studies on growth and distribution of citrus roots

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~e present study was conducted during twoconsecutive seasons, 1985 and 1986 at the Facultyof Agriculture Moshtohor, Zagazig University,Kalubia Governorate.Bio_fertilization studies have called theattention toward soil microorganisms as a goodalternative to chemical fertilization because ofits cheep costs and it causes no pollution. Mycorrhizalfungi is considered as one of the biefertilizerswhich live between plant rootS.Consequently, this investigation was carriedout, to study the effect of endomycorrhizal fungiinoculation and phosphorus fertilization on soilproperties, infection and intensity, mycorrhizaldependency ratio (MDR) of rootstock, dry weight ofdifferent parts of seedlings, top/root ratio, rootgrowth and distribution, leaf and root mineralscontent, leaf chlorophyll and carotene contents,leaf sugars and stem total carbohydrates, leaf androot amino acids content, and leaf cyto~ininscontent of two citrus rootstocks.Two-year-old seedlings of two citrus rootstocks,i.e. Cleopatra mandarin and sour orange weretransplanted in woody boxes filled with clay loamsoil disinfected with 2% Formalin solution (2 Seedlingsper each box).The treatments used in this study involved I1. Boxes left untreated as control.2. Boxes fertilized with phosphorus at the rateof 5g P205 as superphosphate (control).3. Boxes unfertilized with P but the soil Wasinoculated with glEm~ m~££E£§rp~fungi.4. Boxes unfertilized with P but soil was inoculatedwith Glo.!!l~1..!§!!i~£~ fungi.5. Boxes fertilized with phosphorus at the rate of5g P205 as superphosphate and the soil Wasinoculated with g12m~.§m~££9~§EPus fungi.6. Boxes fertilized with phosphorus at the rate of5g P205 as superphosphate and the soil Wasinoculated with Q1Em~§ ~ustrale fungi.On the other hand, other set of seedlings wereplanted in 30 cm diameter clay pots treated withmycorrhizae and fertilized with phosphorus with thesame rate for boxes for the infection and intensi’t7stUdies.The obtained results could be summerized asfollows :5.1 IDfecUoD I1. Mycelium and arbuscules of mycorrhizaefuugi on roots of Cleopatra mandarin and sourorange started with low percentages in Mayfollowed by a gradual increase in July toreach the maximum (l~) in September. However,in both rootstocks vesicles percentages oncitrus roots were almost l~ in all samplingdates.2. Mycelium, vesicles, and arbuscules on rootsof control rootstocks used were nil.:3. In May and July, seedl~. inoculated withmycorrhizae fuugi and unfertilized with phosphorU8gave hip;herpercentages of myc.eliWl aDd arbusculeson their roots as compared to that of inoclllatedand fertilized ones.4. Generally, in all sapling dates, $ll0!!l1lSaustrw fwl8i was associated with higher percentagesof arbuscllllesthaD ’su’CPM 88&rocarplMlmycorrhi ••••1795.2. Intensity:1. Number of mycelium. vesicles. and arbusculeson roots of the two studied citrus rootstocksstarted with low numbers in May followed by anincrease in July and a sudden increase in September.2. Citrus seedlings inoculated with mycorrhizaeand unfertilized with phosphorus had roots withhigher number of mycelium. vesicles. and arbusculesas compared with those treated with mycorrhizaeand fertilized with phosnhorus.3. Glomus australe fungi caused a hip;her increasein number of vesicles and arbuscules onrootl or o1trua rootltocks aore thaD ~QlY’macrocarpus mycorrhizae. On the other hand,the effect of mycorrhizae species on ayc.li_number depended upon the rootstock Wled. Inthis respect, whUe GlomUS aLl!trW funsi weresuperior in increasing number of mycelium onroots of Cleopatra mandarin seedl1Dgs as coaparedto GlomW! macrocarpy!!. the picture waschanged to the opposite when lour oraus. s.84-1illgs were concerned.5.3. ~corrhizal dependency ratio (1IlJil) I1. Cleopatra mandarin dependecl51.ightly_on mycorrhizae than sour orange rootstock.2. QJ,0l!!!.l1 .9lacfocarplWf’UJ:l6iwas more effectiveon MDR of seedlings than the .Ql..£I!l.9!austral,!! fungi.3. Applying phosphorus to citrus seedlingsdecreased visually MDR as compared to

unfertilizedplants.1. Higher Values of dry weight parameterswere observed for sour orange seedlings ascompared to Cleopatra mandarin.2. Mycorrhizae fungi treatments increased cU7weight of different parts of seed.l1np:s and top/root ratio as compared to control plants •.ilO!!lW! lIacfocarpW! flUUl:iwas 1I0re prOlllis1ngin iDCreasi~ dr;y weights of whole seed.lilUl.,leaves, stem and roots than 'suQ!I,Y! ,,,,trw.Such reSQIt was not clearly noticed ror top/root ratio.3. Applying phosphorus only to citrus Seed-1111gscaused. s1gn1finant 1Dcreue ill cU7.weight of roots whereas other parameters ofdry weight used in this study were decreasedunder phosphorus fertilization.5.5. Boot growth :1. Cleopatra mandarin and sour orange seedlingsunfertilized with phosphorus and inoculatedwith lilolll,.mWa!crocarpus fungi gavehigher Values of root growth expressed asroot coefficient.2. Cleopatra mandarin seedlings gave general.Q'higher Values of root growth as cOlllparedto theanalogouS ones of sour orange rootstock.3. Generally as a Spec1tic effect of mycorrhizalfungi. Glomus austral, enhanced betterroot growth of citrus seedl~8 than GIO!i!iterooarpYi fun~i under the experimental 8011environment.4. Unfertilized seedlings with phosphorus8urpas8ed in their root growth the P fertUize4ones.5.6. Root distribution ,1. Cleopatra mandarin seedlings inoculatedWith GIOJllusaustraJ& fungi and unt'ertilizedwith phosphorus was preferable cOJllbinationfor encouraging root distribution of plantsamong the other treatments used whUe sourorange seedlings received phosphorus andtreated with GIOJllusmacrocarRB!! fungi surpassedall other treatments relDaTkably in thisrespect.2. Cleopatra mandarin plants had higher numberof 3-5 m.m. and 2-3 m.m. roots whereas sourorange seedlings were Superior in 1-2 m.m. rootsand total number of roots.3. Mycorrhizae fungi treatments increased s1g_n1ficantly root number of different diametersand total root number. In the same time, ~!,ymacrocarpy'! fungi wart more promising in increasingnumber of'1-2 m.m. and 3-5 a.m. roots.On the other hand, ~.Y§ ~.&U III¥corrhi••ef'ungi. encouraged developing of'2-3 m.m. rootsand total number of'roots.4. P unfertilized seedliDgs not only increasedroot number of different diameters but also thetotal number of roots than fertilized seedlings.5.? Lea:t1Il1neJ.'aclosntent :1. Generally 10weJ.'amounts of N and Ca and werehigher levels of K and Zn/existed in leavesof sour orange rootstock as compared with thoseof Cleopatra mandarin. No statistioidifferencebetween the two rootstocks used was observedconcerniDg leaf P and Mg contents.2. Mycorrhizae species raised up Leaf N. P, I,and Kg contents and decreased lea:t Oa and 2Qcontents in respect of contJ.'olplants. GlaRy!austrai§ fungi were more positive in stimulatingleaf p. K. and Mg contents than Gl!MlLlm!acJ.'ocarpusspec~e. The significant difference waslackiDg in case of leaf N and Oa contents.3. Phosphorus fertilizer eitheJ.'added for SOUl.'oJ.'aDgeOJ.'Cleopatra mandarin seedlings increasedlea:t p. K. and Oa contents and decJ.'easedlea:t _,JIg. and Zn l."els.5.8. Root minerals content I1. Control seedliDKs fertilized with phosphorushad roots with higher amounts of N and P andlower levels of K and Mgas coapared with unfertilizedcontrol plants. No clear trend or differencewas noticed in case of zn anrl Ca nutrients.2. Roots of sour or~e seedliDKs containedhigher amounts of N, K, Ca, Mg, and znthan those of Cleopatra mandarin seedliDKswhich were more rich in root P content.3. ~corrhizae fungi decreased root P, Ca, Mg,and zn contents and in the S8llletime increased JITand K levels as compared with non inoculatedseedlings (control). §lomus austrw flUlgi hadincreased root N and zn contents aDddecreased root P, K, Ca, and JIg levels. liosignificant difference was observed betweeothe two species of I117corrhiz.e in their effecton root minerals content.4. Phosphorus fertilization 1Dcreased JIT aDdPcontents of citrus rootstocks whilst it had noeffect on root K, Ca, Mg, and 2'.D since thedifference was small.5.9. Leaf chlorop~ll and carotene contents :1. Leaves of sour orange seed1iDP;scontainedhigher amounts of chlorop~ll (A) and totalchlorophyll and lower level of carotene inrespect of Cleopatra mandarin. Citrus sPecie.s had no statistical effect on leafchlorophyll (B).2. Mycorrhizae species used were promising inbuilding up more leaf chlorophyll and caroteneover the control. Meanwhile. G10ll1!laSustaale1'uIlll:ias comparedwith Glom!lSmacrocarpys decreasedleaf chlorophyll (A) and carotene whilstthey increased leaf chlorop~ll (B) and totalchloropb.vll. Such effect was not statistical17observed in case of leaf total chlorop~ll.3. ceedlings receiving phosphoru. were iD1'eriorin their leaf chlorop~ll and carotene contents.However, significant di1'1'ereaces werelacking whenleaf chlorop~ll (B) end carotenecontents were concerned.1865.10. Leaf susars and stem total carbohydrates :1. Sour orange seedlings had leaves withhigher amounts of non redu~and total susarsas iliellas stem total carbohydrates in respectof those of Cleopatra mandarin. LeafreducUg sugars of sour orange wereslightlyless than those of Cleopatra mandarin.2. ,@,omlas.!,!ustralf,u§ngi decreased significantlyleaf non-redu~ and total sugarsand slightly reducUlg susars than the control.3. Applying phosphorus to citrus plants induceda significant decrease in leaf non-reduciagsugars but it had no statistical effect on leafreduciJtgand total sugars as well as stem totalcarbohydrat es•5.11.Leaf nitrogen fractions :1. Leaves of Cleopatra mandarin seedlillgscontained higher amounts of soluble nitrogen,rest nitrogen, and ammonium nitrogen and lowerlevel of crystalloid nitrogen as compared withthose of sour orange. Citrus rootstocks had nostatistical effect on leaf nitrate content.2. Comparing £llomus!!§.crocarpusfungi treatmentwith the control, it significantly decreasedleaf crystalloid nitrogen and nitrate contentsas well as increased leaf rest nitrogen butwithout any effect on leaf soluble nitrogenand ammonium nitrogen contents. Glomus aus~.!fungi, from other hand, increased leafcrystalloid nitrogen and ammonium nitro~en anddecreased leaf rest nitrogen and nitrate contents.3. Phosphorus application decreased leaf solublenitrogen, rest nitrogen and nitrate contents andincreased leaf ammonium nitrogen. Phosphorus,by all means, had no effect on leaf CJ:,Ystall01dnitrop;en.5.12 Boot nitrogen fract10DB :1. Roots of Sour orange seedlinp;swere morerich in soluble nitro~en and poor in nitratecontent in respect of Cleopatra mandarin. Novisual difference was observed between sourorange and Cleopatra mandarin regarding rootcrystalloid nitrogen, rest nitr08en, BDdemaonium nitrogen confents.2.)fycorrhiaae 1'uDgifluctuated in their e1'fec_on root nitrogen fractions content. In thisconcern, Glomus australe fungi succeededin increasing root soluble nitrogen, cr,ystal10idnitrogen, rest nitrogen, and nitratecontents whereas ~s macrocarRU' fungiraised up only root rest nitrogen, and nitratecontents. Both two mycorrhizae fungi used inthis study failed to increase root ammoniumnitrogen over the control.3. Adding phosnhorus to citrus seedlinp;s increasedonly root nitrate content whilst it decreasedthe other root nitrogen tractions determinedin this study.5.13 Leaf and root •.ino acids conten' I1. Cleopatra mandarin seedlings generally gavehill:hervalues of leaf and root _inc acids contentthan those of sour orange.2. I' unfertilized but mycorrhisae inoculatedplants of both rootstocks were hisher in theirvalues of leaf •.ino acids content than correspondinguni.noculated ones.1he opposite w•• t~Qewhan ~corrhi..u fllDgi and fertilized seedlings werecaapared with fertilized control ones.3. Glomusaustral,!! fu.ogi resulted in anincrease in leaf amino acids content thanGlomusmacroc~ mycorrhizae.4. Leucine and Isoleucine, Proline, andHydro.xyProline existed in citrus leaves withhigher amounts whereas leaf Valine, T,yrosine,Threonine, Glysine, Arginine, and Histidineshowedan opposite trend.5. Cleopatra mandarin and sour orange seedli.ogs fertilized with phoRohorus and inoculatedwith Glom~ macrocarpul fungi gave higher valuesof root amino acids content than those unfertilizedand inoculated with the seme mycorrhizaefungi.6. M3'corrhizae fungi treatments increased rootamino acids level as COJllparedto non-inoculatedcontrol plants. At all "'ents, GJ.oags aac£OCarpgfungi were more promisi.og in increasiug rootemino acids content than GleaM austrMe.7. !pplyiDg phosphorus to citrus seedlingsinduced a general inerease in root -.ino acidscontent as coapared with unfertiliZed and. !lbatwas true in either inoculated or non-inoculatedplants.8. Leucine and Isoleucine. Proline. andUydroxy Proline were hi~her in roots of citrusseedli~s wnilst Valine. ~hreonine. Glysine.Arginine. and Histidine were inferior in rootsof citrus rootstocks studied in this research.5.14 Leaf cytokiniDa content I1. .Applying phosphorus to control seedliJ:Igsdecreased leaf cytokinins content in June butin September the effect was changed to thereverse. Such result was more clear in caseof Cleopatra mandarin rootstock.2. Inoculati~ P unfertilized plants WithmycDrrhizae increased leaf cytokinins contentin both June and September samples. In sourorange rootstock such effect was not so 8tro~as in Cleopatra mAndarin.,. jpplyinl ph08phoru8 to inoclllatecl8Hdlqaof both citru. rootstocks iDCre ••eclleat c71iokininscontent in Sept_ber as coapered with Punfertilized and inoculated plants. The picturewas chaDKedto the reverse in June.4. GlomuslIlacrocarpus fungi raised up leaftotal cytokinins content in June in respectof GlolllQsaustrale fungi. The opposite wasgenerally true whenleaves were sampled inSeptelilber.5. Leaf total cytokinins content was highestin June then decreased r6lllarkably in Sept6lllber.5.15 8011 propertle. I1. At the termination of the experillent, analysisof soil showedthat phosphorWifertUizationfor Cleopatra lIlandarin resulted in an increasein available N and a.decrease in F, K, Ca, and1IIg nutrients. In the case of sour orange, pho-8~horus fertilization decreased 80il availableN, P, and Ca contents and. increased avaUableK.2. Adding G1Cll!RlIulascrocarpWlfuugi for unfertilizedsoil of Cleopatra IIlandarin 1J:Iducedanincrease in its contents of avaUable 1f, P, andCa and a decrease in soU K 8Dd Irs levels. Inaddition. Glomus aqstrale was superior inincreasing soil available nutrients discardingP. Moreover. inoculating unfertilized soil ofsour orange with mycorrhizae generally increasedavailable macro-nutrients in the soil.3· Soil fertilized with phospho~us and treatedwith Q!omu§ mac~carpus fungi contained higherlevels of available N. p. and Ca.Similarly. m.~ aqstral! mycorrhizaecaused an increase in soil available N. p.and Ca contents and a decrease in soil K level.mandarin and Sour orangeGenerally. inoculation of Cleopatra/ seedlingsgrown in stere1ized soil with endomycorrhizal fungienhanced vegetative growth. root growth and distribution.and Chemical constituents of bo~h Cleopatramandarin and sour orange seedl1nP:s. lPnrthemore •.9.lC!llH! australe fungi and no phosnhorus fertilizationfor Cleopatra mandarin seedlings and Gl.~,acrocarpus fungi and no phosnhorus fertilizationfor sour orange plants gave the best results of seedlingsgrowth.Therefore. Gl.qs maerocarPUI or .§l-BI llWIYWfun~i could be used as bio-fertilization for citrusseedlings in fuaigated clay loam soil for producinggood seedlings free from diseases.