Use of Bacterial Biofertilizers in Tomato(*Solanum lycopersicum* L.) Cultivation

ABSTRACT

Certain species of *Bacillus* are consideredrhizobacteriathatpromote plant growth, inhibit the growth of plant pathogens and deleteriousrhizosphericmicroorganisms. The aim of thisstudywas to determine the stimulatoryeffect of *Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 on the growth and diseasereduction of tomato plants in Côte d'Ivoire. In this respect, threesubstratesconsisting of soilonly, sawdustonly and a mixture of soil and sawdustwereinoculatedwith the twobacteria, thenleft to ferment for twenty-four (24) hours. The biofertilizersobtainedafter fermentation wereused to assesstheireffects on the development of pottedtomatoes. Growthparameters, infection rate and mortality rate of tomato plants weremeasuredregularlyduring 6 weeks of cultivation. A search for tomatopathogenic fungi wascarried out to demonstrate the efficacy of the twobiofertilizers on plant health. The resultsobtainedshowedthat*Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 had a positive impact on plant growth of tomato plants grown. Infection and mortality rates of 0% wereobserved for tomato plants grown on the threesubstratesinoculatedwiththesetwobacteria. No pathogenic fungi wereisolatedfrom the organs of tomato plants grown on the threesubstratesfermentedwith the bacteria. However, on untreated control plants, a variety of pathogenic fungi, namely*Fusarium*sp, *Phytophtora*sp, *Cladosporium*sp, *Rhizoctonia*sp, *Colletotrichum*sp, *Penicillium*sp, *Rhizopus*sp and *Trichoderma*spwereobserved. However, the *Bacillus subtilis* KBM1 treatmentstood out from*Bacillus venezensis* KBM1 with the best results for the growthparametersmeasured. In view of theseresults, thesetwobacteriacouldbeused to produce an effective biofertilizer for tomato cultivation in Côte d'Ivoire.

Keywords:Tomato, fungaldisease, bacterialbiofertilizer, Côte d'Ivoire.

1. INTRODUCTION

Tomatoes*(Solanum lycopersicum*L.) are annual plants belonging to the *Solanaceae*family[1]. It is the mostwidelyconsumedvegetableafterpotatoes and the world's second most important foodresourceaftercereals.This plant isadapted to a widevariety of growing conditions, in open fields or greenhouses[2]**.**Witharound 187 million tonnes producedworldwidein 2021, Africaaccounted for 20 million tonnes of world production, and tomato production in Côte d'Ivoire wasestimated at 40,306 tonnes, with a yield of 10293.4 kg per hectare [3]. Despitethis production rate, yields are stilllowthan the world'sleadingproducer (China) and Africa'sleadingproducer (Egypt), which are respectively 65 million tonnes and 6.7 million tonnes [3]. One of the causes of thislowyieldis the soil'slack of organicmatter and phosphorusphosphorus, which are the main constraints to intensified production [4]. In addition, the use of mineral or chemicalfertilizer formulas that are not adapted to marketgardening to marketgardencrops leads to unbalanced inputs and, in the long term, to the accumulation of certain heavymetals in the soil[5]. Indeed, numerousstudies have shown the long-termnegativeeffects of mineralfertilizers on soilfertilitynotablythroughtheiracidifyingeffect on the soil[6,7]. Growersalso have to contendwithvariousdiseasesthatattacktheircrops. Frommany cash crops are ravaged by parasites, the mostnotorious of which are phytopathogenic fungi. The chemicalproductscurrentlyused to combat phytopathogenic fungi againstphytopathogenic fungi have their drawbacks. Most of them are toxic to userswho come into contact with the preservative. This justifies the researchcurrentlybeingcarried out in thisfield, with the aim of developingmethodsthat are lessharmful to the environment. As a resultagainstthese plant-pathogenicmolds, through the use of microorganismsthatproduce substances with an antifungaleffect. Biologicalis a verypromising alternative, given the naturalubiquity of microbiological of microbiological agents in ecosystems. The latter are characterized by theirvariety, ease of dissemination, specificity of action and persistence in the environment[8].*Bacillus* species are considered to be important plant growth-promotingrhizobacteria (PGPR), producing a wide range of biologically active secondarymetabolitespotentiallyinhibit the growth of plant pathogens and rhizobacteria and deleteriousrhizosphericmicroorganisms[9]can survive exposure, heat and desiccation, and theirability to beability to beformulatedinto stable dry powderswith a long shelf life [10].Moreover, becausethisgenusisalready a commoninhabitant of the microflora of plant roots, biological control agents based on *Bacillus* spores have little or no effect on the composition of

microbialcommunities in plant roots[11]. The bacterialfertilizersused in thisstudy are strains of *Bacillus subtilis*study are strains of *Bacillus subtilis*KBM1and *Bacillus venezensis*KBM1 isolatedfrom the mangorhizosphere in Côte d'Ivoire. The aim of the studywas to contribute to the improvement of tomatoproductivity in Côte d'Ivoire through the use of microbialorganicfertilizers.

2. MATERIAL ANDMETHODS

2.1 Material

The materialused in thisstudyconsisted, on the one hand, of tomatoseed of variety UC 82 B developed by Green Seeds. and on the other, the biofertilizers*Bacillus subtilis* KBM1 and *Bacillus velezensis*KBM1 isolatedfrom the rhizosphere of mangotrees in Côte d'Ivoire Ivoire and preserved in cryotubes in a freezer (-80°C). The substratesused in thisstudyweresoil and sawdust.

2.2 Methods

2.2.1 Preparation of the study plot

The soil in the plots waspreparedbefore the varioustreatmentswereapplied. This preparationconsisted in cleaning a plot 5m long and 3m wide and weeding the surface. The sparseshrubswerethenfelled, and the trunks and branches werecollected and disposed of in a landfill and discardedoutside the plot boundariesusing a wheelbarrow. Following this, tarpaulinswere spread out along thethe plot, whichwasthendelimited by Chinesebamboostalks and coveredwith mosquito netting(Fig. 1).

Fig. 1. Study plot

2.2.2 Setting up the nursery

Sowingwascarried out in a 77-cell plate, withthreecells for each culture bag, in order to select the

mostdevelopedseedling at the end of the nursery for transplanting. One *Solanum lycopersicum*L tomatoseed of the UC 82 B varietywassown in eachalveolus at a depth of around one centimetre, followed by watering. Sowingwascarried out in rows at distances of 5 to 10 cm. Wateringwascarried out twice a day, once in the morning and once in the evening. The honeycomb plates werethenplacedunder a shadecanopy and coveredwithstraw for up to 21 days(Fig. 2).

Fig.2. Seeding

2.2.3 Biofertilizer production

One hundred (100) mL of yeastextract-peptone glucose (YPG) medium in two Erlenmeyer flaskswereinoculatedwith a 48-hour-old culture. Thesepre-cultures wereincubated at 30°C for 12 h with 105 rpm agitation. The pre-cultures wereused to inoculate 2 L of YPG medium contained in two 1 L Erlenmeyer flasks. Two 1 L YPG media for eachstrain in the Erlenmeyer flaskswereincubatedwithpre-cultures of *Bacillus subtilis* KBM1 and *Bacillus venezensis*KBM1. Media werestored at 30°C with 150 rpm agitation for 72 h, and biofertilizerswerecollected in sterile jars.

2.2.4 Cultivation design

The experimental design wasbased on the Fischer system[12]. A quantity of 100 mL of bacterialbiofertilizerwasadded to 4.5 kg of eachsubstrate. Thus, the treatmentscarried out in thisstudy are represented by treatment T0 whichwas control 1 soilwithoutbiofertilizer, treatment T0' was control 2 containingsoil mixed withsawdustwithoutbiofertilizer, treatment T0'' was control 3 and containedsawdustwithoutbiofertilizer, treatment T1 containedsoil and 100 mLbiofertilizer of *Bacillus subtilis* KBM1, treatment T2 containedsoil mixed withsawdust and 100 mL of *Bacillus subtilis* KBM1 biofertilizer, and treatment T3 containedsawdust and 100 mL*Bacillus subtilis* KBM1biofertilizer. The sametreatmentswerecarried out for the *Bacillus venezensis*KBM1strain. Treatmentswere run in threereplicates. Eachreplicateisrepresented by an agronomicbags. The agronomicbags set up for the trial are 50 cm apart. The experimentwascarried out in 27 agronomicbags. Thesewerearrangedrandomly in each block, under a greenhouse 5 m long and 3 m wide, i.e a surface area of 15m^2.

2.2.5 Plant transplanting

Once the system had been set up, the substrateswereinoculatedwith the strains, afterwhich the plants weretransplantedinto the varioussubstratesthen. After germination of the seeds, the wereselected for cultivation. A total of 54 seedlingsweretransplanted, at a rate of 2 seedlings per agronomic bag. Transplantingtook place on the 21st dayaftersowing. Theseseedlings, with 4 to 6 fullyexpandedleaves, werewereremovedfrom the honeycomb plates and transplantedinto the variousagronomicbags(Fig.3).

Fig.3.Transplanting plants.

2.2.6 Measurement of agronomicparameters

Parametersmeasuredincluded plant size, number of leaves, infection rate and mortality rate of tomato plants.Plant size, corresponding to stem length, wasmeasuredusing a tapemeasure, while the number of leaveswascountedmanuallyeverythreedaysfor 6 weeks. The infection rate expresses the percentage of diseased plants in relation to the total number of plants[13]. It wasdetermined once a week for 6 weeks, using the formula :

$$Infection\ rate(\%) = \frac{Total\ number\ deseased\ plants}{Total\ number\ of\ transplanted\ plants} \times 100$$

- As for the mortality rate, itwascalculatedaccording to the followingformula:

$$Mortality\ rate(\%) = \frac{Total\ number\ of\ dead\ plants}{Total\ number\ of\ transplanted\ plants} \times 100$$

2.2.7 Testing for tomatospoilagemoulds.

The direct contact isolation technique on PDA agar as describedby [14]wasused to test tomato plants for spoilagemoulds. Threealteredleaves, stems and rootswererandomlyselectedfromeachsample, thendisinfectedwith 2% bleach for 2 min to eliminateexogenousmicroflora, and rinsed 2 times withsteriledistilled water to removebleachresidues. Plant leaves, stems and roots are dried in steriletrays, thendisinfectedwith absorbent cottonsoakedin 70% ethanolprior to sampling. Three fragments of leaves, stems and rootswereremovedusing a sterile scalpel. These fragments wereplacedseparately on Petri dishescontaining Potato Dextrose Agar (PDA). The plates wereincubated at 28°C for 5 to 7 days. To obtain a pure strain, several subcultures wereperformed on PDA medium. Specieswereselected by eye, takingintoaccount the similarity of thallus and spore. Once isolated in pure culture, theyweresubcultured on PDA medium to measuretheir apical growth rate, and macroscopic and microscopiccharacteristicswereobserved.

2.2.8 Identification of isolated fungi

Morphological and cultural characteristics are determinedafter inoculation of pure strains[15]. The strains are collected in the form of 1cm-diameter cylinders. The cylinderiscentered, and eachdishcontains a single strain. Incubation iscarried out under the same conditions as the previous purification. Identification isbased speed of growth (fast, medium, slow), colony texture, colonycolor and the color of the front and back of the culture. Microscopic identification involvesremoving a smallmycelial fragment using a sterileplatinumloop. The fragment isthenplaced on a slide withMethylene Blue, and coveredwith a coverslip. Observation iscarried out under a light microscope at various magnifications (×10, ×40). Microscopicstudy of the myceliumisbased on the absence or presence of septa, the color of mycelial filaments, the branching pattern of septa and the differentiation of thallospores[16].

2.2.9 Statisticalanalysis

The resultsobtainedwereprocessedusing Excel 2016 to calculate the averages. Secondly, R software version 3.2.2 wasused to carry out analysis of variance (ANOVA) to highlight statisticaldifferencesbetween the averagesobtained. In the event of a significantdifference at the 5% threshold, the Tukey test wasperformed to determine the differenthomogeneity classes.

3. RESULTS

3.1 Effect of *Bacillus subtilis* KBM1 and *Bacillus venezensis*KBM1 on tomato plant mortality.

Fig.4 shows mortality rates of 0% for tomato plants grown on the threesubstratesinoculatedwith thetwobacteria. However, thosegrown on substrateswithoutbacteriashowedmortality rates rangingfrom 6 to 33% for soil and sawdustrespectively.

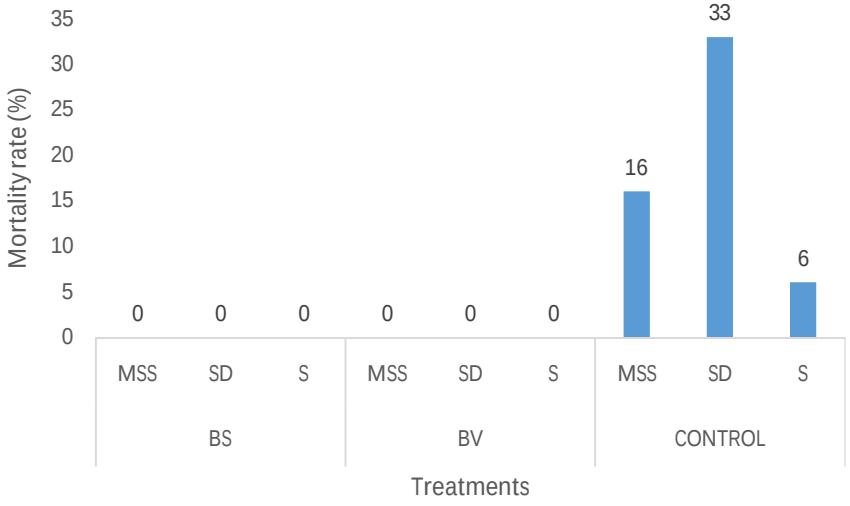

Fig. 4.Plant mortality rate (%) as a function of treatments

BS: Bacillus subtilis KBM1, BV: Bacillus venezensis KBM1, S: Soil, MSS: Mixed soil of sawdustand SD: Sawdust.

3.2 Effect of *Bacillus subtilis* KBM1 and *Bacillus venezensis*KBM1 on the infection rate of tomato plants.

Fig. 5 shows the development of diseasesymptoms on control plants comparedwith plants grown on substratesinoculatedwith the twobacteria, whichshowed no diseasesymptoms. Overall, it can beseenthat all tomato plants grown on substrateswithoutbacteriarecorded infection rates of 26, 31 and 42% for soil, sawdust and non-inoculatedsoil and sawdustrespectively. However, tomato plants grown on substratesinoculatedwith*Bacillus* strainsshowed infection rates of 0%(Fig.6).

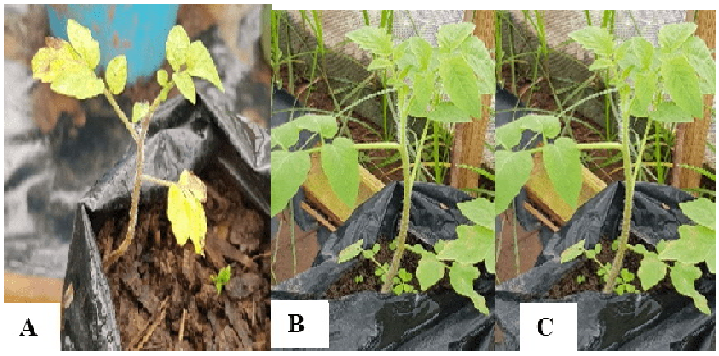

Fig. 5.Development of diseasesymptoms on tomatoplants: A-Control, B-SBV and C-SBS. SBS:Soilwith*Bacillus subtilis* KBM1, SBV: Soilwith*Bacillus venezensis* KBM1

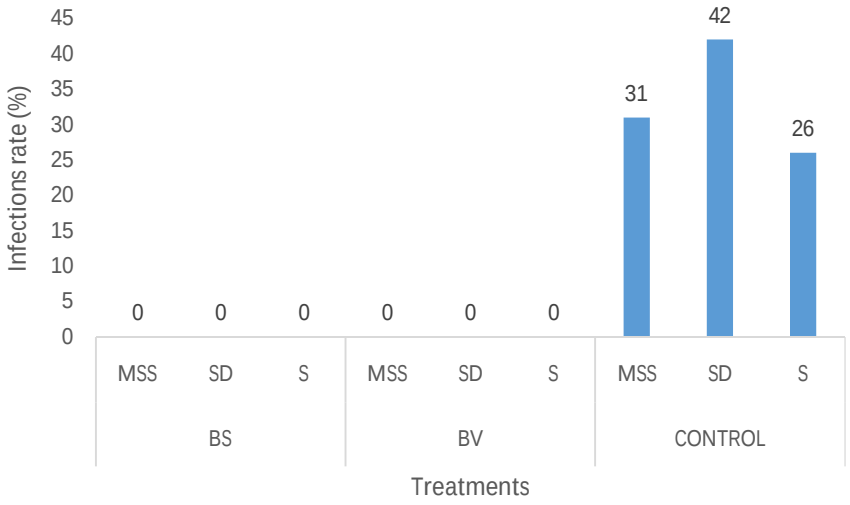

Fig.6.Rate of infections of treated and untreated plants as a function of time (%).
BS: Bacillus subtilis KBM1, BV: Bacillus venezensis KBM1, S: Soil,
MSS: Mixed Soilwithsawdust and SD: Sawdust.

3.3 Effect of *Bacillus subtilis* KBM1 *and Bacillus venezensis* KBM1 on tomato plant size.

Fig. 7 shows that inoculation with*Bacillus subtilis* KBM1 and *Bacillusvenezensis*KBM1 strainshad a highlysignificant impact ($p<0.05$) on the evolution of tomato plant over the course of the experiment on the threesubstratesused. Control plants hadlowaverageheights, rangingfrom 9.93 to 17.43 m for sawdust and soilrespectively. On the other hand, with the addition of the two*Bacillus*strains, therewas

a definiteincrease in plant size, with the highestgrowth rates recorded at soillevel, at 45.81 cm for *Bacillus subtilis* strainKBM1 and 42.16 cm for *Bacillus venezensis*strainKBM1. The growth rates obtained for *Bacillus subtilis* KBM1 and *Bacillus venezensis*KBM1 were 86.90% and 85.76% respectively, comparedwith 65.57% for the soil control(Fig. 8).

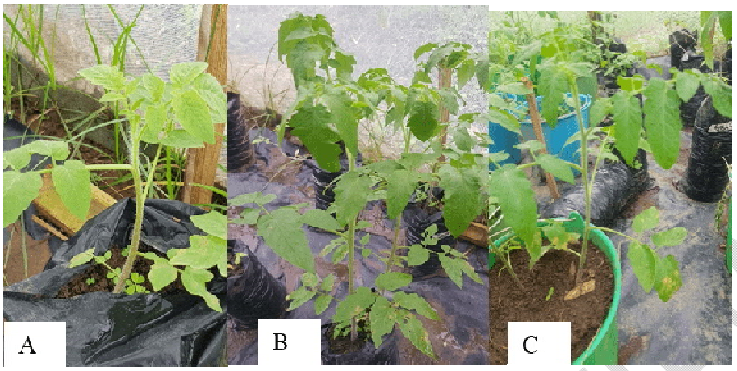

Fig.7.Size of tomato plants after 6 weeks: A- Control plant, B- Tomato plant with*Bacillus venezensis* KBM1 and C- Tomato plant with*Bacillus subtilis* KBM1.

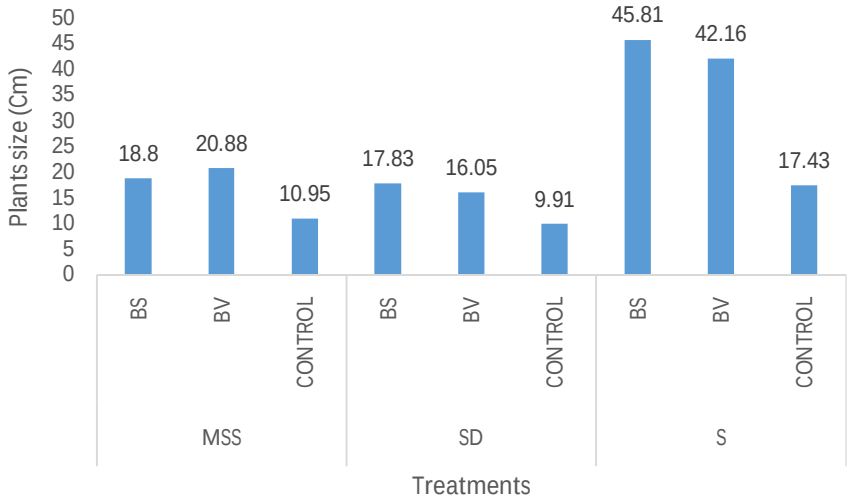

Fig.8. Effect of *Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 on tomato plant size.

BS: Bacillus subtilis KBM1, BV: Bacillus venezensis KBM1, S: Soil,

MSS: Mixed soil of sawdust and SD: Sawdust

3.4 Effect of *Bacillus subtilis* KBM1 and *Bacillus venezensis*KBM1 on leafnumbers of tomato plants

The positive influence of *Bacillus* on the number of leaves on tomato plants isshown in fig. 9 and 10. Tomato plants grown on substratessupplementedwithbacteria more leavesthan control plants. The number of leavessignificantlydifferentfrom one substrate to another and according to bacterialstrain ($p<0,05$). Control plants showedleafnumbersrangingfromaround 21, 23 and27 respectively for plants grown on sawdust medium (SB), sawdust medium mixed soil (SSB) and soil (S). Tomato plants grown on substratesinoculatedwithinoculatedsubstratesshowedleafnumbers of 31.27, 36.47 and 70.07 respectively for plants plantsgrown on sawdust (SB), sawdust mixed withsoil (SSB) and soil (S).

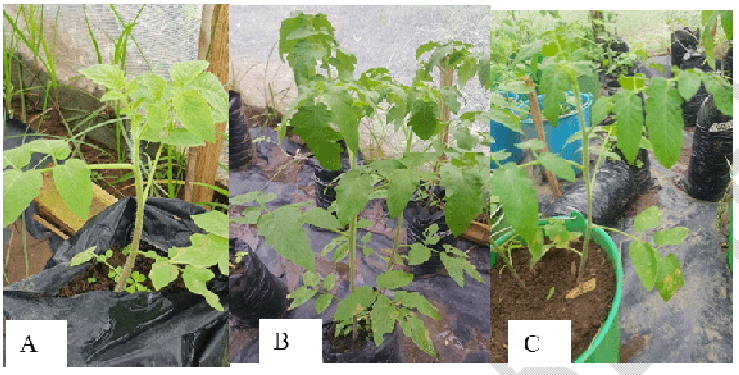

Fig. 9. Number of leaves of tomato plants after 6 weeks of cultivation: A- Control plant, B- Tomato plant with *Bacillus Venensis* KBM1 and C- Tomato plant with *Bacillus subtilis* KBM1.

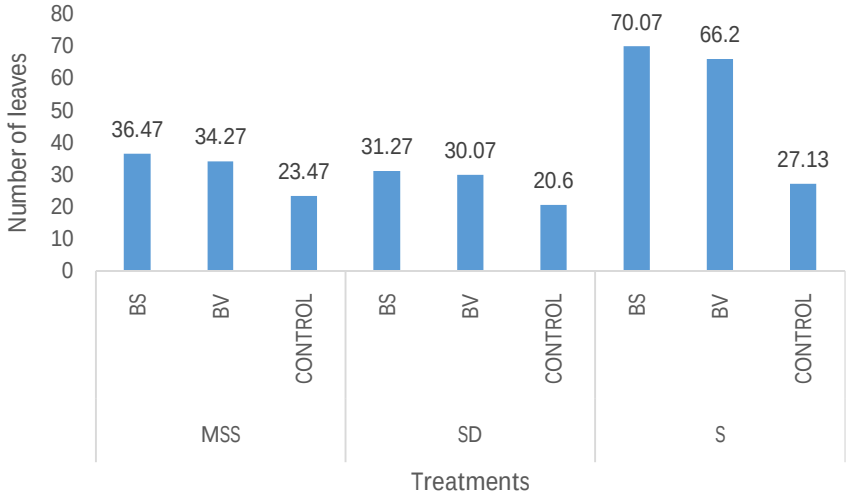

Fig.10. Effect of *Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 on the number of leaves of treated and untreatedtomato.

BS: Bacillus subtilis KBM1, BV: Bacillus venezensis KBM1, S: Soil,

MSS: Mixed soil of sawdust and SD: Sawdust

3.5 Identification of weatheringmoulds on untreatedtomato plants

The identification resultsshowed the presence of pathogenic fungi on the roots, stems and leaves of tomato plants grown on substrateswithoutfertilizingbacteria. However, no pathogenic fungi wereisolatedfromsamples of tomato plants grown on substratesinoculatedwithbothstrains of bacteria. 32 fungalisolateswereassimilated to 8 genera, namely*Penicillium, Rhizopus, Fusarium,Trichoderma, Rhizoctonia, Cladosporium, Phytophtora* and *Colletotrichum*(Fig. 11, 12, 13, 14, 15, 16, 17, 18).

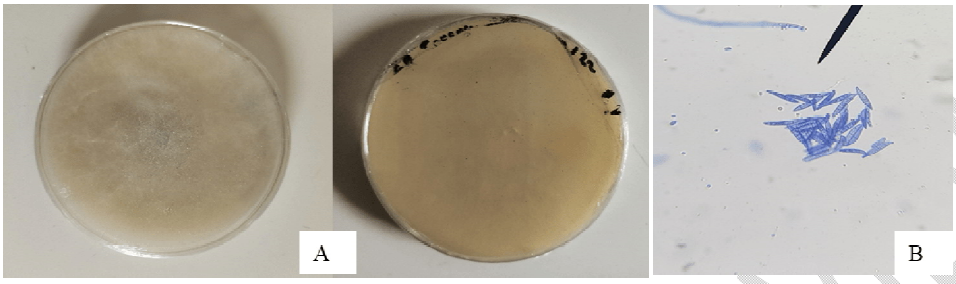

Fig.11. *Fusarium*sp:macroscopicappearance (A) and microscopicappearance (B)

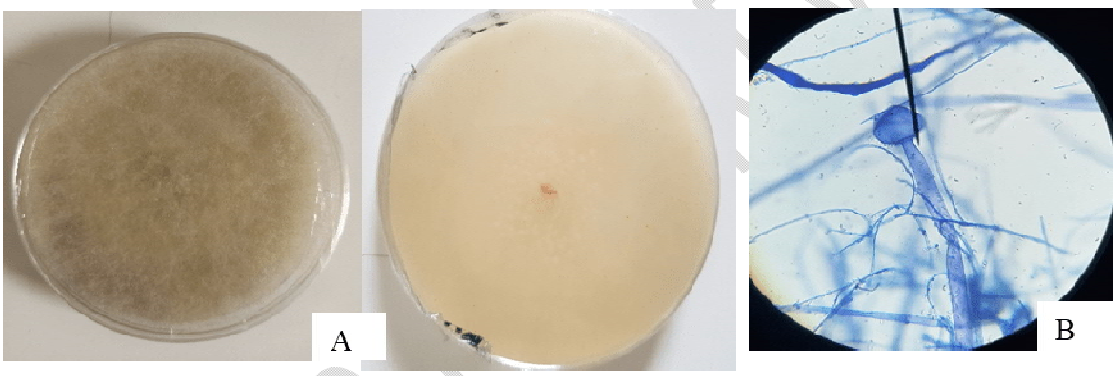

Fig. 12. *Rhizopus*sp:Macroscopicappearance (A) and microscopicappearance (B)

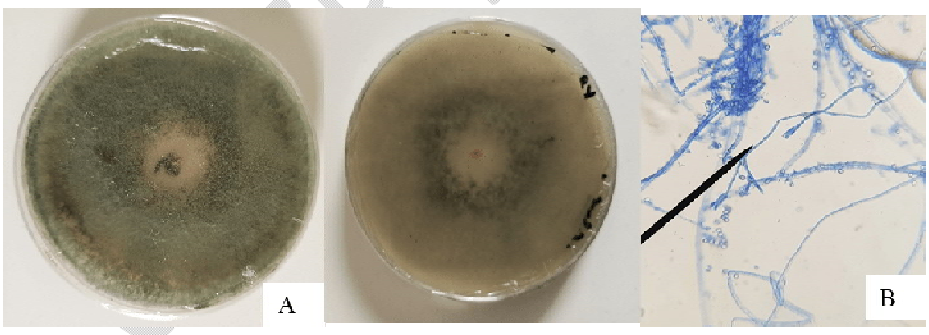

Fig. 13.*Penicillium*sp:Macroscopicappearance (A) and microscopicappearance (B)

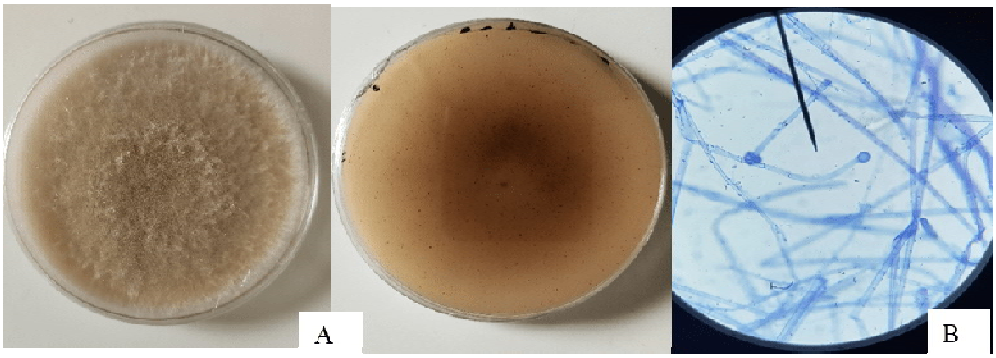

Fig. 14.*Phytophthora*sp:Macroscopicappearance (A) and microscopicappearance (B)

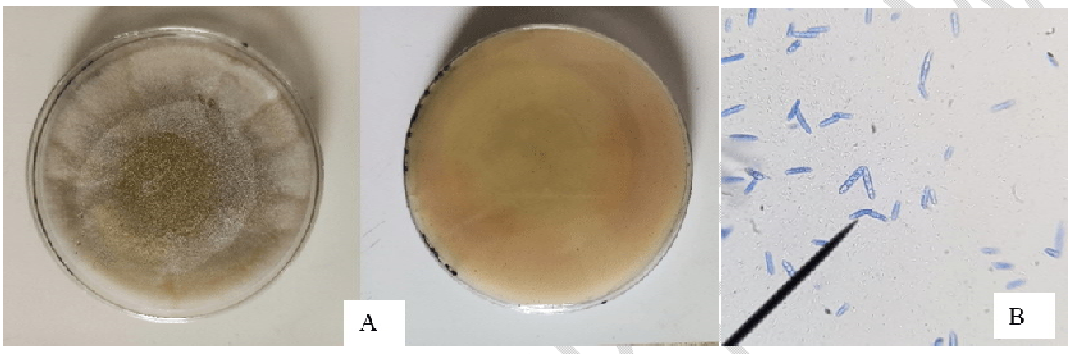

Fig. 15. *Cladosporium*sp:Macroscopicappearance (A) and microscopicappearance (B).

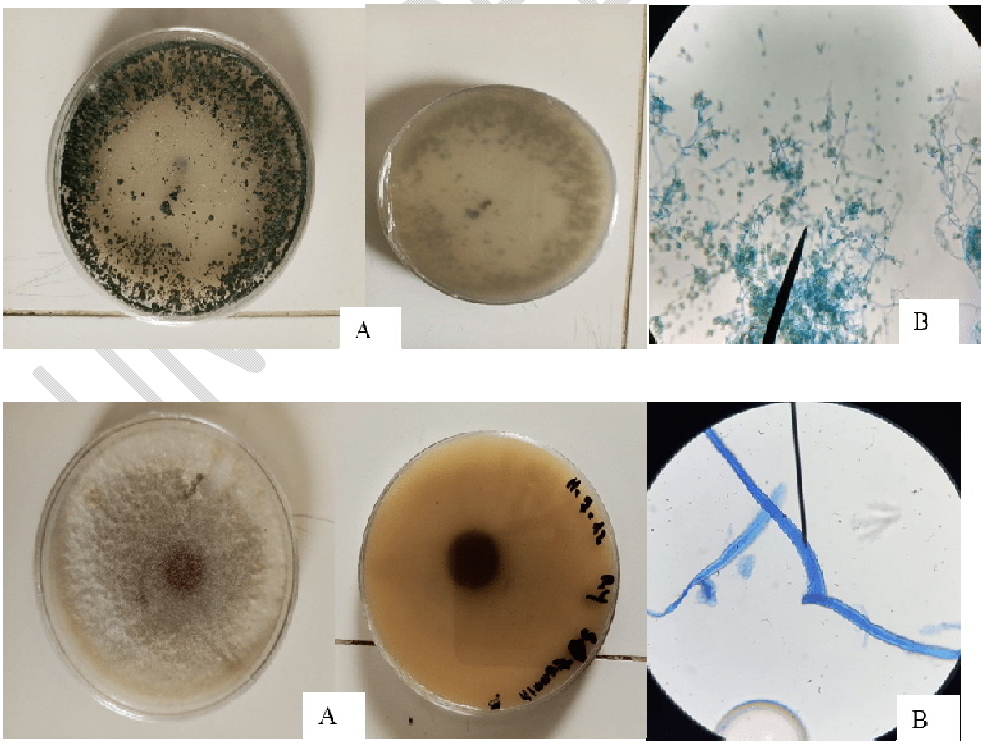

Fig. 16.*Trichoderma*sp:Macroscopicappearance (A) and microscopicappearance (B)

FUNGAL ISOLATES	ISOLATING FREQUENCY BY ISOLATES (%)		ISOLATION FREQUENCY PER SAMPLE (%)		
					ROOT
Fusar					36,36(4)
Clado **p**					0
Phyto					9,09(1)
Rhizo					7,27%(3)
Trich					18,18(2)
Penic					9,09(1)
Rhizo					0
Colletotrichum **sp**	2	6,25%	0	18,18(2)	0
TOTAL	32	100,00%	31,25%(10)	34,38%(11)	34,38%(11)

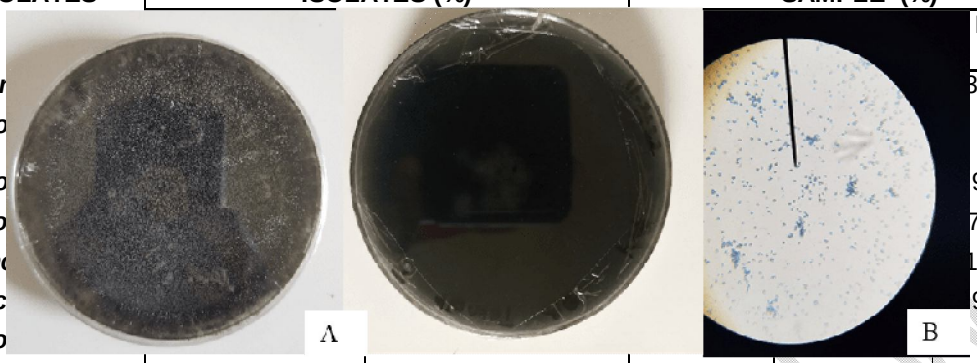

Fig. 17.*Rhizoctonia*sp:Macroscopicappearance (A) and microscopicappearance (B).

Fig. 18.*Colletotrichumsp*:Macroscopicappearance (A) and microscopicappearance (B)

3.6 Frequency of isolation of fungi

Of the 32 moldisolates, *Fusarium* sp and *Rhizoctonia*spdominated, with isolation frequencies of isolation frequencies of 25%. *Penicillium* sp, *Cladosporium*sp, *Phytophtora* sp and *Colletotrichum*spshowed isolation frequencies of 6.25%. The majority of fungi werefound on all tomato plant organsexcept*Cladosporium*spwhichwas not isolatedfrom stems and leaves. In addition, the frequency of isolation of fungi was on roots and stems, at 34.38% and 31.25% respectively(Table 1).

Table 1. Frequency of isolation of pathogenic fungi fromtomato plants.

4. DISCUSSION

With the aim of improvingtomatoproductivity, the stimulatoryeffect of *Bacillus subtilis* KBM1and *Bacillus venezensis*KBM1 in the growth of tomato plants and in the reductiontomatodiseases. Inoculation of substrateswith the twobacterialstrainsbacterialstrains to stimulatetomato plant growth by progressivelyincreasingthe size and number of leaves. This stimulation of tomato plant growthcouldbeexplained by the factthat the *Bacillus* strainsfacilitatebetterassimilation of plant nutrients. In the literature, the stimulatingeffect of *Bacillus*on plant growthiswidelyreported. The work of [17] hasreportedsuperiorgrowth of tomato plants inoculatedwith*B. amyloliquefaciens*and B. subtilis.*B. subtilis*. Bacteria of the *Bacillus*genus are recognized for their direct mode of action (phytostimulatoryeffect), whichstimulates plant growth by increasingaerial and root mass, root elongation and acceleratedseedlingemergence, have undoubtedly made available to plants the nutrientsthatwereavailable in the soil but whichtheywereunable to use. Nitrogen-fixing rhizobacteriasuch as the *Bacillus* genus are important for good soilfertilization and a sustainable agricultural system.Theseresults are supported by severalauthors, including[18], whoshowedthatnitrogenlevels have a significanteffect on potatoleafyield. Somebacteria are capable of producing enzymessuch as phosphatase, or organicacids capable of convertingphosphorusintoformsusable by plants: H2PO4- and HPO42-. Phosphorussolubilizationis the mostcommon mode of action of PGPR rhizobacteria capable of improvingnutrientavailability[19]. As

such, certain Bacillus have been studied for thiscapacity on variouscropsby [20].Solubilizingrhizosphericbacteriaphosphate (PSB) couldthereforeconstitute a promising source as an agent biofertilizers in agriculture. The results of thisstudy show that the strains of *Bacillus subtilis* KBM1 (BS) and *Bacillus venezensis* KBM1 (BV) influence the attack of tomato plants by fungi withreduction and infection rates of 0%. The addition of strains of *Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 significantlyreduced the action of severaltomatopathogens on treated plants originatingfromsubstratesinoculatedwith the bacteria. It has been shown by severalauthorsthatorganicsoilfertilizers can suppressdiseasescaused by soil-borne pathogenssuch as Rhizoctonia[21]. This suppression has often been attributed to a compost microflorasuch as *Bacillus* and fungi, antagonistic to soil-borne phytopathogens[22]. Numerousworkspresent the diversity of microbial agents involved in biological control which can suppress a widespectrum of bacterial, fungal and parasiticdiseaseswhere the *Bacillus*genusiscited[23]. The beneficialeffect of *Bacillus* on the reduction of attacksisassociatedwith an increase in the resistance of plants to colonization by the pathogendueessentially to the formation of physicalbarriers at the penetration sites of the fungus [24]. Theseresults are corroborated by the study of [25],whichshowed an increase in the survival of tomatoseedlingsinoculatedwith B. subtilis RB14-C. The application of *Bacillus* in the soil not onlyprotects plants againstsoil-borne diseases, but can alsostrengthen the overallhealthstatus of plants by inducingsystemicresistance (ISR) in the plant [26]. During the phenomenoncalled “inducedsystemicresistance” (ISR), non-pathogenicrhizobacteria, notably certain species of *Bacillus*, can confer on the plant a certain degree of protection againstsubsequentattacks by a phytopathogen via the stimulation of systemicdefensemechanisms. This immunityisinitiatedfollowing the perception by the plant of so-calledelicitormoleculesproduced by the beneficiarymicroorganism. Theseresultscorroboratewiththoseof [27]whoshowed in theirworkthatrhizobacteriainteractwith the roots of the host and produceelicitorswhich are perceived by the plant. After the recognition of the determinants, a signal isconveyedthroughout the plant in order to alertit and finally, during a possible attack by a phytopathogenic agent, the plant willbe able to respond more effectively to the attack, thusgivingitresistance. The second part of thisstudyaimed to test the effectiveness of *Bacillus subtilis* KBM1 and *Bacillus Venensis* KBM1 on the reduction of tomatodiseases in Côte d’Ivoire. The resultsobtainedfollowing the phenotypic identification of fungalstrainsisolatedfrom the leaves, stem and root of tomato plants frominfectedcontrols made it possible to show that a diversity of molds are responsible for the deterioration of the pre-harvest in Côte d’Ivoire. Eight (8) types of mold have been identified, namely*Fusarium*sp, *Rhizoctonia*sp, *Cladosporium*sp, *Colletotrichum*sp, *Phytophtora*sp, *Trichoderma*sp, *Rizopus*sp, and *Penicillium*sp. Amongtheseisolatedstrains, many are recognized as pathogens of tomatoes in pre- or post-harvest. *Colletotrichum*sp by examplethatwasisolatedfrom the tomato stem in ourstudyissimilar to one of thesespecies (*Colletotrichumcoccodes*) whichisresponsible for anthracnose on tomato fruit. [28]showed in thesestudiesthat “anthracnose” or root rot or anthrax is a diseaseinduced by *Colletotrichumcoccodes*which causes damage to roots, leaves, stems and fruits. Recognized as a pathogenspecific to tomato, *Cladosporiumfluvum* or *Passalorafulva*isresponsible for the diseasecalled olive mold or cladosporiosis in tomatoes. [29]showed in theirworkthat the causative agent of olive moldwasPassalorafulva, itseems to presentgreataffinities for the tomato, in particular for itsleaflets but remainsharmful for this one. A recentlydefineddisease in tomatoes, downymildewis one of the main aerialdiseases of tomato cultivation, particularlywhen conditions are cool and damp. The phytopathogenic agent of thisdiseaseis*Phytophthora* infestons. [30]to show in hisstudiesthatduring the progression of the disease due to *Phytophthora*weinfest, the foliagegraduallyturnsyellowthenbrown, curlsthenshrivelsbeforedie. As for Fusarium sp, itisresponsible for root and crown rot and creates*Fusarium*wilt in tomatoes. [31], to prove inthesestudiesthat*Fusarium*isresponsible for vascularwilting by their invasion of the xylemvessels. There tomato can beattacked by twodifferent fusarium diseases, fusarium wiltcaused by *Fusarium oxysporum*lycopersici and root and crown rot caused by Fusarium oxysporumradicis-lycopersici. Rhizoctoniaspisalsorecognized in the crown rot and root rot of tomato. The genera of *Penicillium* sp, *Trichoderma*sp and *Rhizopus*sp are recognized as saprophytictomatomolds, responsible for fruit rot [32]. Inoculation of *Bacillus*strainsinto plants has significantlyreducedtomatodiseases. The samestudieswerecarried out with[17]whomeasured the effectiveness of four *Bacillus* (*B. megaterium* MB3, *B. subtilis*strains MB99 and *B. subtilis* MB14 and *B. amyloliquefaciens*MB101) against*Rhizoctoniasolani* on tomato. The authorsmeasured the production of systemicdefense enzymes, whichincreasesfollowing the application of certain Bacillus treatments: β-1,3-glucanases, chitinases (PR-3), phenylalanineammonia lyase (PAL), and proteases. The sameauthorsalsorevealedthat Bacillus subtilis MB14 provided 60% inhibition of the disease as well as greatergrowth in the presence of the pathogen. In ourstudy, the resultsshowedthat the strains of *Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 thereforereduceddiseases in tomato by a zero percentage of infection and mortality in treated plants.

5. CONCLUSION

The aim of thisstudywas to contribute toimprovingtomatoproductivityin Côte d'divoirethrough the use of organicfertilizer of microbialorigin. The resultsobtainedshowedthat the strains of *Bacillus subtilis* KBM1 and *Bacillus venezensis* KBM1 stimulated the growth of tomato plants through an increaseimportance of the growthparametersstudied. Thesetwobacteriaalsoshowedtheirability to protecttomato plants through 0% infection and mortality rates for plants grown on the threesubstratesinoculatedwith the twostrains of *Bacillus*. However, the *Bacillus subtilis* KBM1 strainwas more effective than*Bacillus venezensis* KBM1. In view of theseresults, thesetwostrainsproveuseful for makingof a biofertilizer to improvetomatoproductivity in Côte d'Ivoire.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) herebydeclarethat NO generativeAI technologies such as Large LanguageModels (ChatGPT, COPILOT, etc) and text-to-image generators have been usedduringwriting or editingof manuscripts.

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