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Effect of Arbuscular Mycorrhizal Fungi on Growth and Development of Potato (*Solanum tuberosum*) Plant

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ABSTRACT

Arbuscular Mycorrhizal Fungi (AMF) have mutualistic relationships with more than 80% of terrestrial plant species. Arbuscular mycorrhizal fungal symbiosis have remarkable role in sustainable growth and development of plants as they help the land plants to acclimatize the biotic and abiotic conditions for their better survival, growth and development. In the present study surface sterilized tubers and seeds of potato were sown in earthen pots filled with sterile soil. Half the pots were inoculated with sterilized 30 AMF spores of the *Glomus intraradices* and *G. mosseae* and 10 g of maize root inoculated with the species of *G. intraradices* and *G. mosseae*. Another half represented controls with no AMF inoculation. Inoculation was done twice 3 days before sowing the tubers and seeds and on the onset of germination. Potted plants were regularly watered. After seedling emergence, the inoculated plants along with their controls were sampled at 20, 40, 60 and 80 days of growth. The observed data seems to predict that there is a net increase in the above and below ground growth of the plant with each 20 days interval after seedling emergence. The present study seems interesting since it pertains the work on modified stem *vis a vis* mycorrhizal relationship of a modified stem than normal root. The Chlorophyll content besides morphological growth parameters and fresh and dry weight content of both cultivars of potato plant are shown to present in higher level in the mycorrhiza infected as compared to the non-inoculated ones.

Key words: AMF, potato, stem modification, growth and development, plant improvement

INTRODUCTION

Mycorrhizae or *mycorrhiza,* a symbiotic association between a fungus and the roots of a plant (Kirk *et al*., 2001). Despite only a small proportion of angiospermic species having been examined, mycorrhizae form a mutualistic relationship with the roots of nearly eighty percent of such plant species (Wang and Qiu, 2006). AM fungi and plant roots, improve water and nutrient uptake like phosphorus, nitrogen and micronutrients and thus enhance plant growth (Goussous and Mohammad, 2009). Most of the research effort is concerned with mycorrhiza as a mutualistic association between the underground root of the host plant and soil fungi. However, there are reports that besides roots, these fungi can also associate mutualistically with underground modifications of stem like rhizomes and other associated structures. Taber and Trape (1982) reported for the first time, the presence of AM fungi in the vascular system of rhizomatous tissue and the scale like leaves of *Zingiber officinale* L. Later Nazim (1990) reviewed the presence of AM fungi associated with the portions other than roots in twenty one angiosperms and some non-angiosperm species. Incidence of AM fungal colonisation has been reported in scale leaves and leaf bases of *Curcuma longa* L. (Sampath and Sullia, 1992), corms of *Amorphophallus commutatus*

Engler (Rodrigues, 1995) and tubers of *Pueraria tuberosa* (Willd.) DC (Rodrigues, 1996). Arbuscular mycorrhizal fungi have been documented in tubers of *Colocasia esculenta* (L.) Schott (Bhat and Kaveriappa, 1997), garlic bulbs (Kunwar *et al*., 1999), tubers of *Gloriosa superba* L. (Khade and Rodrigues, 2003) and corms of saffron (Lone, 2014). On further perusal the availability of literature on stem modifications and AM fungi associations is scanty because of dominance of studies on root-fungi associations. Present study is therefore, based on a simple premise whether or not the AM fungi have any constitutive association with potato underground stem propagules which constitute the prime propagule for vegetative propagation and also being the part of commercial utility and importance and thereby assessing a substantive role of AMF associations in the growth and development of the potato plant.

MATERIALS AND METHODS

Seeds of *Solanum tuberosum* (TPS, SM/93-237) and potato tubers var. Jyoti were procured from Potato Research Center, Gwalior. These were soaked in distilled water for 2 h and then treated with 0.01% cetrimide solution for 3-5 min. After surface sterilisation these were washed 3-4 times with distilled water. Seeds and also similar sized tubers of uniform weight ranging 60-70 g were separately sown in pots filled with sterile soil. Soil (3:1 ratio of soil: sand) was autoclaved twice at 15 lbs pressure and 120°C temperature for 30 min. Half the pots were inoculated with AMF spores of the species of *G. intraradices* and *G. mosseae* and also maize root inoculated with the species of *G. intraradices* and *G. mosseae*. Half the pots represented controls which had no AMF inoculation. Pot inoculations were done 3 days before sowing and onset of seedling emergence. Potted plants were regularly watered. Potato seed took 15-20 days while tubers took 10-12 days to seedling emergence. After seedling emergence, the inoculated plants along with their controls were sampled at 20, 40, 60 and 80 days of growth after seedling emergence. The roots were stained with 0.05% tryphan blue stain using the method suggested by Phillips and Hayman (1970). Root colonization estimation was carried out using Biermann and Linderman (1981) method. Percent root colonization was calculated using following relationship:

$$\text{Colonization (\%)} = \frac{\text{Total number of colonized root pieces}}{\text{Total number of root pieces examined}} \times 100$$

Once seedling emergence, both planted as seed and tuber, the growth and development parameters were recorded at every 20 days interval. The plant height was measured with the meter scale from the base of the plant to the top most leaf of the plant. The neck diameter was measured above 5 cm from the surface of the soil. Total leaves per plant and branches were counted for all the plants in a pot and divided by the number of plants. After uprooting plants the root length was measured and tubers counted.

For fresh and dry weight analysis, the plants were uprooted and separated into root, shoot and tubers. After noting the fresh weight the shoot and root were oven dried transferred to desiccator and reweighed for dry weight determination. For the tubers however, after weighing to know fresh weight, these were oven dried for 48 h and the dry weight noted.

For chlorophyll a, chlorophyll b and total chlorophyll the method of Arnon (1949) and Witham *et al*. (1971) was employed. Calculation of the amount of chlorophyll present in the extract as mg chlorophyll per gram green tissue using the following equations for each fraction;

For chlorophyll a:

$$\text{mg chlorophyll a per g tissue} = 12.7(A663) - 269(A645) \times \frac{V}{1000 \times W}$$

For chlorophyll b:

$$\text{mg chlorophyll a per g tissue} = 12.7(A645) - 269(A663) \times \frac{V}{1000 \times W}$$

Total chlorophyll:

$$\text{mg chlorophyll a per g tissue} = 20.2(A645) - 8.02(A663) \times \frac{V}{1000 \times W}$$

Where:
A = Absorbance at specific wavelength
V = Final volume of chlorophyll extract in 80% acetone
W = Fresh weight of tissue extracted

RESULTS

The tuber of potato plant (*Solanum tuberosum*) is an important vegetable crop of the world. The "Tuber" of the plant constitutes the underground modification of a stem. In present study propagation has been performed by both seed as well as the tuber. Seeds seem to be of uniform stock, since all the pots sown with the seeds showed nearly 70-75% uniform seedling emergence and subsequent seedling growth. However, the tuber propagation scored better to that of seeds as far as germination which was 100% and also subsequent seedling growth under pot culture conditions. Pots which were infused with AMF spores and also the roots of exclusively monosporal cultured maize roots show that given proper conditions for the growth and development potato plants do produce comparative effects with and without Arbuscular Mycorrhizal Fungi (AMF). The various stages of plant growth were therefore set at 20 days intervals of 20, 40, 60 and 80 days after seedling emergence in both propagation types.

The roots of the potato plants in the control pots did not show any of the AMF structures implying adequate soil sterility. The percent root colonisation of AMF in both potato varieties presented a consistent increase as the plant grows with the inoculums. Seedling establishment at 20 days growth shows minimum percent root colonisation in both the varieties (Table 1). Plant root percentage colonization of AMF was higher in the Jyoti variety of potato which was propagated by tuber and that too at all stages of growth than TPS variety which was propagated by seed (Table 1).

Mycorrhizal colonisation is confirmed in all pots inoculated with AMF. This assumption is based on the AMF presence in various morpho-presentations like vesicles, arbuscules or hyphae in the infected roots. The absence of AMF in any form, from the uninoculated pots show the proper experimental conditions as control.

Tuber propagated AMF treated potato plants (var. Jyoti) don't show any significant increase in plant width, number of branches per plant, leaf length and root length whereas plant height,

Table 1: Comparative colonisation percentages of potato root at various stages of growth when infused with mixture of species of genus *Glomus* under pot culture

	Root colonization (%)			
	Var. Jyoti		Var. TPS	
Days	-AMF	+AMF	-AMF	+AMF
20	0.00±0.00^{e}	16.50±1.00^{d}	0.00±0.00^{e}	9.14±0.52^{d}
40	0.00±0.00^{e}	21.64±1.64^{c}	0.00±0.00^{e}	16.34±0.86^{c}
60	0.00±0.00^{e}	48.16±2.14^{b}	0.00±0.00^{e}	36.25±2.25^{b}
80	0.00±0.00^{e}	68.56±4.32^{a}	0.00±0.00^{e}	47.86±2.32^{a}

Table 2: Various growth and developmental parameters of tuber propagated potato (var. Jyoti) as affected by the presence of AMF

	Plant height (cm)		Plant width at base (cm)		No. of branches/plant		Total No. of leaves/plant	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
20	4.89±1.12^{e}	6.64±0.26^{f}	0.93±0.04^{e}	0.95±0.04^{e}	5.88±0.24^{e}	6.68±0.32^{e}	11.76±0.64^{e}	14.18±0.86^{f}
40	16.39±0.64^{e}	18.08±1.32^{e}	1.64±0.12^{e}	2.26±0.18^{d}	10.28±0.26^{c}	14.68±0.48^{c}	34.97±1.64^{e}	51.22±4.36^{d}
60	24.23±1.24^{d}	28.66±1.42^{c}	2.77±0.24^{c}	3.84±0.28^{b}	13.91±0.08^{c}	17.77±0.98^{b}	52.30±6.32^{d}	67.47±3.84^{c}
80	35.01±2.14^{b}	38.18±2.36^{a}	4.10±0.18^{b}	5.34±0.32^{a}	18.57±0.14^{b}	26.17±1.64^{a}	74.57±3.68^{b}	81.45±5.32^{a}
LSD value	1.979		0.3048		1.399		3.531	
	Largest leaf length petiole-tip (cm)		Largest leaf breadth (cm)		Root length origin to last (cm)		No. of tubers/plant	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
20	1.33±0.12^{g}	1.44±0.24^{g}	1.48±0.12^{e}	1.51±0.08^{e}	1.88±0.24^{g}	1.86±0.14^{g}	0.00±0.00^{e}	0.00±0.00^{e}
40	3.41±0.86^{f}	4.14±0.24^{f}	2.54±0.04^{d}	2.68±086^{d}	3.30±0.24^{f}	5.81±0.36^{e}	0.00±0.00^{e}	2.26±0.14^{d}
60	4.67±1.62^{d}	5.86±0.26^{b}	4.02±0.14^{c}	4.55±1.36^{b}	7.63±0.56^{d}	11.21±0.86^{b}	3.08±0.16^{c}	3.20±0.16^{c}
80	5.36±0.42^{c}	6.86±0.32^{a}	4.78±0.12^{b}	5.14±2.36^{a}	9.70±0.48^{c}	13.72±1.02^{a}	5.44±0.26^{b}	6.14±0.36^{a}
LSD value	0.424		0.2948		0.8758		0.5046	

Different superscripted letters over standard error denotes significance in difference (factorial ANNOVA followed by Duncan Multiple Range test $p<0.05$)

number of leaves per plant significantly increase at 20 days after seedling emergence (Table 2). A general but significant increase in plant width, number of leaves per plant and root length in AMF inoculated plants in comparison to its control is visible at 40 day sampling. Tuberisation seems to starts in inoculated plant and is delayed in non-AMF inoculated plants. At 60 days growth all the growth parameters are shown to be increasing effectively and significantly in inoculated plants than controls. In AMF containing plants these increments then taper with the increasing age of the plant. In an overall assessment, the number of leaves per plant followed by plant height, number of branches, root length and number of tubers per plant followed by plant height, number of branches, root length and number of tubers per plant with LSD value of 3.530, 1.979, 1.399 and 0.5046, respectively show definite increase in these growth parameters with AMF presence (Table 2) whereas leaf and plant width and also leaf length increments due to inoculation with LSD values of 0.2948, 0.3048 and 0.4240 respectively are slightly less significant compared to controls at 60 days growth (Table 2).

The seed propagated potato (var.TPS) run similar trends as shown by the tuber propagated variety Jyoti. However, there are visible differences at all levels of sampling and in all the growth parameters (3). Between the two varieties the later shows 1- 2 fold significantly higher values than the earlier (2; 3). The trends are comparable between the two even with their respective controls. In potato var. Jyoti, AMF seems to cause insignificant increase in both fresh and dry weights at early stages of plant growth which then shows significant increase at 40-60 days in inoculated plants. These then taper with the aging at 80 days (Table 3). At 60 days growth the increase in the dry matter content of shoot, root and tuber is significantly higher in AMF inoculated plants (4). At

Table 3: Various growth and developmental parameters of seed propagated potato (var. TPS) as affected by the presence of AMF

	Plant height (cm)		Plant width at base (cm)		No. of branches/plant		Total No. of leaves/plant	
Days	-MF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
20	2.14±0.14^{f}	2.20±0.14^{f}	0.46±0.02^{f}	0.48±0.02^{f}	2.44±0.14^{f}	2.48±0.12^{f}	4.76±0.24^{e}	5.13±0.12^{e}
40	2.65±0.14^{e}	3.88±0.22^{d}	0.55±0.03^{f}	0.94±0.04^{e}	3.76±0.27^{e}	4.57±0.26^{d}	5.42±0.32^{e}	6.99±0.62^{d}
60	4.37±0.24^{c}	8.01±0.38^{b}	1.20±0.06^{d}	1.78±0.12^{c}	7.00±0.36^{c}	9.08±0.64^{b}	8.07±0.52^{d}	14.16±1.06^{c}
80	8.11±0.36^{b}	13.15±1.02^{a}	2.14±0.12^{b}	3.72±0.26^{a}	9.56±0.62^{b}	15.24±1.06^{a}	16.85±0.86^{b}	24.82±1.86^{a}
LSD value	0.4096		0.1642		0.7663		1.384	
	Largest leaf length Petiole-tip (cm)		Largest leaf breadth (cm)		Root length origin to last (cm)		No. of tubers/plant	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
20	0.63±0.03^{c}	0.64±0.04^{c}	0.47±0.04^{e}	0.48±0.02^{e}	3.06±0.26^{f}	3.120±0.24^{f}	0.00±0.00^{e}	0.00±0.00^{e}
40	0.64±0.02^{c}	0.98±0.06^{c}	0.88±0.06^{d}	0.91±0.04^{d}	5.05±0.32^{e}	6.880±0.51^{d}	0.00±0.00^{e}	1.24±0.08^{d}
60	1.93±0.12^{b}	2.10±0.12^{b}	2.06±0.10^{c}	2.14±0.14^{b}	7.31±0.56^{d}	12.04±0.86^{b}	2.4±0.18^{c}	3.87±0.10^{b}
80	2.42±0.22^{a}	3.73±0.26^{a}	3.12±0.23^{a}	3.13±0.20^{a}	8.96±0.78^{c}	13.10±1.04^{a}	4.2±0.14^{b}	4.92±0.28^{a}
LSD value	0.3672		0.0774		0.6902		0.5741	

Different superscripted letters over standard error denotes significance in difference (factorial ANNOVA followed by Duncan Multiple Range test p<0.05)

Table 4: Fresh and dry matter content with and without AMF in the plant and tubers of potato plant var. Jyoti

	Shoot fresh		Shoot dry)		Root fresh		Root dry		Tuber fresh	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
Weight g/plant										
20	6.03±0.24^{g}	6.34±0.32^{g}	0.54±0.03^{f}	0.520±0.02^{f}	1.44±0.12^{g}	1.52±0.14^{g}	0.12±0.01^{g}	0.18±0.01^{g}	0.000±0.00^{e}	0.000±0.00^{e}
40	8.76±0.42^{f}	10.97±0.98^{e}	0.88±0.32^{e}	0.1.08±0.03^{d}	3.73±0.32^{f}	4.86±0.26^{e}	0.34±0.02^{f}	0.47±0.02^{e}	0.000±0.00^{e}	2.140±0.12^{e}
60	18.14±1.24^{d}	22.76±1.06^{c}	1.88±0.12^{c}	2.760±0.14^{a}	5.94±0.42^{d}	7.32±0.51^{c}	0.58±0.04^{d}	0.75±0.04^{c}	31.75±2.31^{d}	38.01±3.14^{c}
80	26.42±1.32^{b}	32.02±1.68^{a}	2.44±0.22^{b}	3.440±0.14^{b}	8.82±0.62^{b}	11.45±0.79^{a}	1.02±0.08^{b}	1.44±0.14^{a}	72.14±3.57^{b}	83.32±4.36^{a}
LSD value	0.9143		0.1448		0.4022		0.09481			

	Tuber dry		Total fresh		Total dry		Total plant fresh weight/dry weight ratio	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
Weight g/plant								
20	0.000±0.00^{d}	0.00±0.00^{d}	7.47±0.62^{e}	8.22±0.65^{f}	0.60±0.04^{e}	0.54±0.03^{e}	8.83±0.64^{f}	8.90±0.54^{f}
40	0.000±0.00^{d}	0.25±0.01^{d}	16.34±1.32^{ef}	15.42±1.62^{e}	1.01±0.04^{e}	1.41±0.12^{e}	9.76±0.42^{de}	10.01±0.36^{d}
60	5.350±3.24^{c}	7.41±0.42^{c}	55.83±2.36^{d}	68.09±3.62^{c}	8.59±0.04^{d}	10.59±0.68^{c}	13.98±1.04^{c}	15.64±1.12^{b}
80	13.38±1.68^{b}	18.13±0.68^{a}	107.38±8.63^{b}	126.80±12.34^{a}	21.60±0.36^{b}	24.18±0.86^{a}	15.68±1.14^{b}	18.53±0.98^{a}
LSD value	1.527		5.842		1.554		1.2104	

Different superscripted letters over standard error denotes significance in difference (factorial ANNOVA followed by Duncan multiple Range test p<0.05)

each stage, from 40, 60 and 80 days, the dry weight accumulation is higher in inoculated plants than their respective controls. Meanwhile the tubers which show their differentiation between 20 and 40 days consistently show much higher levels of both fresh and dry matter content in AMF presence which maximizes between 60-80 days of growth (Table 4). Overall potato plant var. Jyoti which is seeded by tuber, therefore, shows insignificant increase in both fresh and dry weight in inoculated plants than control till 40 days of plant growth, which then significantly and continuously increases till 60 and maximizing at 80 days.

The fresh and dry weight of potato plant var. TPS though show similar trends as that of Jyoti, yet the amounts and contents of increase and changes in these as above parameters at all stages are much lower than the later; at certain times being tenfold lower (Table 5). Tubers from the two varieties show similar trend, Jyoti variety of potato responds with nearly 10 times more accumulation of fresh and dry matter content. This is irrespective of the stage and also the presence or absence of the AMF (Table 4 and 5).

Table 5: Fresh and dry matter content with and without AMF in the plant and tubers of potato plant var. TPS

	Shoot fresh		Shoot dry		Root fresh		Root dry)		Tuber fresh	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
Weight g/plant										
20	1.52±0.23^{e}	1.46±0.24^{f}	0.10±0.01^{e}	0.09±0.01^{e}	1.10±0.08^{f}	1.23±0.10^{f}	0.07±0.01^{c}	0.07±0.01^{c}	0.00±0.00^{f}	0.00±0.00^{f}
40	3.28±0.24^{e}	3.28±0.32^{e}	0.26±0.01^{d}	0.29±0.01^{d}	1.86±0.12^{e}	2.24±0.20^{d}	0.17±0.01^{c}	0.23±0.01^{c}	0.00±0.00^{f}	2.17±0.12^{e}
60	5.28±0.32^{d}	5.84±0.22^{c}	0.47±0.02^{c}	0.59±0.02^{c}	3.56±0.32^{c}	3.68±0.14^{c}	0.40±0.02^{b}	0.45±0.02^{b}	5.02±0.32^{d}	6.02±0.62^{c}
80	8.97±0.48^{b}	9.86±0.42^{a}	0.81±0.04^{b}	1.01±0.04^{a}	5.42±0.28^{b}	5.73±0.32^{a}	0.77±0.02^{a}	0.38±0.02^{a}	9.44±0.86^{b}	11.03±0.86^{a}
LSD value		0.4709		0.0547		0.2844		0.0547		0.567

	Tuber dry		Total fresh		Total dry		Total plant fresh weight/dry weight ratio	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
Weight g/plant								
20	0.00±0.00^{f}	0.00±0.00^{f}	2.62±0.14^{g}	2.69±0.22^{g}	0.17±0.02^{f}	0.16±0.01^{f}	6.84±0.36^{g}	5.94±0.54^{f}
40	0.00±0.00^{f}	0.22±0.03^{e}	5.14±0.14^{f}	7.69±0.30^{e}	0.43±0.02^{f}	0.74±0.02^{e}	8.36±0.62^{e}	9.62±0.48^{d}
60	0.67±0.03^{d}	0.87±0.04^{c}	13.86±1.06^{d}	15.54±1.24^{c}	1.54±0.14^{d}	1.91±0.14^{c}	11.11±0.96^{c}	12.29±0.68^{bc}
80	1.53±0.14^{b}	1.96±0.14^{a}	22.83±1.68^{b}	26.62±2.14^{a}	3.03±0.12^{b}	3.74±0.24^{a}	13.27±1.06^{b}	14.04±0.98^{a}
LSD value	0.0774		1.339		0.1341		0.8464	

Different superscripted letters over standard error denotes significance in difference (factorial ANNOVA followed by Duncan Multiple Range test p<0.05)

Table 6: Chlorophyll fractions and their content in the potato plant var. Jyoti with and without the presence of AMF

	Chlorophyll a (mg/g)		Chlorophyll b (mg/g)		Total chlorophyll (mg/g)	
Days	-AMF	+AMF	-AMF	+AMF	-AMF	+AMF
20	0.124±0.01^{e}	0.124±0.02^{ed}	0.058±0.02^{a}	0.060±0.01^{a}	0.182±0.03^{d}	0.188±0.01^{d}
40	0.156±0.02^{d}	0.186±0.01^{c}	0.084±0.04^{a}	0.093±0.01^{a}	0.252±0.04^{c}	0.292±0.02^{c}
60	0.269±0.01^{b}	0.308±0.03^{a}	0.134±0.02^{a}	0.151±0.06^{a}	0.428±0.03^{b}	0.471±0.04^{ab}
80	0.286±0.02^{b}	0.324±0.03^{a}	0.138±0.02^{a}	0.156±0.04^{a}	0.438±0.02^{b}	0.492±0.02^{a}
LSd	0.017		0.3238		0.0547	

Different superscripted letters over standard error denotes significance in difference (factorial ANNOVA followed by Duncan Multiple Range test p<0.05)

Table 7: Chlorophyll fractions and their content in the potato plant var. TPS with and without the presence of AMF

	Chlorophyll a (mg/g)		Chlorophyll b (mg/g)		Total chlorophyll (mg/g)	
Days	- AMF	+AMF	- AMF	+AMF	- AMF	+AMF
20	0.071±0.01^{d}	0.052±0.01^{d}	0.035±0.01^{d}	0.038±0.01^{d}	0.113±0.02^{d}	0.108±0.01^{d}
40	0.072±0.01^{d}	0.121±0.02^{c}	0.062±0.01^{c}	0.082±0.02^{b}	0.154±0.02^{c}	0.194±0.02^{c}
60	0.155±0.02^{b}	0.205±0.02^{a}	0.096±0.02^{b}	0.123±0.02^{a}	0.248±0.01^{b}	0.342±0.02^{ab}
80	0.160±0.02^{b}	0.218±0.01^{a}	0.098±0.01^{b}	0.130±0.01^{a}	0.264±0.03^{b}	0.354±0.03^{a}
LSD value	0.0173		0.0173		0.0547	

Different superscripted letters over standard error denotes significance in difference (factorial ANNOVA followed by Duncan Multiple Range test p<0.05)

Chl a, Chl b and total chlorophyll content in potato plant var. Jyoti show continues increments from the seedling stage till 60 days and then smoothens at the 80 day stage, both in their respective controls and also the AMF inoculated ones. Chl a content at every stage is higher in amounts than the Chl b. The increase in various fractions and their levels at every stage of sampling are significant and their leveling off from 60 days onwards is also slightly significant (Table 6). As far as a, b and total chlorophyll content is concerned the var. TPS which is seed propagated broadly show trends wise similar to var. Jyoti (Table 7). The Chlorophyll a and b contents are at every stage lower in var. TPS than the var. Jyoti, therefore total chlorophyll content at every stage is also significantly lower at every stage. However, also at 20 days sampling stage the var. TPS shows a lower Chl a and b and total contents in the AMF inoculated seedlings with their respective controls, which in any case proved statistically insignificant in comparison to both between the two varieties as well as within the varieties (Table 6 and 7).

DISCUSSION

The present study has been undertaken with a sole view that after a large perusal of literature, work on the potato plants growth and development *vis a vis* mycorrhizal relationship is at the most scattered and variously different. As far as AMF symbiosis is concerned, the metabolite mobilization and metabolism in crops and other plants has been a subject of interest for many workers (Van der Heijden *et al*., 2006; Smith and Smith, 2011; Smith and Smith, 2012; Lehmann *et al*., 2014; Rillig *et al*., 2014). Though there is sizable amount of referral material available on various such studies yet there seems to be none available on the modified or storage underground stem systems. Moreover, it is felt that the overall work available pertains predominantly to the shoot or above ground parts of commercial importance dependent on shoot vis., a vis their relationship with the mycorrhizal presence or absence in their underground root part. Therefore, there seems a meager attempt made to study the growth and development changes of the underground stem itself, more so, when a modified stem system becomes mycorrhizic.

Although, AMF increased the number of tubers produced in Jyoti variety significantly, it increased shoot fresh weight and root dry weight in both the cultivars. Furthermore, in Jyoti, inoculation with AMF produced higher tuber and root fresh and dry weights than those not inoculated with AMF. These results suggest a kind of compatibility between potato cultivars and AM fungi. Such compatibility between AMF fungi and host plant was previously observed in other plants also such as onion (Shuab *et al*., 2014) and soybean and maize cultivars (Khalil *et al*., 1994). Earlier too it has been reported that underground stem propagules show AMF colonization as Taber and Trape (1982) reported for the first time the presence of AMF in the vascular system of rhizomatous tissue and scale like leaves of ginger (*Zingiber officinale*) and later was reported in the tubers of *Colocasia esculanta* by Bhat and Kaveriappa (1997), the tubers of *Gloriosa superba* by Khade and Rodrigues (2003) and corms of saffron (Lone, 2014).

Hyphae, arbuscules, vesicles were seen in the roots of Jyoti variety and hyphae and arbuscules in the TPS variety. It is well established that during mycorrhiza formation, the AMF undergoes several developmental stages (Buee *et al*., 2000). In asymbiotic stage, spores germinate and AMF show limited hyphal development in the absence of developed rhizal system both morphologically and metabolically. Once the roots mature and produce root exudates with advanced plant growth they switched to presymbiotic growth stage showing extensive hyphal branching. Subsequently fungus contacts the matured root surface followed by hyphal penetration of the root epidermis and colonisation of the root cortex tissue. This model of Smith and Read (1997) may be very close in explaining the root colonisation pattern.

Depending on the individual AMF and soil conditions many plant species show large positive growth response to AMF colonisation (Cordier *et al*., 1998). Both potato plant varieties are highly responsive to several AM Fungi which tend to associate with potato roots and later peel to improved plant growth and nutrient uptake. Sharma and Adholeya (2000) too have shown that AMF can significantly increase bulb diameter, bulb yield, shoot dry weights and the shoot phosphorous content. These observations presented are in agreement to the present observations.

The compatibility of the mycorrhizal fungus with potato plants may be of particular importance because they often form very weak root colonisation under field conditions (Ocampo *et al*., 1980). In this study the mycorrhizal colonisation of potatoes in this study was 68.56 percent in Jyoti variety and 47.86% in TPS. Swaminathan and Verma (1979) reported up to 72% and in another experiment which was performed with two cultivars of potato namely Karin and Krista in presence of *G. etunicatum* reported 18.9-22.4 and 8.1-19.4% respectively (Vosatka and Gryndler, 2000). It

is well known that the extent of colonisation of host roots by symbiotic fungi does not necessarily correlate with their benefits to the plant, as it was shown by Plenchette *et al.* (1982) in experiments with strawberry and some other plants under inert substrates.

As potato plants are not although known for high colonisation levels, yet even trace levels of 0.4% colonisation are reported to enhance growth (Niemira *et al*., 1995). In present work, the best mycorrhizal colonisation was observed in Jyoti inoculated with AMF depicting its compatibility with the variety. Higher colonisation of Jyoti with AMF and its higher dry matter of shoot in comparison to TPS shows that there is a correlation between colonisation and shoot dry matter. This may be explained by other qualitative characteristic of this cultivar. Potato plant during and at the end of growth transfers photosynthates to the subground parts and develops tuberization (Yao *et al*., 2002). The increase in shoot fresh and dry weight as here in both the varieties has been similarly reported by Vosatka and Gryndler (2000) by using the *G. etunicatum* and *G. intraradices* on two local cultivars of potato. There was a marked difference in dry weight between inoculated and uninoculated plants and especially after tuber starts attaining full growth. The dry matter of shoot becomes uniform or starts diminishing in both inoculated Jyoti and TPS varieties. This can be attributed to major translocation of assimilates towards roots and tubers acting as sink. This is to some extent substantiated by higher starch and reducing sugar contents than their comparable non-AMF potato plants. TPS consistently shows lower values than the Jyoti. This may be that the type of propagation as tuber and/or seed works as a factor. However, there is a contradictory report too which says that the extent of colonisation of host plant by AMF doesn't necessary correlate with their benefit to the plant (Plenchette *et al*., 1982). McArthur and Knowles (1993) in an attempt to evaluate the influence of AMF on the response of potato to phosphorous deficiency reported that dry shoot weight of plant in presence of *G. fasciculatum* was higher at 54 days of growth and decreased after 63 days. Something similar has been observed in present study too that after 60 days of seedling emergence there is diminished dry weight in shoot in Jyoti and TPS varieties. What is interesting is that percent increase of dry matter in the tuber coincides with the decreasing of dry matter of shoots which further justifies that there might be transferring of carbohydrates to sink-a tuber. Karam *et al*. (2009) concluded that mycorrhizal fungi symbiosis played a role in transferring carbohydrates from source to tubers through source-sink relationship wherein too AMF treatments had higher dry matter in tuber than control. Once again tuber propagated plant seems scoring better over the seed propagated ones.

The inoculation of AMF significantly initiated and stimulated production of tubers. Such promoting effect of AMF on potato tuber initiation was observed previously too (Graham *et al*., 1976; Niemira *et al*., 1995). Considering that tuber initiation is hormonally mediated (Ewing, 1995) it may be that in present study too AMF affected hormone balance in potato plants, leading to increased initiation and production of tubers. It will be genuine to consider that the involvement of other mechanisms, such as morpho-physiological or biochemical too may play their roles. Beneficial effects of AMF inoculation on potato growth, yield which were observed in this study were despite relatively low level of root colonisation. This is validly explainable on the basis of the observations of Dugassa *et al*. (1996) who have said that the influence of AMF symbiosis on plant health depends more on host plant than on AMF fungal colonisation level.

Mycorrhizal plants have been reported to have significantly higher root length, projected area, surface area and volume than non mycorrhizal plants (Wu *et al*., 2010). The observations here are in complete agreement with these reports. In the present study also the potato plants inoculated with a mixture of the species of *G. intraradices* and *G. mosseae* an AMF, showed elevated growth

characteristics of fresh and dry matter and also the potato root length and root diameter in comparison to those not infected with AMF. Al-Karaki and Clark (1999) indicated that shoot dry matter and root dry matter were higher for mycorrhizal infected wheat plants than non-infected plants which were ascribed to an already established phenomenon of higher Phosphorus (P) uptake by AMF infected roots for the plants. The observation of prominence here is that the tuber propagated and AMF induced potato plants are many fold better performers than seed propagated plants in various aspects of growth and seem to be better adapted than the later one.

CONCLUSION

The present study pertains that AMF colonization improved positively the overall growth and development of both cultivars of potato plant. Chlorophyll content too was found higher in AMF inoculated than control. This study shows that AMF can increase growth and development parameters and therefore, increases the production of potato.

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