvesting. The whole earthen boll of each pot was taken out and washed under tap water gently to separate roots.

Plant analysis: Shoot and fruit samples were dried and ground to determine total nitrogen by Hu & Barker (1999) method of Sulphuric acid digestion and distillation on micro Kjeldhal's apparatus (Jackson, 1962). Nitrogen uptakes were calculated by multiplying nitrogen concentration in fruit and shoot with fruit or shoot yield.

Statistical analysis: Data collected for various characteristics were analyzed statistically using Fisher's analysis of variance technique (Steel & Torrie, 1980). The treatment means were compared by Duncan's Multiple Range test at 5% probability level (Duncan, 1955).

Results

Number of flowers plant^{-1} was significantly enhanced with the application of Calcium carbide (CaC_2) as compared to L- methionine (L-Met). Maximum number of flowers observed where CaC_2 plus NPK fertilizers were applied 10 days after transplantation (Fig. 1). Reduction in number of flowers was observed where alone CaC_2 and L-Met were applied. Though number of fruits plant^{-1} increased with NPK fertilizers but these were further enhanced significantly with addition of Calcium carbide (Fig. 2). Response of tomato plants for fruit production was more to CaC_2 plus NPK fertilizers than L-Met plus NPK fertilizers. Similarly shoot dry matter increased where alone NPK fertilizers was applied compared to control, however, maximum shoot dry matter was observed when CaC_2 was added with NPK fertilizers (Fig. 3).

Effect of precursors of growth regulator 'ethylene' on fruit weight is presented in Fig. 4. Higher fruit weights were observed with NPK fertilizers than control where no fertilizers were applied. Fruit weight was further increased with the addition of Calcium carbide than L-Met. Maximum fruit weight was noted in the treatment where CaC_2 plus NPK fertilizers were applied. Little increase in fruit weight was found in the treatment of L-Met plus NPK fertilizers compared to NPK fertilizers alone.

Response of tomato regarding root weight to Calcium carbide and L-Met with and without fertilizers application is shown in Fig. 5. Minimum root weight was observed in control and it was slightly increased in treatment where NPK fertilizers were applied. It further increased in the treatment where Calcium carbide was applied. Maximum root weight was observed where CaC_2 plus NPK fertilizers were applied. Data indicate that Calcium carbide application stimulated the root growth to fetch more nutrients from the soil.

Nitrogen concentration in tomato shoot (Fig. 6) increased with the application of N fertilizer compared to control. Nitrogen was applied @ 100 kg ha^{-1} *via* urea. Addition of precursors with fertilizer helped to conserve the nutrient in soil that is why more N concentration in shoot was observed in the treatments where CaC_2 and L-Met were applied with NPK fertilizers. However, maximum increase in N concentration was observed where CaC_2 plus NPK fertilizers were applied compared to all other treatments.

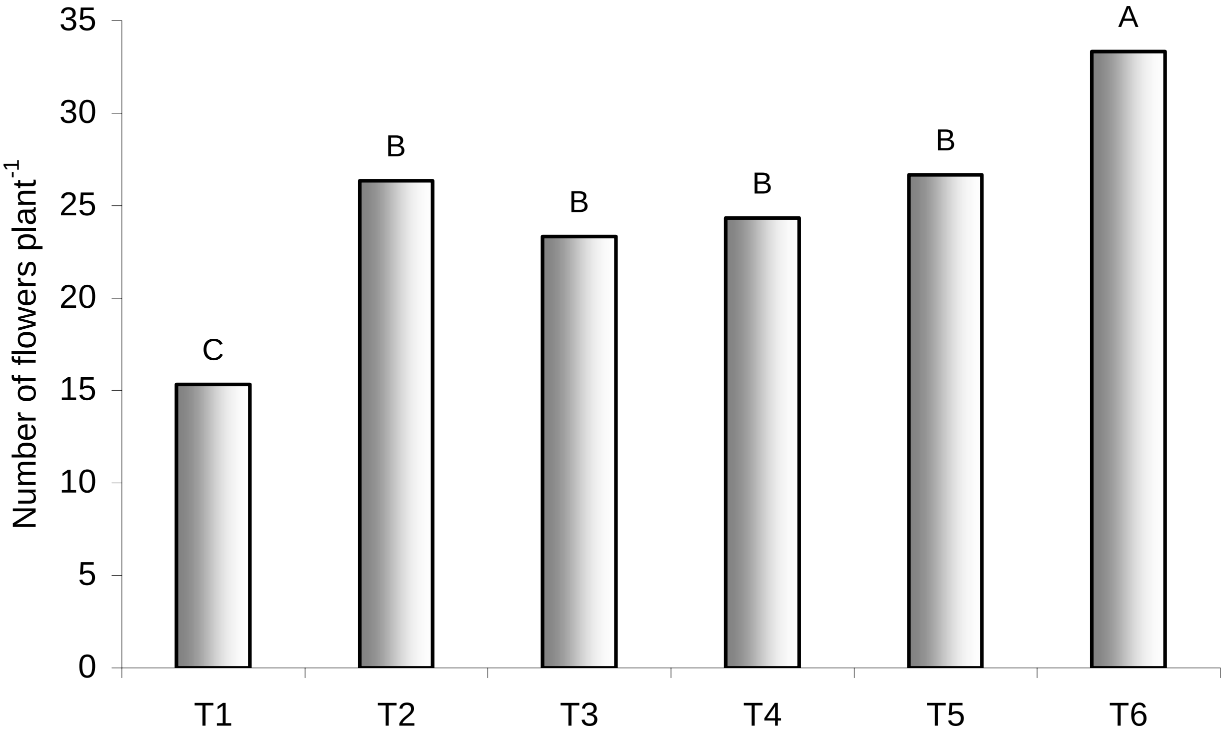

Fig. 1. Effect of precursors of growth regulator on number of flowers.
Bars with different letter (s) differed significantly at p≤ 0.05.
T1= Control , T2= NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

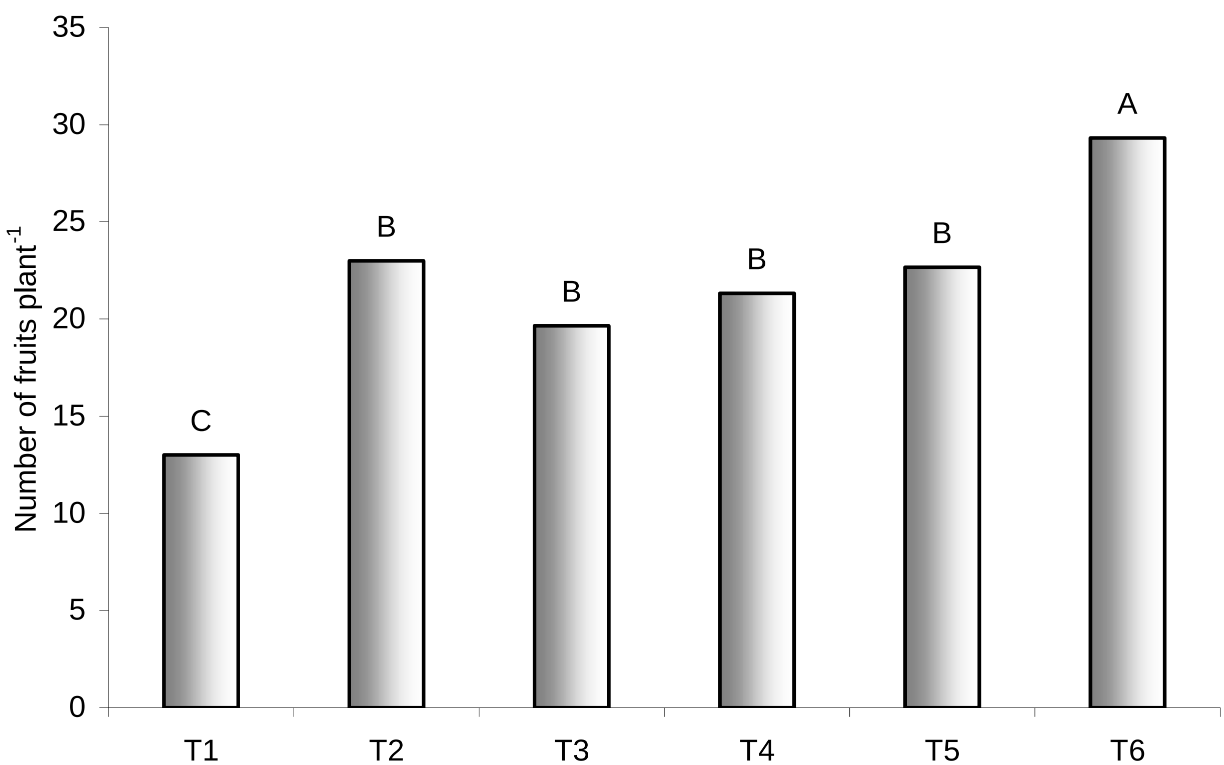

Fig. 2. Effect of precursors of growth regulator on number of fruits.
Bars with different letter (s) differed significantly at p≤ 0.05.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

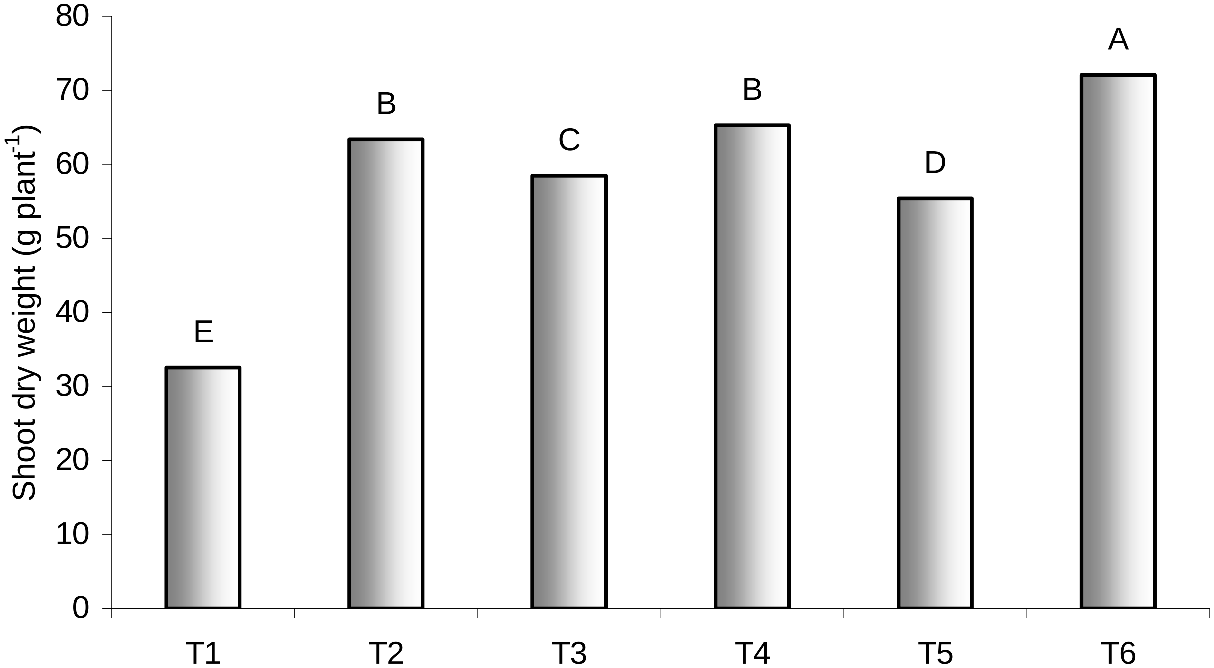

Fig. 3. Effect of precursors of growth regulator on shoot dry weight.
Bars with different letter (s) differed significantly at $p \leq 0.05$.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

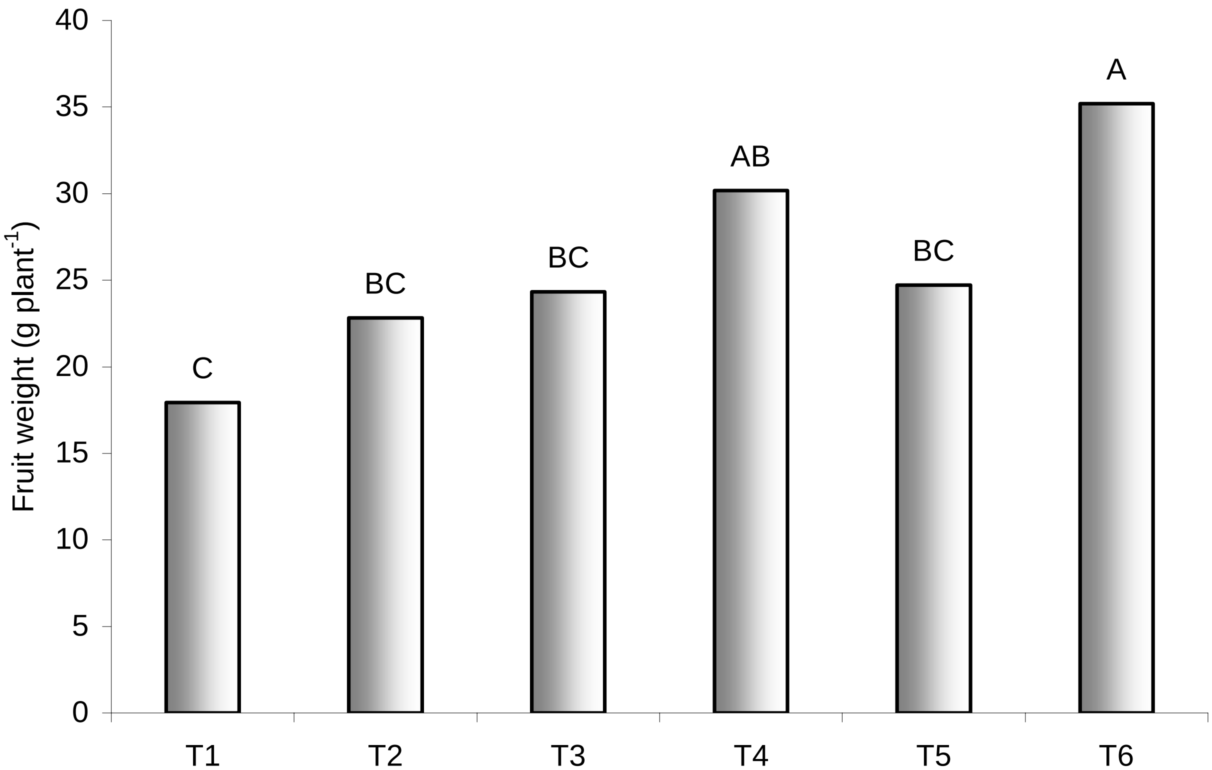

Fig. 4. Effect of precursors of growth regulator on fruit weight.
Bars with different letter (s) differed significantly at $p \leq 0.05$.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

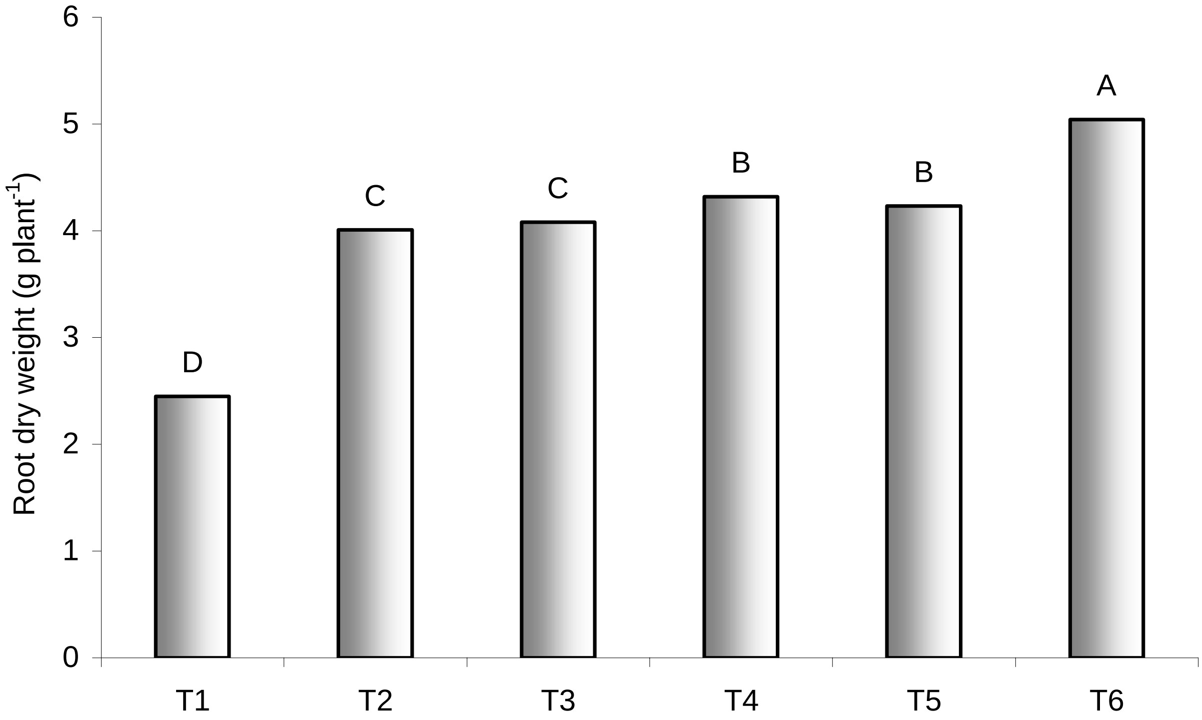

Fig. 5. Effect of precursors of growth regulator on root weight.
Bars with different letter (s) differed significantly at p≤ 0.05.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

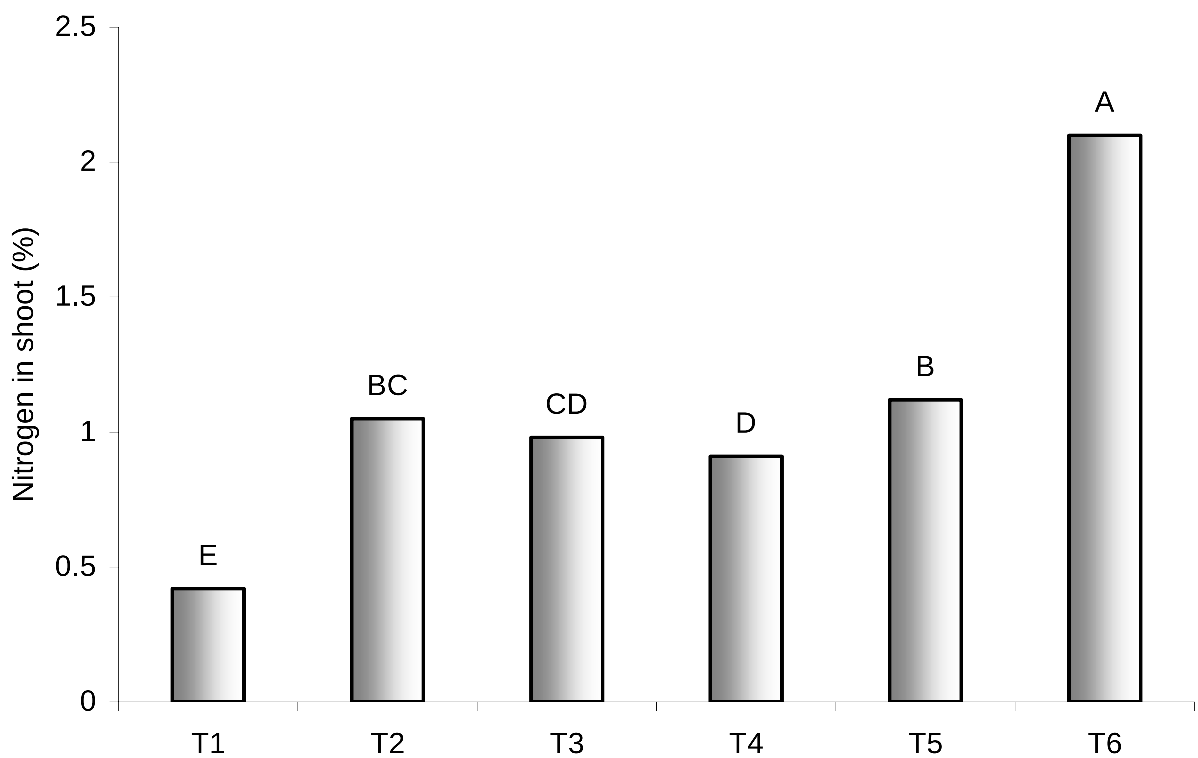

Fig. 6. Effect of precursors of growth regulator on nitrogen concentration in shoot.
Bars with different letter (s) differed significantly at p≤ 0.05.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

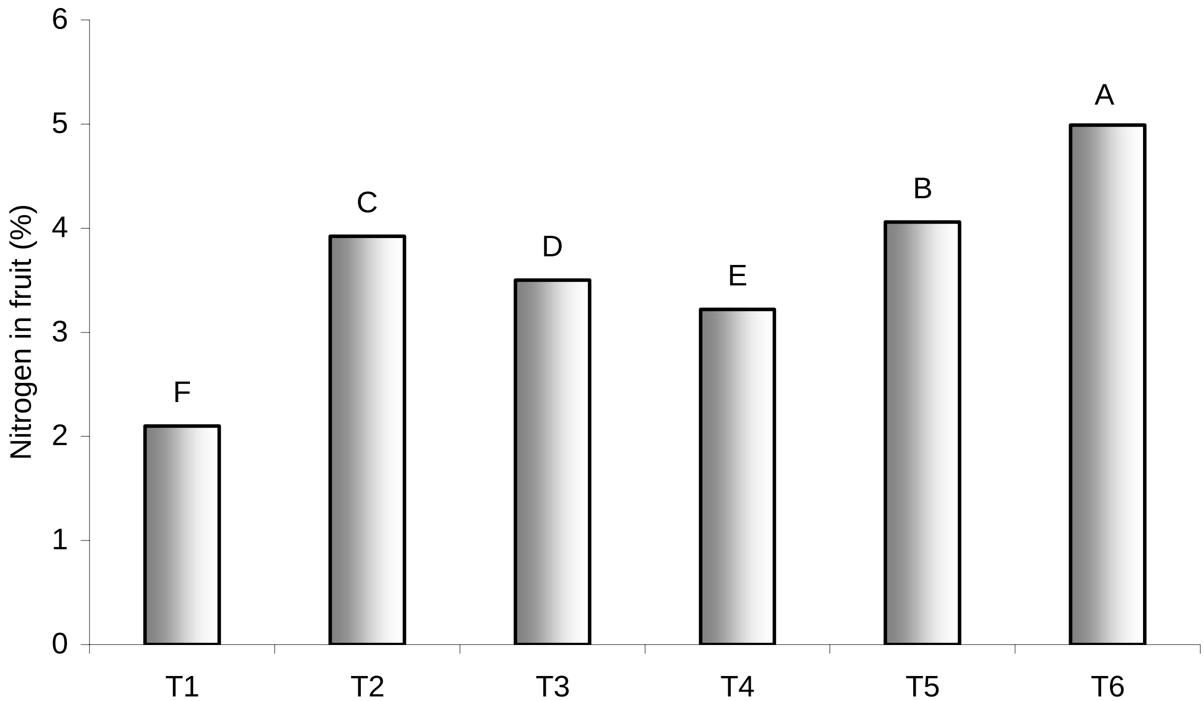

Fig. 7. Effect of precursors of growth regulator on nitrogen concentration in fruits.
Bars with different letter (s) differed significantly at $p \leq 0.05$.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

Data in Fig. 7 illustrated that treatment where alone NPK fertilizers were applied, significantly increased N concentration in fruits over control. Addition of Calcium carbide with NPK fertilizers further enhanced the N concentration. Treatment where L-Met plus NPK fertilizers were applied also showed significant increase in N concentration compared to NPK fertilizers alone.

Nitrogen uptake by shoot was calculated by the product of shoot yield and nitrogen concentration in shoot. Fertilizer treated plants showed more N uptake compared to plants in control (Fig. 8). Nitrogen uptake by shoot was the highest in treatment where CaC_2 plus NPK fertilizers were applied. NPK fertilizers alone and L-Met plus NPK fertilizers had almost similar effect on N uptake by shoot. Data also clearly showed that Calcium carbide had highly significant effect on nitrogen uptake by tomato fruits as its increase was observed in treatments of NPK fertilizer, L-Met plus NPK fertilizer and CaC_2 plus NPK fertilizer compared to control (Fig. 9). Treatment where L-Met plus NPK fertilizers were applied showed more increase in N uptake over NPK fertilizer alone. Maximum N uptake was observed where Calcium carbide plus NPK fertilizer was applied.

Discussion

Calcium carbide is well known as a source of nitrification inhibitor gas acetylene, which is converted into plant hormone ethylene by soil microorganisms (Muromtsev *et al*., 1988; Arshad & Frankenberger, 2002; Yaseen *et al*., 2006). Both the gases had pronounced influence on plant growth from germination to maturity and thus influence the yield and yield contributing parameters (Bronson *et al*., 1992; Freney *et al*., 1992; Kashif *et al*., 2007). Application of Calcium carbide also stimulates root growth and early onset of flowering in agronomic and vegetable crops (Yaseen *et al*., 2006; Kashif *et al*., 2007).

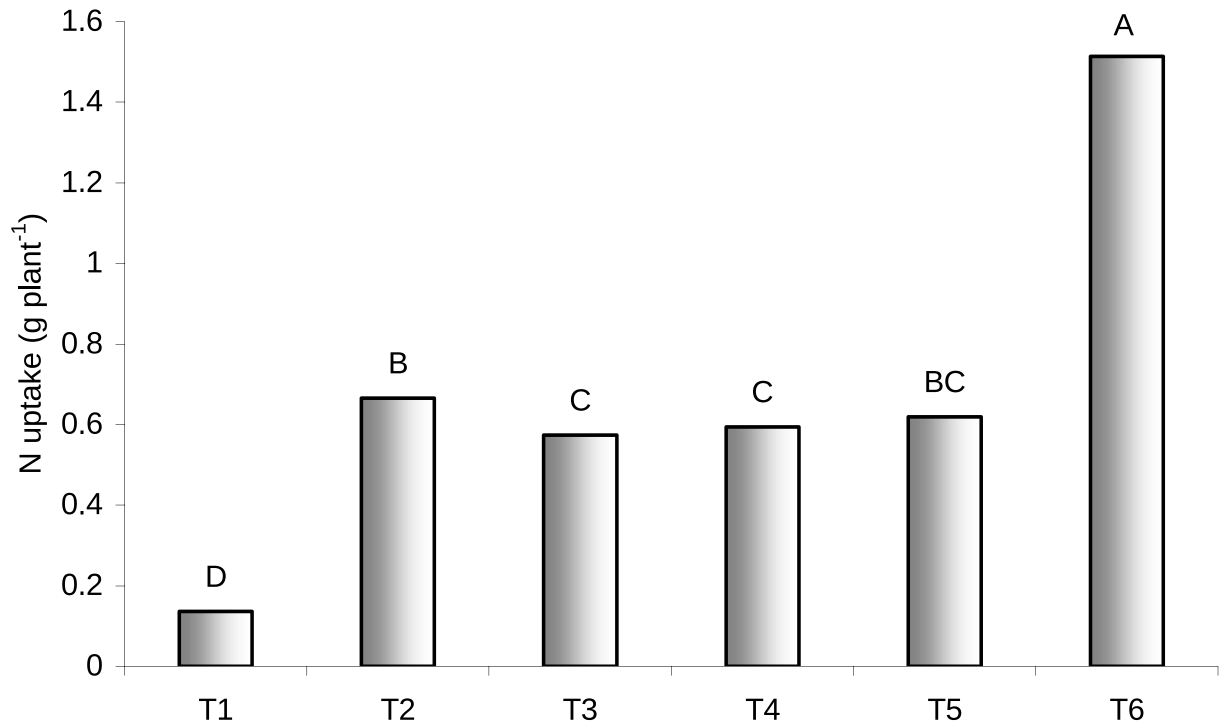

Fig. 8. Effect of precursors of growth regulator on nitrogen uptake by shoot.
Bars with different letter (s) differed significantly at $p \leq 0.05$.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

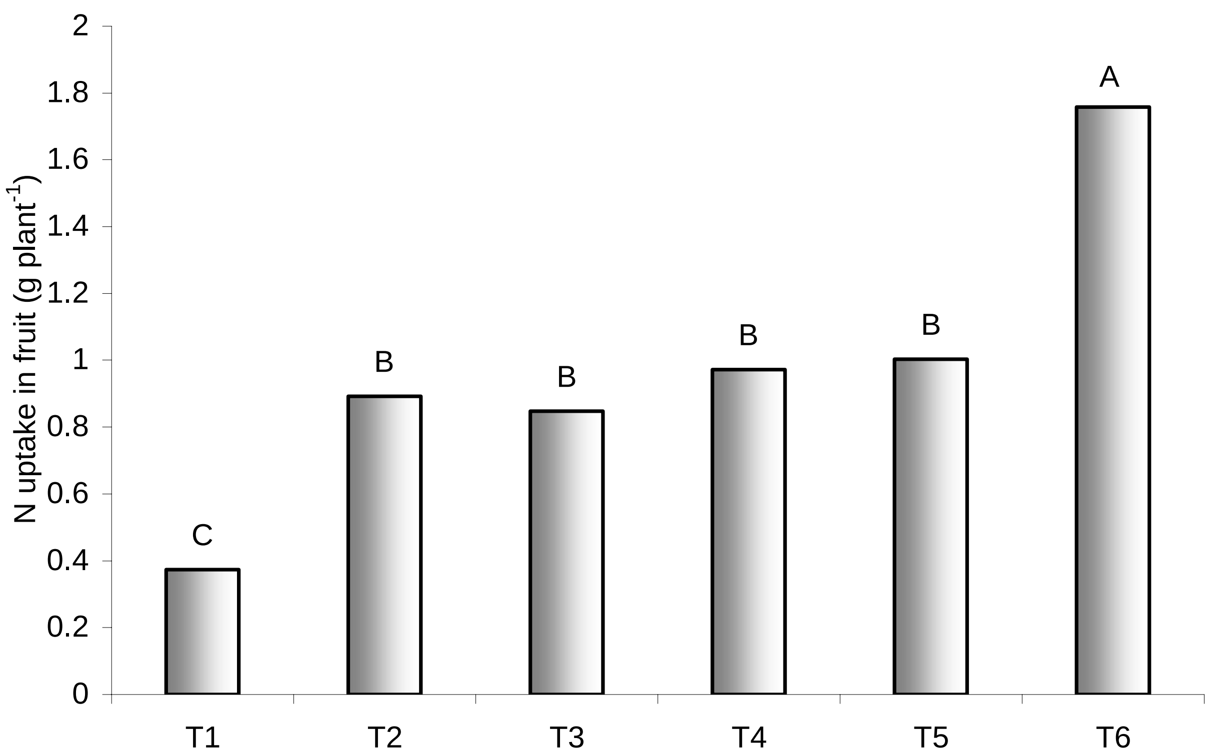

Fig. 9. Effect of precursors of growth regulator on nitrogen uptake by fruits.
Bars with different letter (s) differed significantly at $p \leq 0.05$.
T1 = Control, T2 = NPK Fertilizers (100-90-60 kg ha^{-1}), T3 = L-methionine (1 mg kg^{-1} soil), T4 = Calcium carbide (15 mg kg^{-1} soil), T5 = L-methionine + NPK fertilizers, T6 = Calcium carbide+ NPK fertilizers

Results showed significant improvement in number of flowers, number of fruits and fruit weight of tomato with application of Calcium carbide in the presence of recommended doses of NPK fertilizers. This increased yield due to improvement in yield contributing parameters of tomato with the application of Calcium carbide is attributed to enhanced uptake of nutrients by tomato due to either acetylene that enhanced the N economy of the soil and thus more uptake of nutrients or plant hormone ethylene that stimulated flowering and fruit formation in tomato. It may also be due to increase in root primordial to explore more volume of soil to acquire nutrients (Ahmad *et al*., 2004). Enhanced N uptake by fruit due to Calcium carbide application in this study is evident as application of Calcium carbide significantly increased the fruit yield than that of fertilizers application alone. These results suggest the application of Calcium carbide in a better formulation could be recommended by general use on farmer's field.

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