RESEARCH COMMUNICATIONS
(An International Open Access, Peer Reviewed, Multidisciplinary Online Journal)
https://research-communications.cmpcollege.ac.in/
ISSN: Under Process
Vol.: 1, Issue: 1, January-June 2023, pp.12-27

Studies on the Effect of AM Fungi on the Growth and Yield of *Lycopersicon esculentum* Mill.

Pallavi Rai[1], Roshni Prajapati[2] & Saumya Tewari[3]

Assistant Professor[1], Research Scholar[2] & Research Scholar[3]
Department of Botany
CMP Degree College, Prayagraj, Uttar Pradesh, India
E-mail: pallavigoodan@gmail.com

Abstract

Arbuscular mycorrhizal fungi (AMF) play a very important role for the improvement of crops. In the present study we observe that AM fungi when applied singly or in combination with vermicompost increase the growth and yield of tomato plant. Application of AM fungi as organic fertilizer is very effective ecofriendly technology. It is very good substitute of chemical fertilizers and protect the crops from harmful impact of chemical fertilizers.

Keywords: AM, Chemical Fertilizer, Crops, Organic Fertilizer, Tomato, Vermicompost

Introduction

The AM fungi are very helpful to their hosts as they enhance the ability of plants to absorb phosphorus from soil, which is relatively inaccessible to the plants (Mcgonigle and Miller, 1996; Miller, 2000). The AM association may also increase the Phyto availability of micronutrients, e.g., copper and zinc (Smith and Read, 1997). In a study, absorption of trace elements, such as boron and molybdenum, was thought to be enhanced by AM mycorrhizae (Sieverding, 1991). In addition, it has been suggested that some AM associations are able to mobilize organically bound nitrogen, which the plants are unable to absorb (Hodge *et al*., 2001). Phosphorus content in tomato plants was increased when inoculated with the AM fungus *G. etunicatum* (Kim *et al*., 1997).AM technology increase the production of vegetables, including potato, brinjal, tomato, lady's finger, lettuce, onion, tomato, etc.

Arbuscular mycorrhizal symbiosis very effective association for promoting plant health and productivity. Chemical fertilizer not very effective to increase production of agriculture soil because its decreases productivity of soil. Chemical fertilizer also very costly. Therefore, AM fungi very effective as a bio fertilizer, in terms of cost effectiveness and as environment friendly, is a promising perspective. The main objective of this work was to study the effects of AM fungi with other biofertilizers like cow dung and vermicompost on the growth & yield of plants.

Material and Methods

Site description: For the experiments, soil was collected from Agriculture field of village Rampur, Post Dan (Mungra Badshahpur), District Jaunpur, Uttar Pradesh (Plate 1). Characteristics of agriculture soil used in the experiments are presented in Table-1.

Collection of soil samples: The rhizospheric soil samples were collected from the root region of the plants growing in agriculture soil.

Isolation of AM fungi: AMF spores were isolated by wet sieving and decanting method (Gerdemann and Nicolson 1963). A known amount of soil was dissolved in water. After through shaking, it was left for some time for the soil particles to settle down. The clear solution was passed through sieve of 500, 350, 210, 150, 90 and 60 micro meters in descending order. The AM spores retained on various sieves were transferred on filter papers. Filter papers were examined under binocular microscope. Identification of AM fungi: Different AM spores present in the soil were recovered and AM spores were mounted in PVLG and identified to the species level using the synoptic keys of Trappe (1982), Schenck and Parez (1990) and INVAM species guide (*http//: invam.caf.wvu.edu*).

The most dominant indigenous AM fungi was the species of *Glomusviz. Glomus aggregatum, Glomus fasiculatum.*

Extraction of chlorophyll: One gram of finely cut fresh leaves were taken and ground with 20 – 40ml of 80% acetone. It was then centrifuged at 5000 –10000rpm for 5mins. The supernatant was transferred and the procedure was repeated till the residue becomes colourless. The absorbance of the solution was red at 645nm and 663nm against the solvent (acetone) (Arnon, 1949).

Estimation of Chlorophyll content: The concentrations of chlorophyll a, chlorophyll b and total chlorophyll were calculated using the following equation:

Total Chlorophyll: 20.2(A645) + 8.02(A663)

Chlorophyll a: 12.7(A663) – 2.69(A645)

Chlorophyll b: 22.9(A645) – 4.68(A663)

Maintenance of Trap culture: Numerous healthy spores of different AMF species collected from the plants growing in the agriculture field of Jaunpur. Shoots were removed at crown and roots were chopped into small fragments. These root segments along with rhizospheric soil were mixed with autoclaved coarse sand soil mixture 1:1 ratio (v/v). These mixtures were then transferred to sterilized earthen pots and seeds of *Trifolium repens* (L.) were sown in each pot. Cultures were grown under greenhouse conditions for three months. After three months spore population was determined in trap cultures. Another set of trap cultures was prepared on *Sorghum bicolor* (L.) using the soil of first set. Mycorrhizal inoculum consisted of soil having 60 AM spores/10 gm. soil, mycelia and infected root fragments (95% root length colonization). This consortium was used as inoculum for the experimental work.

Mycorrhizal colonization: Mycorrhizal colonization was measured by the technique of Phillips and Hayman (Phillips and Hayman, 1970).

Experimental Design: For experiment tomatoplants grown in pots under greenhouse

condition to evaluate the performance of tomato (NTH – 1800) crop F1 Hybrid tomato, raisedthe plants in agriculture soil of Jaunpur amended with organic fertilizers like vermicompost, cowdung and inoculated with consortium of AM fungi. The experiment had a complete randomized design in one block, seven treatment / block and three replicates / treatment. The seven treatments were as follows

a) Agriculture soil (Control)
b) AgricultureSoil + VAM
c) Agriculture Soil + Vermicompost (VR)
d) Agriculture Soil + VAM+Vermicompost (VR)
e) Agriculture Soil + Cowdung (CD)
f) Agriculture Soil + VAM+Cowdung (CD)
g) Soil+VAM+Cowdung (CD) +Vermicompost (VR)
h) Agriculture Soil+ Vermicompost (VR) +Cowdung (CD)

After sowing finally emergence and establishment only five seedlings per pot were maintained. Five plants from each treatment series were carefully uprooted at different stages of plant growth *viz*; vegetative, flowering and fruiting. Samples of roots along with adhering soil were collected and processed for determining the mycorrhizal intensity in the roots and population of AM spores. Data on dry weight of roots/shoots, fresh and dry weight of fruits were recorded.

Parameters

Microbiological parameters:

Mycorrhizal Intensity: Mycorrhizal intensity in the roots was processed by the method of Phillips and Hayman (1970).

Mycorrhizal intensity = No. of roots bits infected / Total number of root bits examined × 100

AM Spore population: AM spores were isolated by wet sieving and decanting method of Gerdemann and Nicolson (1963). The population of spores in the soil was calculated and expressed in terms of their number per 60g air dried soil.

Growth Parameters: Five plants per treatment were uprooted at different stages of plant growth to record the data on growth parameters.

Root and Shoot Biomass: Dry weight of roots and shoots of the plants for each treatment was determined fruiting stage. For recording the dry weight of roots and shoots the samples were oven dried at 70°C for 48 hrs.

Yield: Number of pods and dry weight of pods for each treatment was determined separately at the time of harvest. For recording the dry weight of the seeds, the samples were oven dried at 70°C for 48 hrs.

***Statistical Analysis*:** Statistical analysis of all the data by using Microsoft Excel.

Results

Table 1: Soil Analysis Report

S. No.	Parameters	Results	Unit	Observation
1	pH	7.5		Normal
2	EC	101	mmho/cm	Normal
3	OC (organic carbon)	0.40	%	Low
4	Nitrogen(N)	90.0	Kg. /Hectare	Low
5	Phosphorus(P)	13.5	Kg. /Hectare	Low
6	Potassium (K)	324	Kg. /Hectare	High

Table 2: Length of Root, Shoot & Fruit of Tomato Plant in different series

S. no.	Series	Length of root	Length of shoot	Length of fruit
1.	**Soil (Control)**	13.066 ±0.27 cm.	26 .1 ±0.071cm.	2.033 ±0.023 cm.
2.	**Soil + AM***	6.366 ±0.087 cm.	31.5 ±0.151 cm.	1.333 ±0.022 cm.
3.	**Soil + VR***	6.433 ±0.102 cm.	30 ±0.055 cm.	1.633 ±0.023 cm.
4.	**Soil + AM* + VR**	23.333 ±0.040 cm.	28.9 ±0.027 cm.	2.3 ±0.001 cm.
5.	**Soil + CD**	13.333 ±0.156 cm.	22.933 ±0.09Cm.	1.966 ±0.060 cm
6.	**Soil + AM + CD**	10 ±0.27cm.	16.833 ±0.056Cm.	1.466 ±0.023 cm
7.	**Soil + AM + CD + VR**	14.2 ±0.32 cm.	23.233 ±0.40 cm.	1. 666 ±0.032c m.

8.	**Soil + VR + CD**	9.633 ±0.149 cm.	28.6 ±0.026 cm.	1.5 ±0.01 cm.

***AM: Arbuscular mychorrhiza *VR: Vermicompost , *CD : Cowdung**

Table 3: Weight of Root, Shoot and Fruit in different series of plant

S. No.	Series	Weight of root		Weight of shoot		Weight of fruit	
		Fresh	Dry	Fresh	Dry	Fresh	Dry
1.	**Soil (Control)**	0.68 ±0.002	0.20 ±0.006	2.46 ±0.001	0.67 ±0.001	11.66 ±0.008	10.42 ±0.016
2.	**Soil + AM**	0.39 ±0.009	0.123 ±0.001	1.21 ±0.001	0.32 ±0.002	6.11 ±0.00003	4.80 ±0.02
3.	**Soil + VR**	1.353 ±0.007	0.33 ±0.001	0.696 ±0.002	1.09 ±0.001	7.19 ±0.002	6.20 ±0.002
4	**Soil + AM + VR**	0.776 ±0.001	0.25 ±0.011	6.106 ±0.001	1.48 ±0.002	11.71 ±0.009	10.42 ±0.001
5.	**Soil + CD**	0.67 ±0.001	0.18 ±0.001	3.81 ±0.001	1.02 ±0.005	7.19 ±0.005	5.30 ±0.005
6	**Soil + AM + CD**	0.88 ±0.01	0.17 ±0.001	3.873 ±0.008	0.70 ±0.0089	11.26 ±0.002	9.20 ±0.01
7.	**Soil + AM + CD + VR**	0.433 ±0.001	0.12 ±0.012	3.326 ±0.002	0.76 ±0.002	7.60 ±0.002	6.49 ±0.001
8.	**Soil + VR + CD**	0.46 ±0.001	0.166 ±0.002	3.37 ±0.005	0.86 ±0.002	6.25 ±0.008	3.52 ±0.002

Table 4 : AM Spore Population in 100gm of Soil in different series

S. No.	Series	Total no. of spores in 100 gm. of soil
1.	**Soil (Control)**	30
2.	**Soil + AM**	62
3.	**Soil + VR**	42
4.	**Soil + AM + VR**	70
5.	**Soil + CD**	32
6.	**Soil + AM + CD**	37
7.	**Soil + AM + CD + VR**	55
8.	**Soil + VR + CD**	57

Table 5 : Percentage Mycorrhization in different series

S. No.	Series	Percentage of Mycorrhization
1.	**Soil (Control)**	50%
2.	**Soil + VAM**	65%
3.	**Soil + Vermicompost**	50%
4.	**Soil+ VAM+ Vermicompost**	75%
5.	**Soil + Cowdung**	30%
6.	**Soil + VAM + Cowdung**	40%
7.	**Soil+VAM+Cowdung+Vermicompost**	60%
8.	**Soil + Vermicompost+ Cowdung**	40%

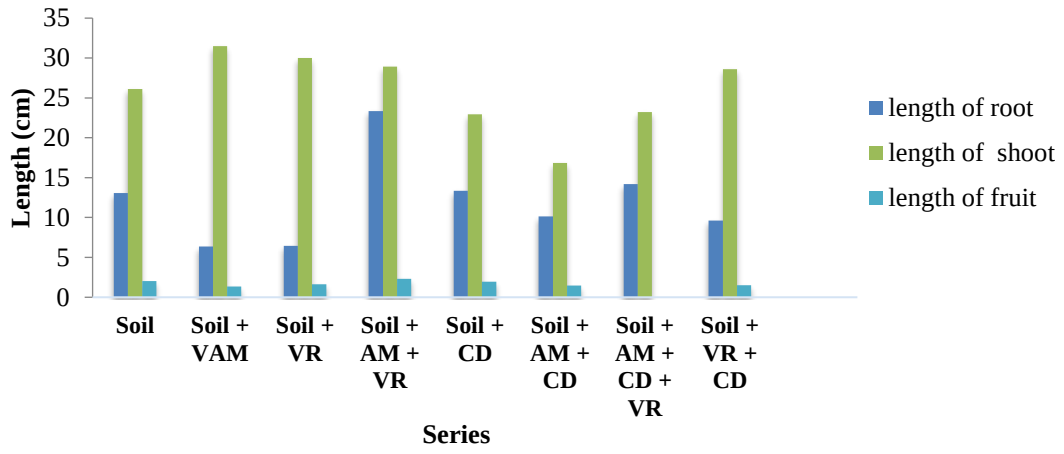
Table 6: Yields of Tomato in different series

S. No.	Series	No. of fruits / plant
1.	**Soil (Control)**	1.667 ± 0.19
2.	**Soil + AM**	1.333 ± 0.15
3.	**Soil + VR**	1.667 ± 0.15
4.	**Soil + AM + VR**	2.333 ± 0.15
5.	**Soil + CD**	1.333 ± 0.15
6.	**Soil + AM + CD**	1.333 ± 0.15
7.	**Soil + AM + CD + VR**	1.667 ± 0.15
8.	**Soil + VR + CD**	2.333 ± 0.15

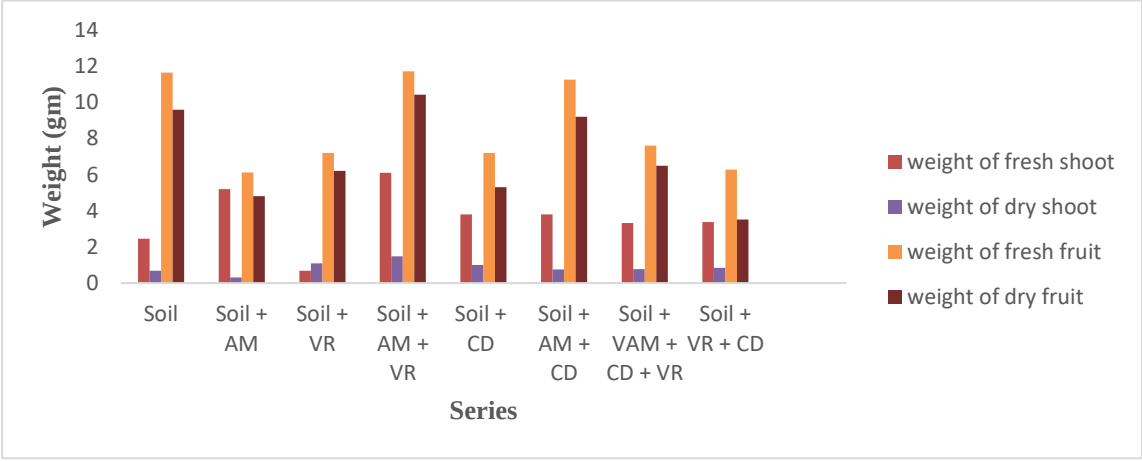
Table 7: Chlorophyll and Carotenoid Content in Plant

S. no.	Series	Chl. 'a'(mg/g)	Chl . 'b' (mg/g)	Carotenoid (mg/g)	Total chl. (mg/g)
1.	**Soil (Control)**	1.47±0.004	0.32±0.01	1.78±0.001	0.003±0.0002
2.	**Soil + AM**	1.45±0.005	2.60±0.57	2.32±0.006	0.11±0.002

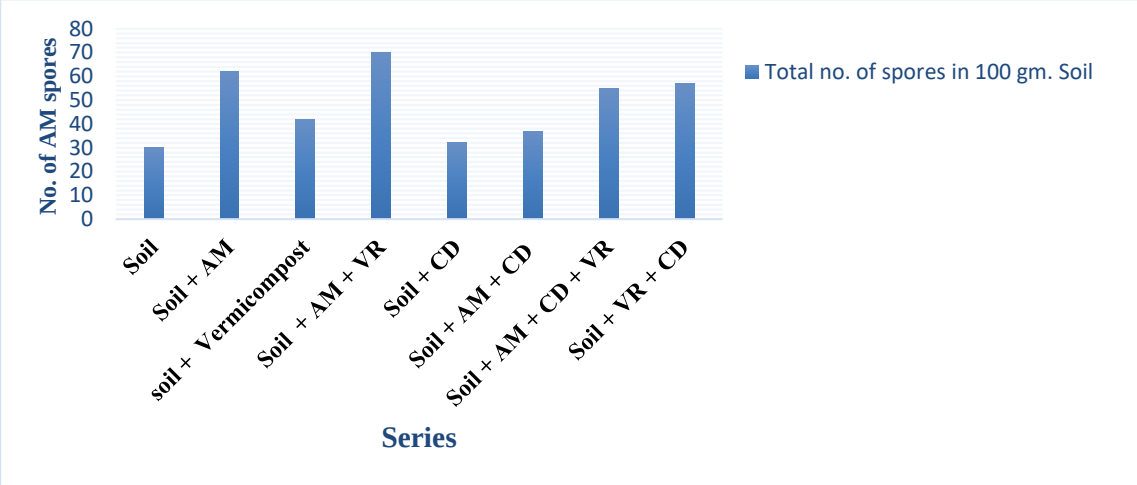
3.	**Soil + VR**	1.56±0.002	0.61±0.004	2.18±0.002	0.12±0.002
4.	**Soil + AM + VR**	1.32±0.002	0.85±0.002	3.89±0.002	0.09±0.002
5.	**Soil + CD**	1.11±0.002	0.46±0.069	1.62±0.005	0.07±0.002
6.	**Soil + AM +CD**	1.05±0.002	0.54±0.004	1.56±0.005	0.06±0.004
7.	**Soil + AM + CD + VR**	1.34±0.002	0.54±0.002	1.84±0.005	0.12±0.002
8.	**Soil + VR + CD**	0.85±0.002	0.45±0.002	1.31±0.002	0.12±0.002



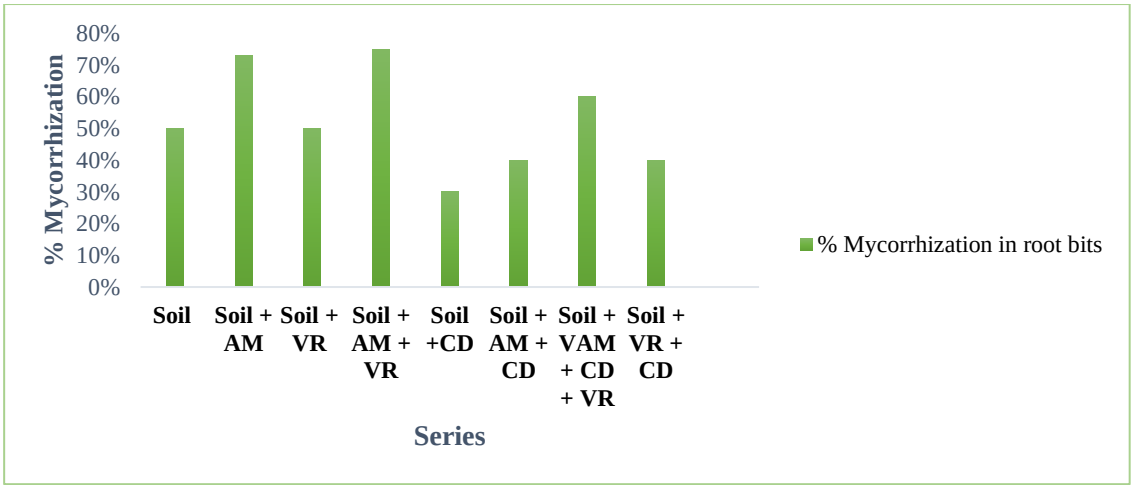
Graph 1: Length of Root, Shoot and Fruit



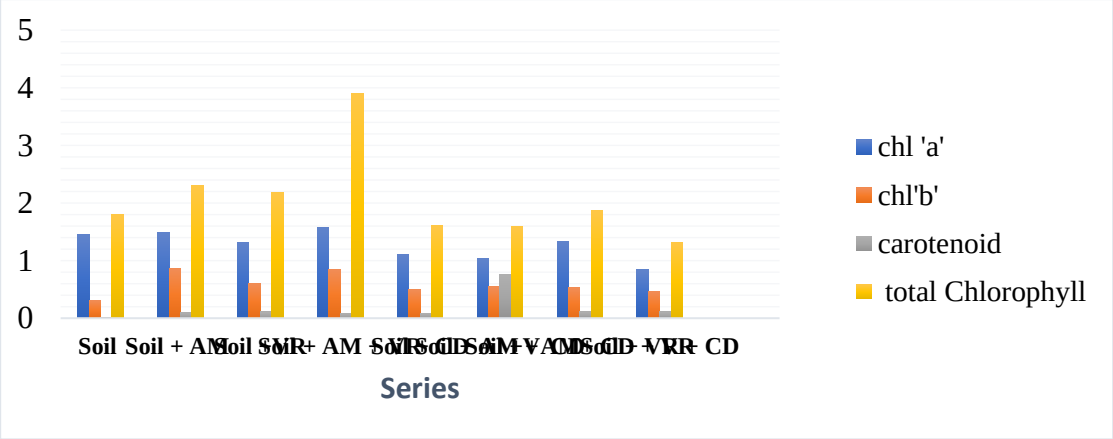
Graph 2: Weight of Shoot & Fruit (fresh & dry)



Graph 3: Total No. of Spores in 100 gm. Soil



Graph 4: Percentage Mycorrhization



Graph 5: Chlorophyll ‘a’, ‘b’, carotenoid and total chlorophyll

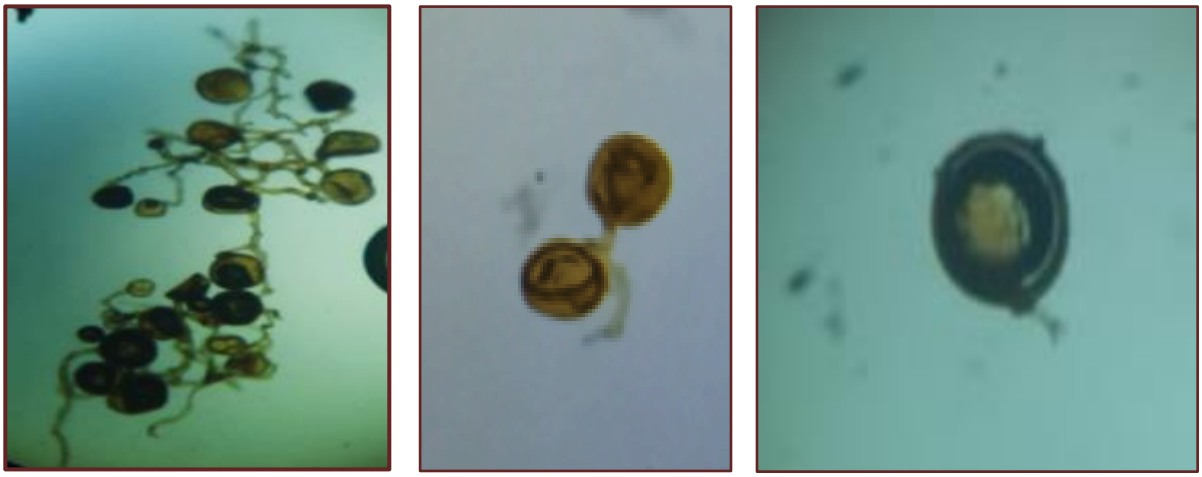
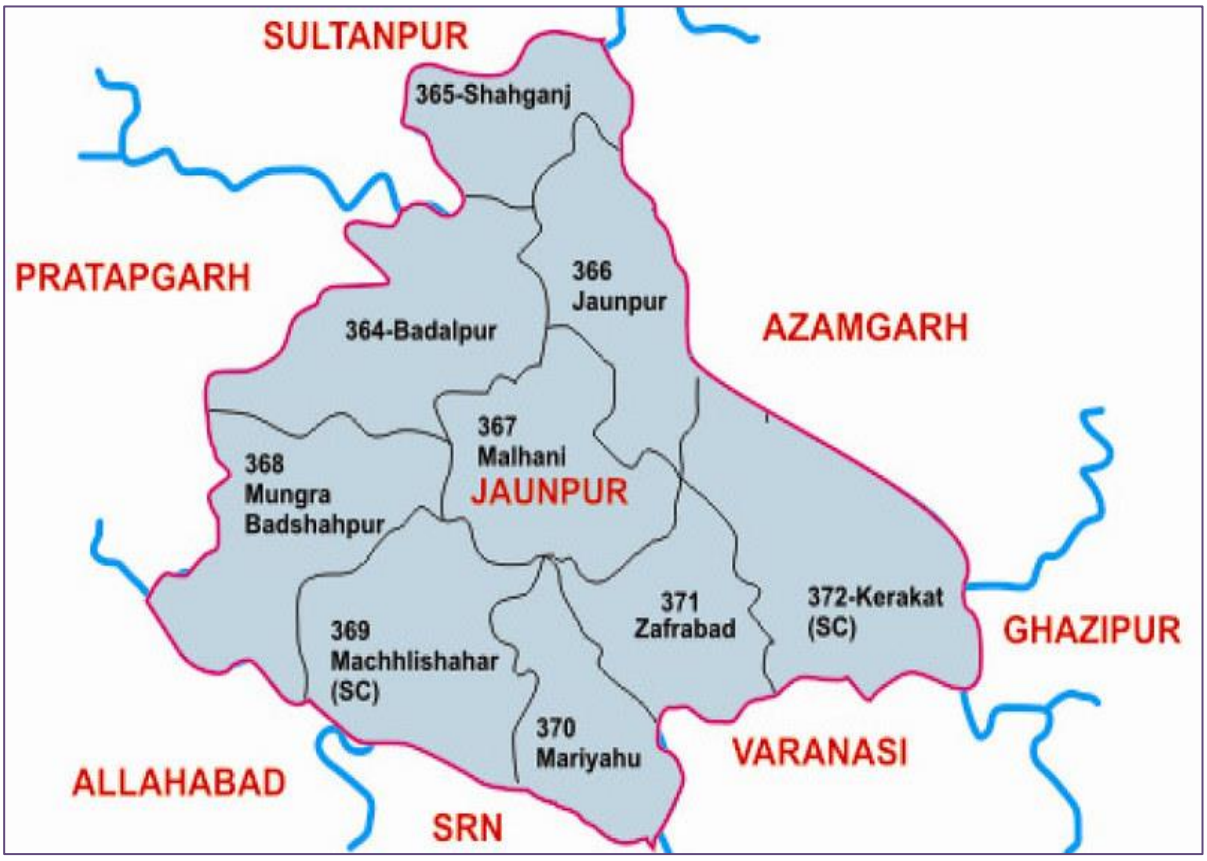


Figure 1: Diversity of ***Glomus*** sp. in the experimental soil



Map: Collection site of Agriculture soilfor experimental set up (Source Googleimage) Jaunpur district Uttar Pradesh Election 2017 | Jaunpurdistr… | Flickr

Figure 2: Agriculture soil collection site

Figure 3: Maintenance of Trap Culture

Figure 4: Pots set up of different series of *Lycopersicon esculentum* (tomato) (NTH – 1800)

Figure 5: Fruiting stage of plants in different series (Tomato)

Figure 6: Tomato plants in VAM + VR series

Discussion

In India, vegetables alone contribute 58.73% of total horticultural production. India produced 162.89 million tonnes of vegetables from an area of 9.39 million ha. (Arora *et al*., 1980).

The 'Green Revolution' in the 1960s and 1970s ushered in by the heavy use of agro-chemicals, increased food productivity but also created several socio-economic and environmental problems like decreased nutritional quality of food produced, decreased soil fertility, higher demand for water for irrigation, soil and water pollution and pesticide poisoning (Sinha, 1998, 2004; Sinha *et al*., 2009). The pesticide remaining in vegetables can cause neurological and blood disorders and lung ailments, and affect the reproductive system of women (Mandal, 2009). Sharma (2009) reported that indiscriminate use of chemical fertilisers in the wake of the Green Revolution in Punjab has pushed the state to the brink of health hazards. To preserve the global agro-ecosystems and protect human health from the harmful agro-chemicals "Ecological Agriculture and Organic Farming" has to be promoted (Gomiero, 2008). Ecological agriculture is relatively more sustainable, and it could be an economically and environmentally viable alternative to the destructive chemical agriculture (Rasul and Thapa, 2003; Sinha, 2004). The effective utilization of 'biological fertilizers' for

vegetable crops will not only provide economic benefits to the farmers but also improve and maintain soil fertility and sustainability in natural soil eco-systems (Kannaiyan, 2002). Manure is an important input for maintaining and enhancing soil fertility. As per Fulhage (2000) manure contains the three major plant nutrients, nitrogen, phosphorus and potassium (NPK), as well as many essential nutrients suchas Ca, Mg, S, Zn, B, Cu, Mn etc. That, in addition to supplying plant nutrients, manure generally improves soil health, aeration, and water holding capacity of the soil and promotes growth of beneficial soil organisms.

Cowdung manure plays a significant role in maintaining the nutrient status of the plant. Vermicomposting of cow manure using earthworm species *E. andrei* (Atiyeh *et al*., 2000b) and *E. foetida* (Hand *et al.*, 1988) favored nitrification, resulting in the rapid conversion of ammonium-nitrogen to nitrate-nitrogen. Therefore, it improves the nutrient cycling and helping to convert unavailable nitrogen in available forms to plants. It is widely acknowledged that using composts and vermicompost as amendments, rather than industrialized fertilizer and raw manure, could improve soil nutrients and promote soil health (Jack and Thies, 2006).Manure compost has been widely applied as it is highly accessible at low price (Hepperly*et al*, 2009; Ramirez- Guerreo and Meza – Figueroa,2014), and greatly improved most of the characteristics of crop plants compared with mineral fertilizer (Da Silva *et al*, 2011).AMF were shown to confer numerous benefits to their host plants including the enhancement of plant growth and mineral nutrition and the improvement of soil properties (Bousselmane and Achouri, 2002; Diouf *et al*., 2013; Mrabet *et al*., 2014), we also observed that when AMF and vermicompost used in combine, itpromotes the growth and yield of tomato plant as compare to alone (Table 2,3,4,5,6,7).A significant effect of compost and AMF complex on tomato growth in greenhouse experiment, where the root colonization and root dry weight have been improved (Akhter et al., 2015). We also observed, AMF and vermicompost mixture also promote the biomass and mycorrhization in tomato plants (Table 4,5). Indigenous or commercial arbuscular mycorrhizal fungi (AMF) and compost were recently involved to improve plant growth and mineral nutrition of many species such as *Argania spinosa* (Mrabet *et al*., 2014), *Triticum aestivum* and *Trifolium alexandrium*. where a full and half dose of compost inoculated with commercial or indigenous AMF increased significantly root and shoot biomass (Jan, 2014; Jan *et al*., 2014) (Table 3). Also, the use of compost and mycorrhizal fungi have increased growth of *Medicago polymorpha* and a positive correlation was found between biomass production and compost rate(Akhzari*et al*., 2015). The efficiency of vermicompost and AMF on nutrient acquisition, e.g. total nitrogen, potassium as well as pH (from 3.05 to 7.96) and conductivity increasing in contrast with application of vermicompost alone (Akhzari*et al*., 2015). We observed that after experiment, AMF and vermicompost combination very beneficial for the tomato plant. It promotes the biomass and yield of plants. When vermicompost or cowdung apply as single combination it is not much effective for the growth and yield of tomato plant. AMF always beneficial for the growth and yield of plant when combine with vermicompost its give best result. So, after observation we conclude that AMF and vermicompost is best combination for the growth and

yield of tomato plant.

Conclusions

In this study, we observed that when plants grown in AMF and Vermicompost treated soil give best performance. Both growth and yield of tomato plant increases in AMF and vermicompost treated soil in combination as compare to singly. This experiment proves AM technology is eco-friendly technology which promote the quality of tomato plants.

References

Abbasi, H., Ambreen, A.&Rushda, S.(2015). Vesicular Arbuscular Mycorrhizal (VAM) Fungi: A Tool for Sustainable Agriculture. *American J. of Plant Nutrition and Fertilization Techno*., 5: 40-49.

Akhter, A., Hage-Ahmed, K., Soja, G. &Steinkellner, S. (2015). Compost and biochar alter mycorrhization, tomato root exudation, and development of *Fusarium oxysporum* f. sp. *lycopersici*. *Front. Plant Sci*., 6: 529

Akhzari, D., Attaeian, B., Arami, A., Mahmoodi, F.&Aslani, F. (2015). Effects of Vermicompost and Arbuscular Mycorrhizal Fungi on soil properties and growth of *Medicago polymorpha* L. *Compost Sci. Utilization.,* 23 (3): 142–153.

Arora, D., Chandel, K.P.S., Joshi, B.S.& Pent, K.C. (1980). Rice bean: Tribal pulse of eastern India. *Economic Bot*., 34:260-263.

Aron, D.(1949). Copper enzymes isolated chloroplasts, polyphenoloxidase in *Beta vulgaris*. *Plant Physiol*., 24: 1-15.

Atiyeh, R.M., Arancon, N.Q., Edwards, C.A. & Metzger, J.D. (2000). Influence of earthworm- processed pig manure on the growth and yield of green house tomatoes. *Bioresour Technol.*,75:175–180.

Borde, M., M. Dudhane&Jite, P.K. (2009). Role of bioinoculant (AM fungi) increasing in growth, flavor content and yield in *Allium sativum* L. under field condition. *NotulaeBotanicae Horti Agrobotani.,* 37:124-128.

Bousselmane, F. &Achouri, M. (2002). Effet des mycorhizes à vésicules et arbuscules sur la croissance et la nutrition de l'arganier (*Argania spinosa* L.). *Actes Inst. Agron. Vet*., 22: 193–198.

Da Silva T. R., Menezes J. F. S., Simon G. A., De Assis R. L., Santos C. J. D.& Gomes G. V. (2011). Corn cultivation and availability of phosphorus under fertilization with chicken manure. *Rev. Bras. Eng. Agric. E Ambiental.,* 15: 903–910.

Diouf, D., Fall, D., Kané, A., Bakhmoun, N.&Duponnois, R. (2013). Effet de l' inoculation avec des souches de Mesorhizobium sp. et/ou des champignons mycorhiziensa arbuscules sur la croissance et la nutrition minérale; de plants d' Acacia seyal Del. 235–265. IRD Editions Institut De Recherche Pour Le Developpement, Marseille

Fulhage, C.D. (2000). Reduce environmental problems with proper land application of animal manure. University of Missouri Extension. USA.

Gerdemann, J.W & Nicolson, T.H. (1963). Spores of mycorrhizal Endogone species extracted

from soil by wet sieving and decanting. *Trans. Br. Mycol. Soc.,* 46: 235-244.

Gomiero, T., Paoletti, M. G.& Pimentel, D. (2008). 'Energy and Environmental Issues in Organic and Conventional Agriculture', *Critical Reviews in Plant Sci*., 27 (4): 239-254.

Hand, P., Hayes, W.A., Frankland, J.C. & Satchell, J.E. 1988. Vermicomposting of cow slurry. *Pedobiolo.*, 31:199–209.

Hepperly, P., Lotter, D., Ulsh, C. Z., Seidel, R.&Reider, C. (2009). Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. *Compost Sci. Util.,* 17: 117–126.

Hodge, A., Campbell,C.D. & Fitter, A.H.(2001). An arbuscular mycorrhizal fungus accelerates decomposition and acquires nitrogen directly from organic material. *Natu*., 413: 297-299.

Jack, A. L.&Thies, J. E. (2006). "Compost and vermicompost as amendments promoting soil health," in Biological Approaches to Sustainable Soil Systems, ed N. Uphoff (New York, NY: CRC Press), 453–466.

Jan, B. (2014). Effect of Arbuscular mycorrhiza fungal inoculation with compost on yield and phosphorous uptake of berseem in alkaline calcareous soil. *Am. J. Plant Sci*., 5: 1359–1369.

Jan, B., Sharif, M., Khan, F. & Bakht, J. (2014). Effect of Arbuscular mycorrhiza fungal inoculation with compost on yield and P uptake of wheat in alkaline calcareous soil. *Am. J. Plant Sci.*, 5: 1995–2004.

Kannaiyan, S. (1993).Nitrogen contribution by *Azolla* to rice crop,Energy., 400: 1-67

Khade, S. W. & Rodrigues. B. F. (2009). Studies on effects of arbuscular mycorrhizal (AM) fungi on mineral nutrition of *Carica papaya* L. *Not. Bot. Hort. Agrobot. Cluj*., 37:183-186.

Kim, K.Y., D. Jordan & McDonald, G.A.(1997). Effect of phosphate-solubilizing bacteria and vesicular-arbuscular mycorrhizae on tomato growth and soil microbial activity. *Biol. Fertil. Soils*, 26: 79-87.

Mandal, S. (2009). 'Pesticide peril in vegetables', The Telegraph, March 09, Calcutta, India,

Mcgonigle, T.P. &Miller,M.H.(1996). Development of fungi below ground in association with plants growing in disturbed and undisturbed soils. *Soil Biol. Biochem*., 28: 263-269.

Mrabet, S. El, Ouahmane, L., Mousadik, A. El, Msanda, F.& Abbas, Y. (2014). The effectiveness of arbuscular mycorrhizal inoculation and bio-compost addition for enhancing reforestation with Argania spinosa in morocco. *Open J. For.*, 4: 14– 23.

Miller, M.H. (2000). Arbuscular mycorrhizae and the phosphorus nutrition of maize: A review of Guelph studies. *Can. J. Plant Pathol. Sci*., 80: 47-52.

Phillips, J.M. & Hayman, D.A. (1970). Improved Procedures for Clearing Roots and Staining Parasitic and Vesicular-Arbuscular Mycorrhizal Fungi for Rapid Assessment of Infection. *Transactions of the British Mycological Soc*. 55: 158-161

Smith, S.E. and D.J. Read.(1997). Mycorrhizal Symbiosis. 2nd Edn., Academic Press, London, UK., ISBN-13: 978-0-12-652840-4, Pages: 605

Sieverding, E. (1991). Vesicular-arbuscular mycorrhiza management in tropical agrosystems. Deutche Gesellschaft fur TechnischeZusammenarbeit, GTZ No. 224, Federal Republic of

Germany, pp: 371.

Rahman, S.& Thapa, G.B.(1999). Environmental impacts of technological change in Bangladesh agriculture: farmers' perceptions and empirical evidence. *Outlook on Agri.,* 28 (4): 233–238.

Ramirez-Guerrero H.& Meza-Figueroa, C. (2014). Strengthening potato production and ecological transition using organic fertilization. *Rev. Fac. Agron. Univers. Zulia* 31, 1–11.

Sharma, V. (2009) 'Indiscriminate use of chemical fertilizers leading to health hazards', The Hindu, 05 December, New Delhi, India.

Sharma, V. (2009) 'Indiscriminate use of chemical fertilizers leading to health hazards', *The Hindu,* 05 December, New Delhi, India.

Shivaputra, S. S., C. P. Patil, G. S. K. Swamy & Patil, P. B. (2004). Effect of vesicular-arbuscular mycorrhiza fungi and vermicompost on drought tolerance in papaya. *Mycorrhiza News*, 16:12-13.

Sinha, R.K. (1998) 'Embarking on the second Green Revolution for sustainable agriculture in India: a judicious mix of traditional wisdom and modern knowledge in ecological farming', *J. of Agricultural and Env.Ethi*., 10:183–197.

Sinha, R.K. (2004) 'Vermiculture for sustainable agriculture', Sustainable Agriculture, Surabhee Publication, Jaipur, India, p.370.

Sinha, R.K. &Valani, D. (2009) Agronomic Studies of Earthworms and Vermicompost vis-à-vis Conventional Cow Dung Compost and Chemical Fertilizers on Tomato (*Lycopersicum esculentum*), Vermiculture Project of School of Engineering (Environment), Griffith University, Australia.

Sinha, R.K. (2004) 'Vermiculture for sustainable agriculture', Sustainable Agriculture, Surabhee Publication, Jaipur, India, p.370.