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Research Article

INFLUENCE OF ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND PRODUCTIVITY OF *LYCOPERSICON ESCULENTUM* L.

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ABSTRACT
Arbuscular mycorrhiza increases the water and nutrient absorption capacity of the host plant. This fact was studied by using a host- tomato (Vaibhav variety) and a mixture of 33 mycorrhizal species naturally occurring in the soil. The growth of the host was studied in vegetative and reproductive phase. The vegetative parameters studied were root and shoot length, number of branches, leaves per plant and leaf length. The reproductive parameters were bud bunches and fruits per plant. The average weight of the fruits was also considered. Mycorrhizal plants showed higher growth vigor, more produce and more weight of the fruits as compared to the control plants. Hence, use of mycorrhiza has positive effect on the growth of tomato.

Keywords: *Growth, Productivity, AM Fungi, Lycopersicon Esculentum*

INTRODUCTION
Tomato is the largest vegetable crop cultivated after potato and sweet potato as it is extensively used in several preparations. India ranks third in production of tomato. Maharashtra state is the largest producer of tomato. The edible fruit of tomato is economically very important because it is extensively used in ketchups, soups, juices, pickles, pastas and pizzas in all parts of the world. No salad dish is complete without the use of tomato.
Nutritionally, tomato is low in fats and hence used for all diabetic preparations and incorporated in weight reduction plans. It is also rich in amino acids and it acts as a source of many minerals. What makes it unique is its lycopene pigment along with vitamin A, C and E. Medicinally, it is proved that lycopene, a well known anti oxidant of tomato is useful against prostate, breast, lung, stomach, oral, cervical, oesophagal and pancreatic cancer. Keeping in mind all these uses, tomato was selected for present study.
Mycorrhiza is associated with the roots of 83% dicotyledonous plants and 79% of monocotyledonous plants (Trappe, 1997). Baylis (1959) described the role of phosphate (P) uptake by mycorrhiza. Sanders and Tinker (1973) concluded that the fungal hyphae take up the phosphorus from the soil and transfer it to the host. The external hyphae of AM extend from the root surface to the soil beyond the P depletion zone and access greater volume of undepleted soil than the root alone (Hayman, 1983; Jacobsen, 1986). The mycorrhizal plants grew faster than non mycorrhizal plants. Positive results were recorded by Clark (1963) for tulip poplar tree and Gerdemann (1964) for maize. Mosse (1986) suggested use of mycorrhizae in the development of sustainable systems of agriculture. It was found that better yield was obtained in the second and third harvest of tomato plants with mycorrhiza during transplantation as compared to non mycorrhizal tomato plants (Al-Raddad, 1995). The growth of *Lycopersicum esculentum* transplants inoculated with *Glomus mosseae* in low phosphate soil was better than non mycorrhizal tomatoes. The survival rate of the plants was higher and the nodes, lateral branches and leaves per plant were found double than non-mycorrhizal plants (Khaliel *et al.*, 2008).
The present work aims to examine the effect of arbuscular mycorrhiza in the Indian soil on the vegetative and reproductive growth of the Indian tomato variety.

MATERIALS AND METHODS
The tomato seedlings of Vaibhav variety were bought from ‘Scientific seedling nursery’ from Urali Kanchan. The plantlets or the seedlings were one month old. The soil from the sites of plantation was autoclaved at 15 lbs for 60 minutes. The autoclaved sand was mixed in this soil in the proportion of 3:1.

This mixture along with autoclaved dung manure was filled in the big nursery polythene bags and half of the plantlets were transplanted in this soil. These plantlets were without mycorrhiza and hence were referred to as control plants. Remaining plantlets were transplanted to the plots in the field and these plantlets were referred to as mycorrhizal or experimental plants. The soil contained six genera and 33 species of mycorrhiza. The sand was mixed to the soil to maintain the aeration. As no chemical fertilizers were added to the soil, dung manure was added in the soil. The time required for the mycorrhizal colonization was at least three weeks from the time of transplantation. The plants were not subjected to any type of stress and were watered at a regular interval of time depending up on season.

Tomato plants complete their life cycle in almost three and a half months. Generally, the farmers uproot the plants after the second harvest as the third harvest fruits are smaller and do not fetch good price in the market. For current studies, the plants were retained till the third harvest to study the comparative change. The plants were initially grown in coco peat before transplantation which did not contain any mycorrhiza. The growth parameters were studied on 60^{th}, 75^{th} 90^{th} and 105^{th} day. The vegetative growth parameters included shoot length, root length, leaf number per plant, leaf length and number of branches per plant. The reproductive parameters included number of bud bunches, fruit number per plant and the weight of the fruits. The parameters in mycorrhizal plants were compared to the parameters obtained from the control plants. The data was statistically analysed using T test.

RESULTS AND DISCUSSION

Effect of AM Fungi on Shoot Length and Root Length of Tomato

The height of all the tomato plants during transplantation on 30^{th} day was 15 cm. On 60^{th} day, the non mycorrhizal plants grew 24.22 cm in 30 days and mycorrhizal plants grew almost 34.00 cm. The non mycorrhizal plants grew for only four to five cm in next 15 days where as mycorrhizal plants showed vigorous growth of 34cm. The change in the height on 75^{th} day was more pronounced than the growth on 60^{th} day. In between 75^{th} and 90^{th} day non mycorrhizal plants grew 15.77 cm and mycorrhizal plants grew by 27.22 cm. The plant height at the time of uprooting was recorded maximum (149.00 cm) in mycorrhizal plants and it was recorded 90.00 cm for the non-mycorrhizal plants. During these 15 days, non mycorrhizal plants exhibited a growth of 8.89 cm and mycorrhizal plants showed growth of 21.22 cm. The mycorrhizal plants showed much better growth than non mycorrhizal plants during active growth stages of tomato (Table 1).

Table 1: Effect of AM fungi on vegetative growth responses of tomato plants

No. of days	Treatment	Shoot length (cm)	Root length (cm)	No. of leaves/ plant	length of leaf (cm)
60 days	Control	39.22±2.73	3.67±1.20	6.55±0.88	10.22±1.20
	Mycorrhizal	49.00±4.10	10.22±1.11	9.40±1.55	19.88±0.78
75 days	Control	43.11±4.09	4.26±1.02	8.11±1.44	14.00±2.64
	Mycorrhizal	82.33±5.90	18.97±4.64	24.33±2.00	31.14±1.79
90 days	Control	58.88±6.78	6.24±0.54	11.66±1.00	17.44±2.64
	Mycorrhizal	109.55±7.80	24.11±2.90	32.88±1.75	40.96±2.20
105 days	Control	67.77±5.65	8.26±1.90	16.22±1.34	20.44±2.87
	Mycorrhizal	130.77±7.95	38.29±5.10	38.77±1.22	42.40±3.70

Results differ significantly at $P \leq 0.05$ level

The roots of the non mycorrhizal and the mycorrhizal plants followed the same trend as that of the shoot. The root length of 60 days old non mycorrhizal plants was measured 3.67 ± 1.20 cm and it was 10.22 ± 1.11 cm in mycorrhizal plants. In between 60^{th} and 75^{th} day the roots of non mycorrhizal plants grew only 0.59 cm and mycorrhizal plants grew 8.75 cm. During the next 15 days, the roots of non mycorrhizal plants grew only 1.98 cm and in mycorrhizal plants they grew about 5.14 cm. There was similar trend of growth pattern in roots between 90^{th} and 105^{th} day. The roots of non mycorrhizal plants showed growth of 2.02 cm and that of mycorrhizal roots grew almost 14.18 cm. At the time of harvesting (uprooting) the roots of mycorrhizal plants were four times longer than that of roots of non mycorrhizal plants (Table 1).

Number of Leaves and Their Size

The seedlings of 30 days which were brought for plantation showed 3-4 leaves. The leaves in non mycorrhizal and mycorrhizal plants on 60th day showed increase by two and five respectively. There was increase in number of leaves by two in case of non mycorrhizal plants whereas it was almost by 15 leaves in mycorrhizal plants during the next 15 days. The leaf number of leaves after 90 days in non mycorrhizal plants was 11.66 ± 1.00 and that of mycorrhizal plants was 32.88 ± 1.75. Here, in 15 days, the growth of non mycorrhizal plants was by merely three leaves and that of mycorrhizal plants was by eight leaves. During the last 15 days the non mycorrhizal plants showed increase by five leaves and mycorrhizal plants showed increase by seven leaves. At all the stages, the mycorrhizal plants recorded more number of leaves than the non mycorrhizal plants. At the time of uprooting, the mycorrhizal plants had almost double the number of leaves than the non mycorrhizal plants (Table 1).

The average length of the leaves of 30 days seedlings of tomato was five cm. The length of leaf was increased by 5.22 cm in non mycorrhizal plants and that of mycorrhizal plants was increased by 14.88 cm in 60 days old plants. The non mycorrhizal plants showed 4.22 cm increase in length of leaf and it was recorded 11.26 cm in mycorrhizal plants on 75th day. During the next 15 days the non mycorrhizal plants showed growth of 3.44 cm and that of mycorrhizal plants it was recorded 9.82 cm. The leaf length of 105 days old non mycorrhizal plants was 20.44 ± 2.87 cm and it was 42.40 ± 3.70 cm in mycorrhizal plants. The non mycorrhizal plants showed growth of 3.00 cm and mycorrhizal plants showed 4.88 cm growth. The leaf length of mycorrhizal plants was double as compared to non mycorrhizal plants at the time of uprooting (Table 1).

Number of Branches, Bud Bunches, Number and Weight of Fruits

The 30 days old seedlings brought for plantation were unbranched. After transplantation in the field, 60 days old non mycorrhizal plants remain unbranched even after a month but the mycorrhizal plants showed 1.77 ± 0.66 branches. The 75 days old non mycorrhizal and mycorrhizal plants showed 0.44 ± 0.26 branches and 3.11 ± 0.78 branches respectively. The 90 days old non mycorrhizal plants showed 1.55 ± 0.88 branches while the mycorrhizal plants showed 9.22 ± 1.81 branches. There was no further change in the branch number for non mycorrhizal plants but mycorrhizal plant continued to grow and showed 11.66 ± 1.41 branches. Hence, the control plants looked stunted and slender where as the mycorrhizal plants looked taller and bushy (Table 2).

The 30 days old plants did not have any bud bunches as they were in the vegetative stage. Generally tomato plants flower after 50 to 60 days. The 60 days old non mycorrhizal and mycorrhizal plants showed 0.88 ± 0.18 and 1.77 ± 0.66 bud bunches respectively. The 75 days old non mycorrhizal and mycorrhizal plants showed 0.66 ± 0.06 and 4.00 ± 1.73 bud bunches respectively. The 90 days old non mycorrhizal plants showed 1.44 ± 0.52 bud bunches and the mycorrhizal plants showed 7.66 ± 1.69 bud bunches. The 105 days old non mycorrhizal plants showed 2.77 ± 0.83 bud bunches and mycorrhizal plants showed 10.55 ± 1.42 bud bunches. The total number of bud bunches were five times more in mycorrhizal plants than the non mycorrhizal plants. This implied that the yield of mycorrhizal plants will be much higher than the non mycorrhizal plants (Table 2).

Table 2: Effect of AM fungi on growth responses and yield of Tomato

No. of days	Treatment	No. of branches per plant	Bud bunches per plant	No. of fruits per plant	Weight of fruit g
60 days	Control	0.00	0.88±0.18	0.00	0.00
	Mycorrhizal	1.77±0.66	1.77±0.66	0.00	0.00
75 days	Control	0.44±0.26	0.66±0.06	10.11±6.90	55.66±7.43
	Mycorrhizal	3.11±0.78	4.00±1.73	33.77±3.41	149.55±5.31
90 days	Control	1.55±0.88	1.44±0.52	2.33±1.22	37.44±8.33
	Mycorrhizal	9.22±1.81	7.66±2.69	30.22±2.03	88.88±3.33
105 days	Control	1.55±0.88	2.77±0.83	0.33±0.10	10.33±2.12
	Mycorrhizal	11.66±1.41	10.55±1.42	18.22±6.83	50.33±7.82

Results differ significantly at P≤0.05 level

The mycorrhizal plants showed good vegetative growth. The bud initiation in mycorrhizal plants was prior to the non mycorrhizal plants and the good health of the mycorrhizal plant was reflected in terms of fruit number and size. The 60 days old tomato plants showed only bud bunches. The 75 days old non mycorrhizal and mycorrhizal plants showed 10.11 ± 1.69 and 33.77 ± 2.03 fruits per plant respectively. This was the first harvest of the plants. In the first harvest, the yield of mycorrhizal plants was three times higher than the non mycorrhizal plants. The 90 days old non mycorrhizal and mycorrhizal plants during second harvest showed 2.33 ± 1.22 and 30.22 ± 2.03 fruits per plant respectively. Here, there was a marked difference in the number of the fruits. The yield of non mycorrhizal plants dropped drastically but the mycorrhizal plants showed almost the same number of the fruits as the first harvest. The 105 days old plant, during the third harvest the non mycorrhizal plants showed only 0.33 ± 0.10 fruits and the mycorrhizal plants showed 18.22 ± 6.83 fruits. Here, there was a drop in the yield of both the plants but the drop was high in non mycorrhizal plants as compared to mycorrhizal plants (Table 2).

The first harvest was available when the plants turned 75 days old. The fruits in mycorrhizal plants were not only more but the weight of the fruits was much more than the non mycorrhizal plants. The fruits of mycorrhizal plants were fresh, juicy and red. The fruit weight in non mycorrhizal plants was 55.66 ± 7.43 g and in mycorrhizal plants, the fruit weight was 149.55 ± 5.31g. In 90 days old plants, during second harvest, the fruit weight of non mycorrhizal plants was 37.44 ± 8.66g and it was 88.88 ± 9.33g in mycorrhizal plants. In 105 days old non mycorrhizal plants the fruit weight was only 10.33 ± 2.12g. and in the mycorrhizal plants, the weight was 50.33±7.82g. The first harvest fruits were the best in quality and quantity both. The size and number reduced in the second harvest and was further deceased in the third harvest. The fruits of mycorrhizal plants weighed better than fruits of non mycorrhizal plants (Table 2).

The life cycle of the plant was three to three and a half months. Hence, the GVI was calculated at the end of the life cycle i.e. after 90 days and 105 days. The growth vigor index indicates in general health of the plant which includes shoot length, root length, leaf number, branch number and yield. Growth vigor index (GVI) was calculated by the formula proposed by Anderson and Abdul-Baki, (1973); Maisuria and Patel, (2009) and Bhargava and Bharadwaj, (2010).

Growth Vigor Index= Root length+ Shoot length × Germination %

From GVI it is clearly indicated that health of mycorrhizal plants was much better than the non mycorrhizal plants (Table 3).

Growth and Vigor Index (GVI)

Table 3: Effect of mycorrhiza on the Growth Vigor Index

No. of days	Treatment	Shoot length (cm)	Root length (cm)	Germination %	GVI
90 days	Control	58.88	6.24	90	5860.80
	Mycorrhizal	109.55	24.11	90	12029.40
105 days	Control	67.77	8.26	90	6842.70
	Mycorrhizal	130.77	38.29	90	15215.40

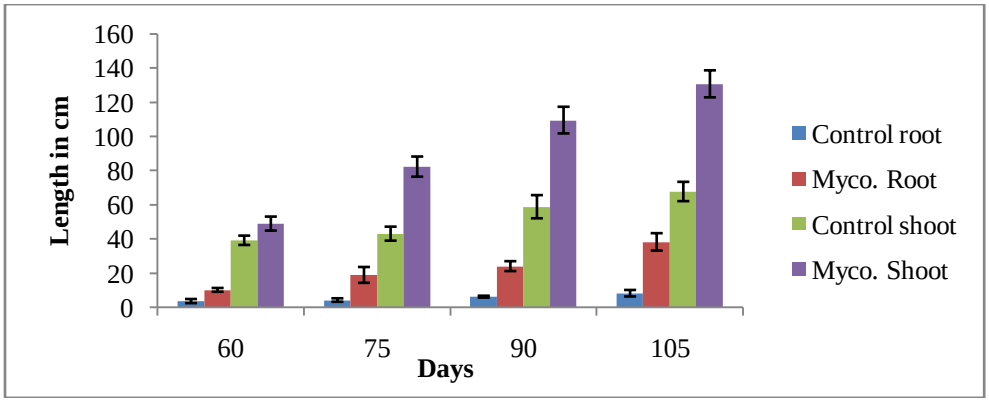

Chart 1: Comparative account of length of control and mycorrhizal roots and shoots of tomato plants

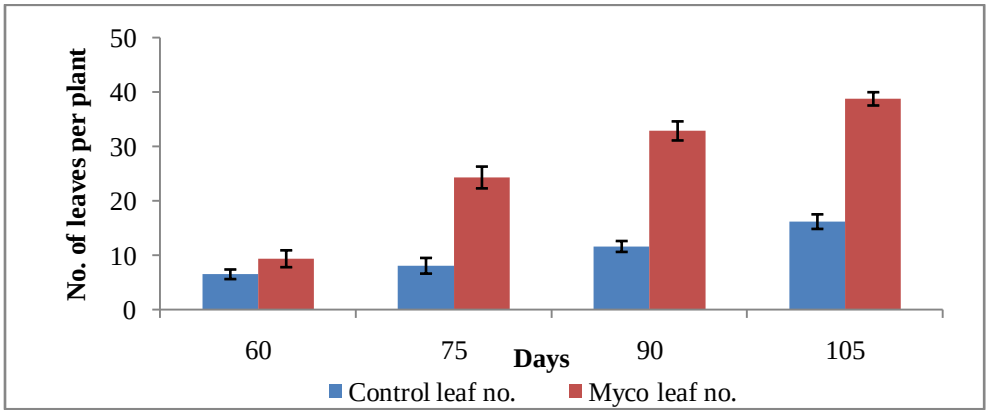

Chart 2: Comparative account of number of leaves in control and mycorrhizal tomato plants

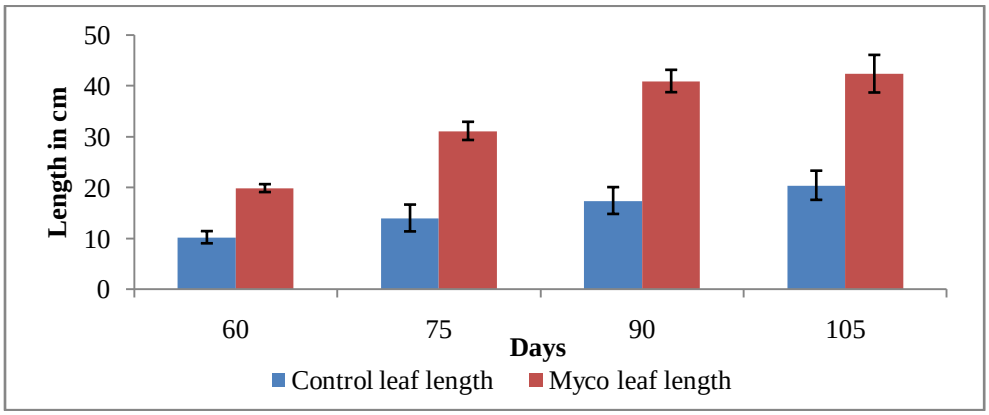

Chart 3: Comparative account of leaf length in control and mycorrhizal tomato plants

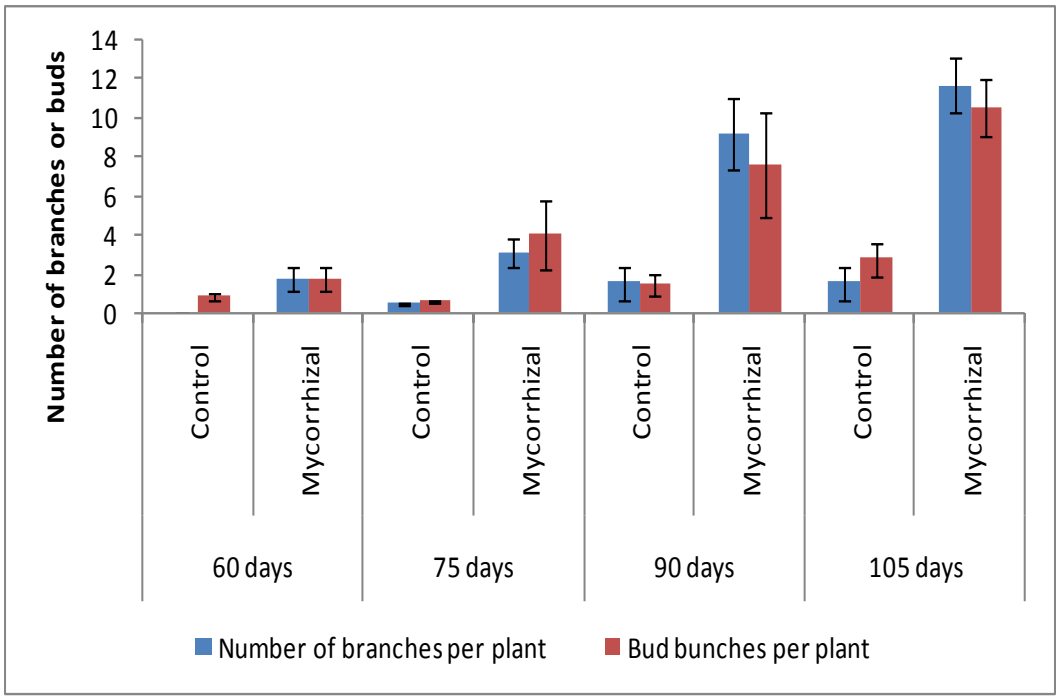

Chart 4: Comparative account of number of branches and bud bunches in control and mycorrhizal tomato plants

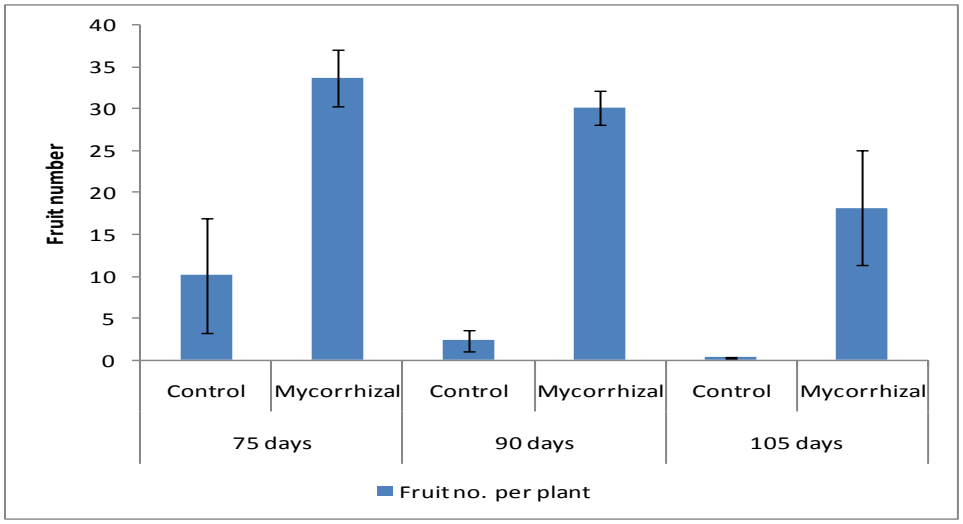

Chart 5: Effect of mycorrhiza on the number of fruits

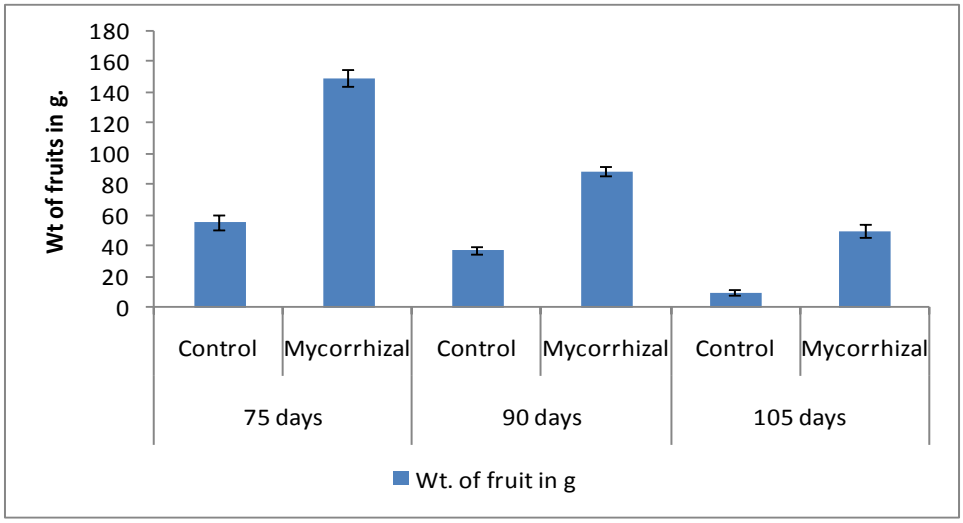

Chart 6: Effect of mycorrhiza on the weight of fruits

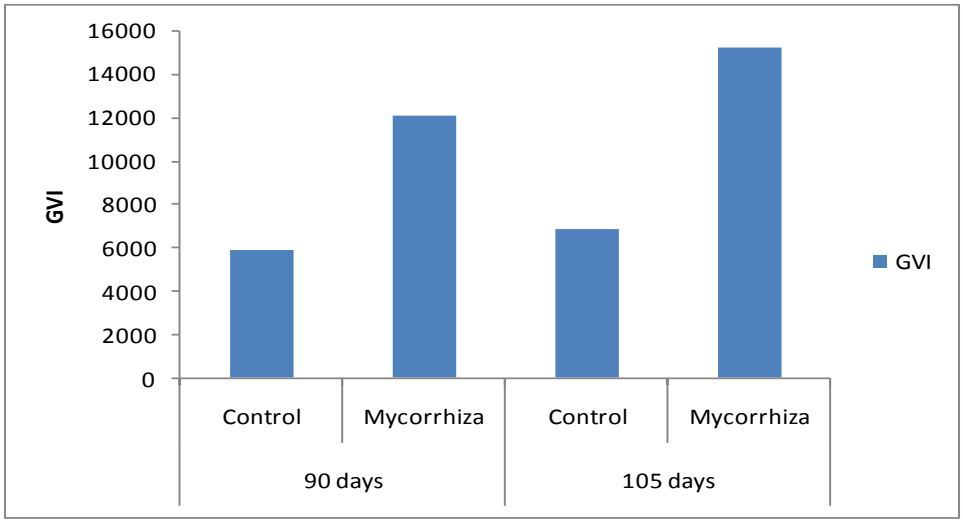

Chart 7: Effect of mycorrhiza on the growth vigour index of tomato plants

DISCUSSION

The mycorrhiza is helpful for uptake of water, phosphates and other crucial micronutrients required by the plant. Hence, the mycorrhizal plants showed rigorous growth as compared to non mycorrhizal plants. This was quite evident from the shoot heights and root lengths. The roots of the non mycorrhizal and the mycorrhizal plants followed the same trend as that of the shoot. At the time of uprooting the roots of mycorrhizal plants were four times longer than that of roots of non mycorrhizal plants.

The non mycorrhizal plants looked stunted and slender with less height, leaves and branches. Ramkrishna and Selvakumar, (2012) reported more leaf number and leaf area in mycorrhizal tomato plants. The mycorrhizal plants show enhanced cytokinin formation which is responsible for more cell division. This causes more vegetative growth in the mycorrhizal plants over non mycorrhizal plants (Baas and Kuiper, 1989). Mycorrhiza provided more phosphate and other micronutrients to the host so mycorrhizal plants showed healthy growth. Similar results were obtained by Marouane *et al.,* (2013) on lettuce, Sharma and Adholeya, (2000) on onion, Nedorost and Polkuda, (2012) on tomato. Tahat *et al.,* (2008) reported more root and shoot formation in tomato with the treatment of AM fungi.

Mycorrhiza not only altered the morphology of the plants but also influenced the reproductive growth. The mycorrhizal plants being healthy reached the reproductive period early. Hildebrandt *et al.,* (2002) reported that a treatment of *Glomus intraradices* accelerates the change from vegetative to reproductive phase. The reason behind this is transition of vegetative meristem to reproductive meristem in tomato is due to improved nutritional status of the plant. Gu *et al.*, (2010) have identified a group of microRNAs in tomato leaves which is exclusively induced by AM symbiosis. The plants showed many bud bunches which eventually gave rise to bunch of fruits. Alessandra *et al.,* (2012) have reported the flowering of mycorrhizal tomato plants significantly early than the control plants. They also reported early formation of green fruits and their transition into red fruits in mycorrhizal plants. The fruit yield was noted to be higher and reproductive phase in mycorrhizal tomato plants was prolonged. The mycorrhizal fruits were dark red, large and shiny in first, second and third harvest. Our results corroborate with Alessandra *et al.*, (2012). Gaude *et al.,* (2012) have indicated the impact of mycorrhization on the transcription of genes in fruit expression. The genes related to ripening are regulated by mycorrhiza. Mycorrhiza inoculated tomato plants produced more fruits and their productive period was remarkably longer (Salvioli *et al.,* 2012). Enhanced productivity has been observed in onion by Sharma and Adholeya, (2000), Al-Karaki and Hammad, (2001) in tomato.

Conclusions

AM fungi improve the vegetative growth and the reproductive growth of the plants. Use of AM fungi is an eco friendly method to improve the health of the plants. The mycorrhizal plants grew taller and produced large number of fruits than the non mycorrhizal plants. Hence mycofertilizer is useful for the growth of the plants. This is a method by which the crop quality can be maintained by reducing the use of chemical fertilizers which is currently a great threat to Indian soils.

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