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Influence of Biotic and Abiotic Features on *Curcuma longa* L. Plantation under Tropical Condition

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Abstract: To evaluate the biotic and abiotic influences were estimated at one life cycle for months intervals in *Curcuma longa* L. plantations from August 2006 to March 2007. For considerations such as soil nutrients, growth patterns, phytochemical nature and population dynamics were analyzed to assess the biological and environmental influences. All the constraints had significant variations according to the month intervals. Each constraint was interlinked and influence by other biotic and abiotic factors. Organic carbon (OC) and organic matter (OM) played a vital role in the availability of other micronutrients with significant level in plant growth and yield. Phytochemicals of *C. longa* had positive and negative correlation with microbial population as well as with microbial products. The assessment of favorable period and factor to enhance the yield of turmeric is understood.

Key words: *Curcuma longa* · Seasonal variations · Growth and yield · Arbuscular mycorrhizal fungi · Glomalin · soil nutrients

INTRODUCTION

Curcuma longa L. (Turmeric) is a major spice crop originated in India and grown in various parts of the world like China, Indonesia, Jamaica, Haili and Peru. Turmeric is categorized under the Zingiberaceae family, extensively used as therapeutic agent for over 6000 years and in Ayurveda, Siddha and Unani medicinal systems [1]. Turmeric has a wide range of essential applications like food, pharmaceutical products, cosmetics and textile industries. As agriculture is concerned, it is indeed necessary to focus on plant growth, rhizosphere microorganisms and soil health. These factors are largely depending upon biological, chemical and physical features. Measuring these features could provide an overall picture of biotic and abiotic influences on the plant growth. Both biotic and abiotic factors are interdependent and influence the crop productivity. For long term sustainable agricultural productivity, the study of biotic and abiotic factors could help to attain the goal.

In the present study, a new and important factor included glomalin, which is produced by arbuscular mycorrhizal fungi (AMF) belonging to Glomaceae family. Glomalin is made up of two fractions namely, easily extractable glomalin (EEG) and total glomalin (TG). The protein has extended capabilities in increasing the soil fertility [2], permeability to air, better root development and higher microbial activity [3]. The assessment of seasonal patterns of glomalin may provide indirect measure of metabolic activities of AMF in relation to soil fertility, plant growth, phytochemistry and its quality aspects. At present, thorough understanding of the influence of abiotic and biotic factors and their interactions with agronomic practices on the growth of turmeric is necessitates to improve the yield of turmeric. Based on these observations, variations in soil nutrients and rhizosphere microorganisms between different seasons can be expected to significantly influence the growth and yield of turmeric. To develop the information on seasonal variations in turmeric growth, detailed profile of soil nutrients, status of rhizosphere microorganisms, phytomorphological and phytochemical natures were compared.

MATERIALS AND METHODS

Site Description and Sample Collection: The study was carried out at Gobichettipalayam, Erode district, Tamil

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Nadu, India where the turmeric cultivation is prevalent. The samples such as rhizosphere soil, root and rhizome were collected at every month intervals from August 2006 to March 2007, for assessing the seasonal patterns of turmeric plant. A pit was dug around the root zone of turmeric plant followed by the removal of surface soil. Rhizosphere soil samples were air dried whereas the root and rhizomes were washed thoroughly with tap water to remove adhering soil particles, rinsed with distilled water and stored at 4°C for further analysis.

pH: Ten gram of air dried rhizosphere soil was taken in a beaker and 100ml of water was added to make a suspension of 1:10 (w/v) dilution and the pH was determined with a digital pH meter (Systronics-335).

Electrical Conductivity: Ten gram of air dried rhizosphere soil was taken in a beaker and 100ml of water was added to make suspension of 1:10 (w/v) dilution and the electrical conductivity was measured with a digital electrical conductivity meter (DEC-1-USA).

Analysis of Soil Nutrients: The total nitrogen (N) and available phosphorus (P) were determined respectively by micro-kjeldahl and molybdenum blue methods [4]. Exchangeable K was extracted from the soil in ammonium acetate solution (pH 7) and measured with a digital flame photometer [4]. The organic carbon (OC) and organic matter (OM) present in the soil were estimated using rapid dichromate oxidation method [5]. The micronutrients such as Cu, Zn, Fe and Mn were estimated as DTPA soil test described [6].

Growth Parameters and Yield: The plant height, root length, shoot and root biomass and number of leaves present in each plant were recorded. The shoot dry weight and root dry weights were obtained from each sample by oven drying at 80°C to get a constant weight.

Analysis of Biochemical Status: The estimation of total chlorophyll in leaves was done following Witham's method [7]. The total carbohydrate and protein concentration was determined by anthrone and Lowry et al methods respectively [8, 9]. The concentrations of phenol content present in the tissues were analysed using sodium carbonate-folin phenol reagent [10]. Easily extractable glomalin (EEG) and Total Glomalin (TG) extractions were done from turmeric root and rhizosphere soil and quantified [11]. The quality of turmeric assessed by estimating curcumin (Cur) using spectrophotometric method [12].

Isolation and Enumeration of Microorganisms: The microorganisms such as bacteria, fungi and actinomycetes were isolated and enumerated to assess the population density by using standard microbiological techniques. The percentage of root length colonization was determined using tryphan blue method [13].

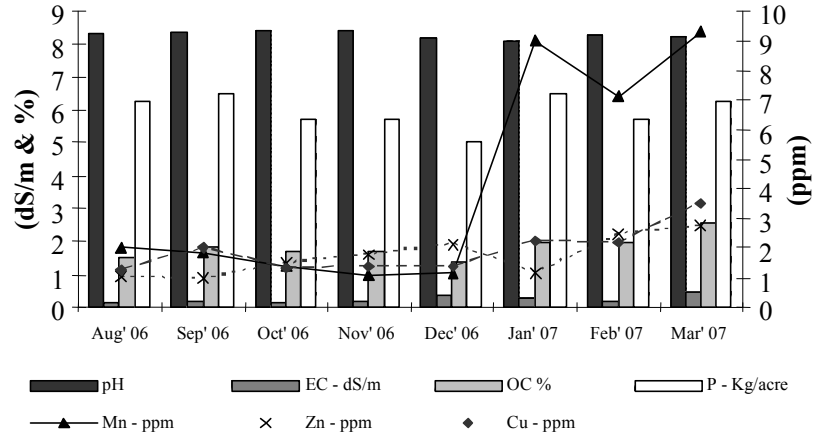
Statistical Analysis: All data were subjected to Analysis of variance (ANOVA) and the means separated using Duncan's Multiple Range Test (DMRT). Pearson's bivariate correlation analysis (SPSS version 10) was used to assess the relationships between biotic and abiotic parameters [14].

RESULTS AND DISCUSSION

Edaphic factors results (Fig 1 and 2) showed that the rhizosphere soils were alkaline in nature (8.1 and 8.45). EC was maximum during March 2007 and minimum during August and October 2007 (0.17-0.445). Organic carbon occurs in the form of organic matter. However, it is a key element for healthy soil [15]. Both OC and OM were maximum during March and minimum during December month. The OC of the soil were found to be higher in the death phase of the plant. This may be due to the sloughing of root cells in the rhizosphere region. The phosphate content of the rhizosphere soil fluctuates widely; the availability of phosphate content depends on various factors such as pH, moisture, rhizoexudates and the influence of PGPR etc., [16]. The fluctuations in the quantities of MN, Zn and Cu were observed throughout the study period. The OM content showed similar variations like OC content. Nitrogen and potassium levels expressed varying levels in the rhizosphere soil through out the life cycle of the turmeric plant. Fe levels showed increased values at the growing stages of the plant and decreased as the developmental stages of the rhizomes.

The population dynamics of turmeric rhizosphere soil were presented in Fig 3. The measurements of microbial population have been used to assess the effect of seasonal variations on soil fertility. Microorganisms play a key role in soil nutrient cycling [17]. The bacterial population was 44×10^{-5} CFU/g rhizosphere soil during March 2007 was maximum and minimum of 9×10^{-5} CFU/g during November 2006. The composition of rhizosphere bacterial community is likely to be influenced by the nature of the exudates released location of the root and soil type [18]. The fungal population was higher during the initial period of August, October and November, 2006 and lower during February, 2007, this may be due the

(Fig. 1)



(Fig. 2)

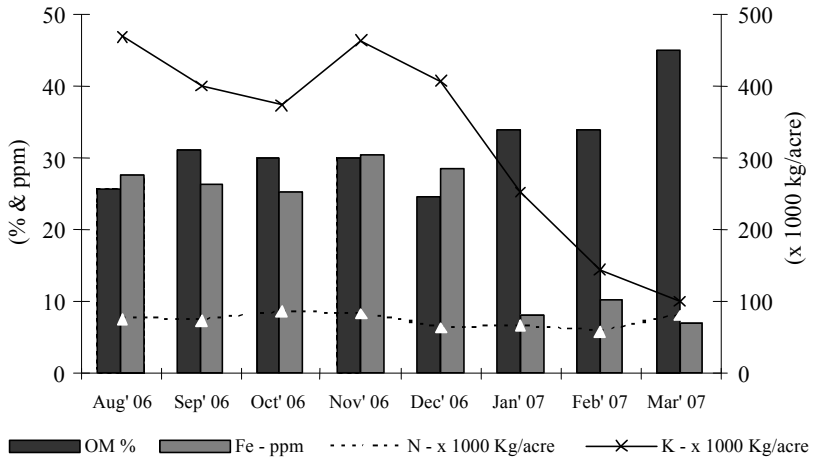
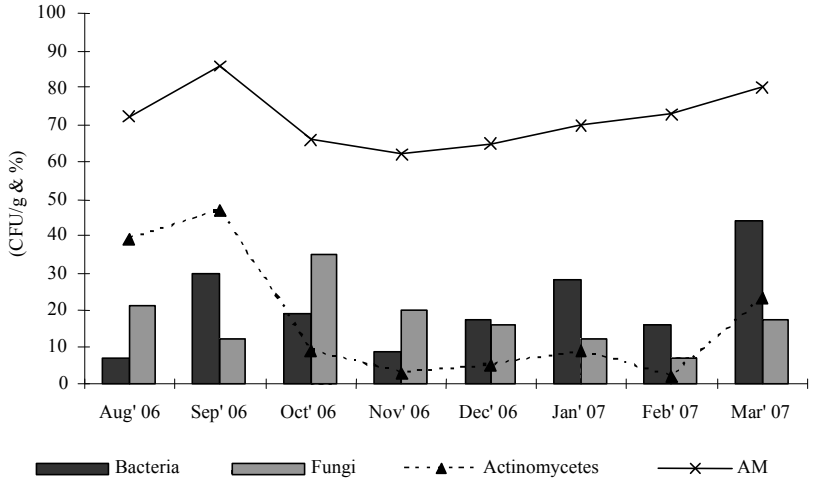


Fig. 1,2: Seasonal variations of soil nutrients in the rhizosphere of *C. longa* plantation under tropical condition



Units Expressed: Bacteria - 10^{-5} CFU/g , Fungi - 10^{-3} CFU/g, Actinomycetes - 10^{-5} CFU/g, AM - % of colonization

Fig. 3: Seasonal variations in the microbial population dynamics of rhizosphere soil of *C. longa* plantation under tropical condition

Table 1: Seasonal variations in growth and yield of *C. longa* L. under tropical condition

Month	No of leaves	Shoot height (cm)	Root length (cm)	Shoot biomass (g)	Root biomass (g)	Rhizome biomass (g)
Aug' 06	4.00^{a}	27.00^{a}	13.75^{a}	14.50^{a}	9.80^{a}	6.60^{a}
Sep' 06	5.00^{bc}	42.75^{b}	14.50^{b}	15.40^{a}	11.41^{b}	8.17^{a}
Oct' 06	7.00^{def}	67.40^{cde}	17.35^{cd}	24.05^{bc}	14.83^{cd}	32.09^{ab}
Nov' 06	8.00^{gh}	96.37^{fgh}	21.00^{efg}	54.93^{i}	15.81^{e}	63.55^{c}
Dec' 06	9.00^{i}	103.00^{h}	22.00^{gh}	51.10^{h}	18.15^{g}	138.00^{de}
Jan' 07	9.00^{i}	109.80^{i}	23.80^{i}	46.35^{efg}	20.28^{i}	208.56^{fg}
Feb' 07	8.00^{gh}	106.30^{i}	24.00^{i}	30.40^{d}	18.40^{gh}	222.50^{gh}
Mar' 07	7.00^{def}	104.80^{hi}	23.30^{h}	25.55^{c}	16.00^{f}	285.00^{hi}

*Means having a common letters are not significantly different.

Table 2: Seasonal variations of phytochemicals and glomalin in *C. longa* L. under tropical condition

Month	Chl a (mg/g)	Chl b (mg/g)	Chl (mg/g)	CH (mg/0.1g)	Prtn (mg/0.1g)	Phe (mg/100g)	EEG-S (mg/g)	EEG-R (mg/g)	TG-S (mg/g)	TG-R (mg/g)	Cur (g/100g)
Aug'06	0.52^{de}	0.21^{ab}	0.73^{c}	9.83^{a}	0.155^{a}	0.01^{a}	0.90^{i}	0.35^{a}	1.12^{b}	0.76^{a}	0^{a}
Sep'06	1.22^{j}	0.31^{cd}	1.52^{h}	12.17^{a}	0.316^{bc}	0.02^{a}	0.70^{ef}	0.53^{b}	1.80i	1.43^{e}	0^{a}
Oct'06	1.18^{hij}	0.42^{def}	1.60^{i}	34.26^{b}	0.380^{d}	0.09^{b}	0.55^{bc}	0.45^{b}	1.79^{i}	1.35^{de}	0^{a}
Nov'06	1.17^{hij}	0.61^{g}	1.78^{j}	76.49^{d}	0.523^{f}	0.15^{c}	0.87^{hi}	1.07^{f}	1.55^{fg}	2.17^{i}	0.039^{ab}
Dec'06	0.79^{fg}	0.41^{de}	1.20^{def}	75.80^{d}	0.660^{gh}	0.23^{de}	0.45^{a}	0.49^{b}	1.04^{a}	1.28^{bcd}	0.047^{c}
Jan'07	0.47^{cd}	0.85^{hij}	1.32^{g}	75.30^{d}	0.776^{i}	0.31^{f}	0.87^{hi}	1.17^{g}	1.73^{h}	2.19^{i}	0.050^{d}
Feb'07	0.22^{ab}	0.36^{cd}	0.58^{b}	46.00^{bc}	0.542^{f}	0.51^{ghi}	0.59^{d}	1.40^{hi}	1.44^{cde}	1.92^{g}	0.055^{e}
Mar'07	0^{a}	0^{a}	0^{a}	196.$^{10e-i}$	0.460^{e}	0.05^{ab}	0.75^{fg}	1.04^{e-f}	1.76^{i}	1.79^{f}	0.059^{f}

*Means having a common letters are not significantly different.

Chl a-Chlorophyll *a*; Chl b-Chlorophyll *b*; Chl-Total Chlorophyll; CH-Carbohydrate; Prtn-Protein; Phe-Phenol; EEG-S-Easily extractable soil glomalin; EEG-R- Easily extractable root glomalin; TG-S- Soil total glomalin; TG-R- Root total glomalin; Cur - Curcumin

influence of fluctuated temperature and soil moisture content that favor the fungal population growth. [19] investigated the seasonal influences on fungal community structure were relevant with our findings. Abundance of AM fungal hyphae fluctuated significantly within a growing season [20]. The present study clearly represents the period and factors that favor the microbial population and higher AMF root colonization in *C. longa*. The percentage of root colonization ranged between 62 and 86. During the present study period the variation in microbial colonization may be due to seasonal influence and several biotic and abiotic factors are responsible for such variations. [21] studied the seasonal variations in the AMF colonization and his results support our findings. Actinomycetes population had significant positive correlation with AMF colonization. From this it is evident that presence of symbiotic and non symbiotic microorganisms in the rhizosphere region influences the population and growth of other microorganisms. Since the effect of AM fungus on other microorganisms in the rhizosphere have been ascribed to have direct interaction as competition for inorganic nutrients between microorganisms [22], or to indirect influence on the quality and quantity of the plant root exudates [23].

The variations among the morphological parameters like number of leaves, shoot height, root length, biomass of shoot, root and rhizome had increased during its growth period upto seven months (February, 2006) and reduced at the harvested period of eighth month (March 2007). The results obtained were due to the arresting of biochemical pathways that supports the increase of hypotrophy. [24] studied the growth, quality and yield of *C. longa* under various environmental influences. However, there occurred a steady state raise in the rhizome biomass through out the study (Table 1). The Chl (*a*+*b*) content of *C. longa* leaves varied in every month intervals (Table 2). The Chl *a* content was high during October 2006 but the total Chl level was maximum during November 2006. The Chl level was nil when the plant attain the eighth month and it is an excellent symptom of plant death phase. The seasonal variations in the chlorophyll content in month intervals and plant species is in accordance with the results of [25]. The concentrations of phenol during the growth of turmeric vary every month intervals, minimum concentration of phenol was observed during initial growth phase of the plant and maximum during February 2007. The seasonal variations of phenolics

Table 3: Correlation coefficient of biotic and abiotic variations in *C. longa* L. under tropical condition

	Soil Nutrients				Growth yield						Biochemical							Microbial	
	OC	K	Fe	Mn	Zn	Lf No.	Plt Hgt	Sht Bio	Rt Bio	RhiBio	Chl *a*	TotalChl	CH	Ptn	Phe	TG-R	Cur	Acti	AM
OC																			
K	0.116																		
Fe	-0.804*	0.369																	
Mn	0.810*	-0.342	-0.988**																
Zn	0.541	-0.179	-0.442	0.412															
Lf No.	0.118	-0.375	-0.336	0.315	0.472														
Plt hgt	0.439	-0.371	-0.579	0.572	0.696	0.924**													
Sht Bio	-0.125	0.516	0.200	-0.301	-0.131	-0.012	-0.180												
Rt Bio	0.265	-0.492	-0.560	0.535	0.487	0.963**	0.945**	-.072											
Rhi Bio	0.727*	-0.428	-0.871**	0.873**	0.750*	0.598	0.832*	-0.325	0.738*										
Chl *a*	-0.599	0.419	0.802*	-0.827*	-0.562	-0.132	-0.421	0.422	-0.332	-0.817*									
Total Chl	-0.599	0.238	0.630	-0.645	-0.602	0.140	-0.185	0.348	-0.032	-0.659	0.920**								
CH	0.776*	0.140	-0.562	0.607	0.729*	0.406	0.655	-0.209	0.436	0.780*	-0.569	-0.557							
Ptn	0.159	-0.488	-0.435	0.435	0.326	0.954**	0.888**	-0.184	0.959**	0.629	-0.189	0.124	0.386						
Phe	0.036	-0.775*	-0.477	0.420	0.378	0.686	0.677	-0.180	0.776*	0.545	-0.357	-0.087	-0.018	0.676					
TG-R	0.523	-0.135	-0.528	0.539	0.338	0.686	0.774*	-0.201*	0.718*	0.570	-0.145	0.110	0.447	0.715*	0.532				
Cur	0.508	-0.470	-0.645	0.671	0.751*	0.765*	0.934**	-0.466-	0.824*	0.910**	-0.640	-0.437	0.724*	0.771*	0.632	0.684			
Acti	0.008	0.218	0.191	-0.156	-0.506	-0.888**	-0.804*	-0.204	-0.828*	-0.442	0.086	-0.146	-0.257	-0.732*	-0.701	-0.570	-0.624		
AM	0.492	-0.092	-0.342	0.338	-0.058	-0.543	-0.329	-0.303	-0.393	0.103	-0.247	-0.420	0.084	-0.374	-0.289	-0.138	-0.159	0.766*	

*. Correlation is significant at the 0.05 level (2 tailed) **. Correlation is significant at the 0.01 level (2 tailed)

OC - Organic carbon; K - Potassium; Fe - Iron; Mn - Manganese; Zn - Zinc; Plt Hgt - Plant height; Sht Bio - Shoot biomass Rt Bio - Root biomass; Rhi Bio - Rhizome biomass; Chl a - Chlorophyll *a*; Chl - Total chlorophyll; CH - Carbohydrate; Prtn - Protein; Phe - Phenol; TG-R- Root Total glomalin; Cur - Curcumin; Acti - Actinomycetes; AM - Arbuscular mycorrhizal fungi

compounds were emphasized previously [26]. In plants, the variation in phenol concentration is sensitive to a wide range of environmental and cultural factors [27]. The morphological characters and phytochemical compositions are proportional to each other that expresses externally when there is a liable change in the biochemical pathways. The total glomalin was maximum during October and November month. The usage of specialized extraction protocols for soils that revealed amounts up to several mg of proteins per gram of soil [11]. However, the concentrations of glomalin in soil are responsive to various factors such as type of soil, cultivation practice, water etc. [28]. Besides, the increased concentration of glomalin shows the soil as fertile one, which implies that there is an increased and active lifecycle of AM fungi. So far the information about the seasonal dynamics of AM fungi hyphal product (glomalin) are very few, these findings may be helpful to understand the lifecycle of AM fungi and its applications.

The correlation coefficient of biotic and abiotic features which influence the turmeric plant was presented in Table 3. The OC was significantly positive correlated with Mn (*r=0.810*), rhizome biomass (*r=0.727*) and carbohydrate (*r=0.776*) at P<0.05 level. But OC was negatively correlated with Fe (*r=-0.804*) for significant at 0.05 levels. However, Soil organic matter influences the availability of micronutrients to plants and it can able to bind tightly with Mn makes unavailable to plant uptake. In addition, it solubilize the insoluble Fe(III) oxides through soil redox potential effect and Fe solubilization is aided by microbial siderophores [2].

Exchangeable potassium content of soil expressed significantly negative correlation with phenol content of plant tissues (*r=-0.775*, P<0.05). Fe content was positively correlated with Chl *a* (*r=0.802*, P<0.05) with a significant value and it also negatively correlated with Mn (*r=-0.988*, P<0.01) and rhizome biomass (*r=-0.871*, P<0.01). Generally, Mn content is inversely proportional to Fe+ [29]. The reason is Fe reduces the valence of Mn to Mn^{2+} facilitating higher Mn uptake [30]. At the same time, Mn was significantly positive correlated with rhizome biomass (*r=0.873,* P<0.01) and negatively correlated with Chl *a* (*r=-0.827*, P<0.05). Zn had positive and significant correlation with rhizome biomass (*r=0.750*, P<0.05), carbohydrate (*r=0.729*, P<0.05) and curcumin (*r=0.751,* P<0.05). The soil nutrients such as OC, Mn, Fe, Zn took part in the yield of turmeric. It is evident with the statement that plant biomass is directly proportional to the soil nutrient availability [31]. Since the communication between root and shoot may be directly or indirectly mediated by the nutrients [32]. A vast range of biotic and abiotic features are responsible for the cycling, mineralization, mobilization and immobilization of soil nutrients [33].

The number of leaves present in *C. longa* had positively correlation with plant height (*r=0.924*, P<0.01), root biomass (*r=0.963*, P<0.01), protein content (*r=0.954*, P<0.01) and curcumin quantity (*r=0.751*, P<0.05) at significant level, but negative correlation with the population of rhizosphere soil actinomycetes (*r=-0.888*, P<0.01). Similarly plant height was positively correlated with root biomass (*r=0.945*, P<0.01), rhizome biomass (*r=0.832*, P<0.05), protein, root total glomalin and curcumin level. This inference is supported that the quantities of root mass, height of crop plants vary with plant and soil type and can be restricted because of physical and chemical impediments [18]. In turn, significant correlation among plant height, protein content, root total glomalin and curcumin were observed. Shoot biomass had negatively significant correlation with root total glomalin (*r=-0.201*, P<0.05). The root biomass had significantly positive correlation with rhizome biomass (*r=0.738*, P<0.05), protein (*r=0.959*, P<0.01), phenol (*r=0.776*, P<0.05), total glomalin (*r=0.718*, P<0.05) and curcumin (*r=0.824*, P<0.05). Root biomass showed negative significant correlation with rhizosphere actinomycetes population (*r=-0.828*, P<0.05). Rhizome biomass had positively significant correlation with carbohydrate (*r=0.780*, P<0.05) and curcumin (*r=0.910*, P<0.01). The broad range of correlation indicates the mycorrhizal association with plants improves the growth, secondary metabolites and quality of crop plants [34]. The Chl *a* had positively correlated with total Chl content and the results were significant (*r=0.920*, P<0.01). But the secondary product Chl *a* was negatively correlated with rhizome biomass. However, this observation was controversy with the demonstration that plant biomass have relationship with chlorophyll content and such type of variations may be influenced by other environmental factors [35].

From this study, the protein content of the *C. longa* were compared with the level of mycorrhizal proteins both in the soil and root as well as the bioactive component of *C. longa* i.e., curcumin. To our knowledge no such kind works had been published, this novel idea expresses the strength of mycorrhizal colonization, involvement of mycorrhizal proteins in the translocation of elements and improving the quality of yield. This is proved by another factor, the positive correlation occurred between glomalin, carbohydrate and curcumin at the level of P<0.01. These significant relation in the protein content in both roots and shoot emphasize the nutrient mobility was central to soil-plant interactions. It was demonstrated that nitrate move long distances whereas P move only short distances. Both nutrients act as key component for protein synthesis. Increase in the quality of crop plants by mycorrhizal inoculation is relevant with correlation between protein, glomalin and curcumin. Carbohydrate also significantly correlated with curcumin (*r=0.724*, P<0.05). The population of actinomycetes in the rhizosphere soil showed significant negative relationship with leaf number (*r=-0.888*) at the level of P<0.05. It also found to express significant negative correlation with plant height, root biomass and protein of the plant. The results obtained represent that actinomycetes population in the rhizosphere population does not support the growth of the plant. The metabolites produced by actinomycetes in the rhizosphere region may not possess the capability in inducing the plant growth or there may be several other factors which interferes the plant growth promoting effect of actinomycetes metabolites.

The present investigation stated that growth parameters were interlinked and associated with phytochemical compounds and rhizosphere microbial community. However the biochemical compounds act as signaling molecules that help the root-shoot, root microbe interactions [15, 36]. The seasonal variations of both biotic and abiotic features involve in the turmeric yield is explained and profile has made by relating all other aspects. This would be helpful to frame nutritional source and biological management strategies could be carried out accordingly to improve the crop yield and to attain sustainable agriculture.

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