J. Agric. Chem. and Biotechn., Mansoura Univ. Vol. ٣ *(*٦*):* ١٥٣ *-* ١٧١*,* ٢٠١٢

RESPONSE OF POTATO TO DIFFERENT STRATEGIES OF FERTILIZATION

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ABSTRACT

A field experiment was conducted on sandy soil at El-Ismailia Agric. Res. Station, ARC, during the winter season of ٢٠١٠/٢٠١١ to investigate the influence of different strategies of fertilization, namely compost, biofertilizer and graded levels of mineral N-fertilizer on the vegetative growth, tuber yield and its components of potato plants using drip irrigation system.

The used compost was tested for physico-chemical, microbiological characteristics and degree of maturity/stability indices. Obtained results revealed that used compost has acceptable values of main physico-chemical properties such as pH, EC and fertilizer value (macro- and micronutrients). Also, this compost has a valuable biotic strength. In addition, all tested maturity/stability indices indicated that used compost has reasonable degree of maturity and it can applied to cultivated soil without any problem.

Data of field experiment showed that growth aspects, potato yield and its components exhibited marked response for compost manuring, N-fertilization or biofertilization, independently and their combination. Soil fertilization with ٩٠, ١٣٥ and ١٨٠ kg N/fed led to increase potato tuber yield by ١٧,٢٧, ٣٩,٣٧ and ٦٦,٠٣٪, respectively over the lowest level of N (٤٥ kg N/fed). On the other hand, compost manuring the potato plants with ١٠ and ١٥ ton/fed resulted in increased tuber yield by ١٢,٢٣ and ٢٥,٠٢٪, respectively over the lowest rate of compost (٥ ton/fed).

Concerning the nutritional status in shoots and tubers of potato plants, results exerted that increasing the applied level of compost or N-fertilizer resulted in significantly increased concentration of NPK in potato shoot. Moreover, rhizobacterial inoculation led to significant increase protein and potassium concentration in potato tubers.

At a given interaction between the fertilization strategies, results clearly exerted that highest values of vegetative growth, tuber yield and nutrient status were attained in case of compost manuring with ١٥ ton/fed with N-fertilization at rate of ١٨٠ kg/fed in presence or absence of rhizobacteria.

INTRODUCTION

Among the materials used in agriculture, fertilizers are the most widely used. Based on the production process, it can be roughly categorized into three types: chemical, organic and biofertilizers, each type of fertilizer has advantages and disadvantages, these advantages need to be integrated in order to achieve optimum performance by each fertilizer type and realize balanced nutrients management of crop growth (Chen, ٢٠٠٦). In addition, organic fertilizers and biofertilizers become the alternative solution for reducing the chemical fertilizers and saving environment (Abdel-Wahab *et al.,* ٢٠٠٥). However, chemical fertilizers is an important culture practice that has a considerable influence ob growth, yield and chemical composition of different crops especially in sandy soil, which may have less fertility in general, and less availability of some elements such as nitrogen (Swaefy *et al.,* ٢٠٠٧).

Using compost in agriculture is one of practices for the sustainable management of soils and it also contributes to recycle organic residues. Compost will improve soil fertility by slow and long time release of essential nutrients and micronutrients, improving soil physico-chemical properties and its profoundly affect rhizospheric microorganisms that promote plant growth (Gosling *et al.,* ٢٠٠٦). Application of mature compost to soil favors plant development and improves soil quality as well as having a suppressive effect on many diseases caused by soil borne plant pathogens (Cotxarrera *et al.,* ٢٠٠٢). Moreover, compost amendments maintain and enhance the fertility and productivity of agricultural soils, allowing a sustainable land use (Piqueres *et al.,* ٢٠٠٦).

Biofertilizers are beneficial rhizobacteria that stimulate plant growth and they referred to as plant growth promoting rhizobacteria or PGPR. Special groups of rhizobacteria such as *Azospirillum*, *Azotobacter*, *Acetobacter*, *Bacillus*, *Serratia* and *Pseudomonas* are known as PGPR. The concept of biofertilization within the farm of clean agriculture was developed to reduce the use of agriculture chemicals, thus conserving the environment and subsidies agricultural sustainability. Biofertilizer being do not exclusively replace agricultural chemicals, but markedly diminish their rate of application (El-Ghadban *et al.,* ٢٠٠٣). Lucy *et al.* (٢٠٠٤) summarized the plant growth benefits due to addition of PGPR to many crops that include increases in germination rate, root growth, yield, leaf area, chlorophyll content, magnesium content, nitrogen content, tolerance to drought and delayed leaf senescence. Mechanisms of PGPR, which triggered these benefits to plants include the provision of bio-available phosphorus for plant uptake, nitrogen fixation for plant use, sequestration of iron for plants by siderophores, production of plant hormones like auxins, cytokinins and gibberellins and lowering the plant ethylene levels (Glick *et al.,* ١٩٩٩).

Potato (*Salanum tuberosum* L.) is Egypt's largest horticulture export. It plays an important role in the economy of the country as a food as well as a cash crop (Pervez *et al.,* ٢٠٠٠). It is a major source of inexpensive energy; it contains high levels of carbohydrate and significant amount of vitamins B, C and minerals, moreover, potato is used in many industries, such as French fries, chips, starch and alcohol production (El-Saiid, ٢٠١١). Potato like other vegetable crops, the needing for supplying with organic and inorganic fertilizers was proved to be very essential for the production of higher yield and improving its quality (Bokhtiar and Sakurai, ٢٠٠٥). Additionally, application of biofertilizers for potato plants as substitute for N-chemical fertilizer resulted in much lower concentration of nitrate and nitrite in tubers and improving yield quality (Abdel-Naem *et al.,* ١٩٩٩). Also, addition of biofertilizers such as *Azospirillum, Azotobacter* and *Pseudomonas* as bundling in the presence of organic manure produced more tuber yield over organic manure alone (Hussein and Radwan, ٢٠٠٢). Abou-Hussien *et al.* (٢٠٠٢) reported that addition of chicken manure and biofertilizers as soil application or as tuber inoculation increased the vegetative growth characters, nutrients uptake, total chlorophyll and total yield of potato plants.

Therefore, the target of this study is to investigate the effect of different strategies, namely different levels of N-fertilizer and different rates of enriched compost in the presence and\or absence of rhizobacteria on the growth and productivity of potato plants cultivated in sandy soil.

MATERIALS AND METHODS

A field experiment was conducted at El-Ismailia Agric. Res. Station, ARC, during the winter season of ٢٠١٠/٢٠١١ to investigate the influence of different strategies of fertilization, namely inorganic, organic and biofertilization on the vegetative growth and tuber yield of potato plants grown in sandy soil using drip irrigation system. The main physical, chemical and microbiological characteristics of experimental soil are presented in Table (١). Split plot design with three replicates was used. The main plots were assigned to the enriched compost treatments as follows:

a)٥ ton/fed enriched compost ($C_١$).
b)١٠ ton/fed enriched compost ($C_٢$).
c)١٥ ton/fed enriched compost ($C_٣$).

The subplots were allocated to rhizobacteria treatments as follows:

١)Uninoculated plots (-Rh).
٢)Inoculated plots (+Rh).

Sub-sub plots were allocated to treatments of N-fertilizer levels as follows:

١)٢٥٪ N (٤٥ kg N/fed) ($N_١$).
٢)٥٠٪ N (٩٠ kg N/fed) ($N_٢$).
٣)٧٥٪ N (١٣٥ kg N/fed) ($N_٣$).
٤)١٠٠٪ N (١٨٠ kg N/fed) ($N_٤$).

Each N-level was divided into to equal five doses, the first three doses applied as ammonium sulphate (٢٠,٥٪ N), whereas the later two doses applied as ammonium nitrate (٣٣٪ N). All doses of each N-level added during the first half of growing season (every ١٥ days, the onset dose is after ١٥ days of tuber planting).

Pieces of potato tuber seeds (*Solanum tuberosum* L.) cv. Nicola were sown on October at ٢٥ cm apart within the rows. The recommended culture practices of potato were applied. Calcium superphosphate (١٥٪ $P_٢O_٥$) was applied before potato sowing at a rate of ٢٠٠ kg/fed. While, potassium sulphate (٤٨٪ $K_٢O$) at a rate of ٢٠٠ kg/fed was added at three portions with the first three doses of N-fertilizer. The mature enriched compost was added at ١٥ days before sowing.

Inocula of rhizobacteria:

a)Preparation of liquid culture:

Serratia sp. grown on peptone-glycerol media (Grimont and Grimont, ١٩٨٤), *Pseudomonas fluorescens* grown on King's media (Alef, ١٩٩٥) and *Bacillus polymyxa* grown on nutrient broth media (Dowson, ١٩٥٧) were incubated for ٤٨ hr. at ٢٨^{o}C to maintain populations of ٣x$١٠^٩$ colony forming unit $ml^{-١}$ (cfu/ml).

Table (١): The main physical and chemical properties of the experimental soil

Property	Value
Particle size distribution (%):	
Sand	٨٩,٩٤
Silt	٥,١٦
Clay	٤,٩٠
Texture grade	Sandy
$CaCO_٣$ (%)	١,٦٦
Saturation percent (S.P %)	٢٢,٠٠
pH (soil paste)	٧,٤٦
E.C (dS $m^{-١}$, at ٢٥°C)	٠,٣٦
Soluble cations and anions (meq $L^{-١}$):	
Ca^{++}	٠,٩٢
Mg^{++}	٠,٦١
Na^{+}	١,٤٢
K^{+}	٠,١٨
$CO^{=}_{٣}$	٠,٠٠
$HCO^{-}_{٣}$	١,٧٥
Cl^{-}	٠,٧٢
$SO^{=}_{٤}$	٠,٦٦
Organic matter (%)	٠,٣٥
Total-N (%)	٠,٠٢٩
Available- P (mg $kg^{-١}$)	٦,٢٠
Available-K (mg $kg^{-١}$)	٤٨,٧٠
DTPA-extractable (mg $kg^{-١}$):	
Fe	٢,٥٠
Mn	٠,٦٠
Zn	٠,٥٠
Log. No. of bacteria (cfu/g)	٤,٢٥
Log. No. of fungi (cfu/g)	٣,٣٢
Log. No. of actinomycetes (cfu/g)	٤,٠٠

b) Preparation of solid inoculants :

Vermiculite supplemented with ١٠٪ Irish peat was packed in polyethylene bags (٣٠٠g carrier/bag) then sealed and sterilized by gamma irradiation (٥x $١٠^{٦}$ rads). Each culture of rhizobacteria was injected in the sterilized carrier bag to satisfy ٦٠٪ of water holding capacity.

Inoculation of potato tuber pieces with rhizobacteria was done by two phases, the first by dipping the potato pieces in equal potions from the cultures of three rhizobacteria for ١٠ min. The second inoculation phase was done by incorporating these potato pieces with mixture of equal portions from solid inoculants of three rhizobacteria at rate of ٦٠٠g/tuber of fed. using Arabic gum solution as adhesive material.

Enriched mature compost:

Compost used was prepared from rice straw as main feedstock, which supplemented with farmyard manure (٢٠٪), bentonite (١٠٪), rock phosphate (٥٪), feldspars (٥٪) and elemental sulfur (١٪) and inoculated with lignocellulolytic fungus, it was then composted for ٩٠ days. Afterwards, it was cured for one month with adding ١٪ of vinass (Abdel-Wahab *et al.,* ٢٠٠٩). The physico-chemical and microbiological properties of mature compost as well as its maturity and stability indices were monitored (Tables ٢, ٣).

Analyses :

Soil: Physical, chemical and microbiological analyses of soil used were conducted according to Piper (١٩٥٠) and Page *et al.* (١٩٨٢).

Compost: Physical, chemical, microbiological and indices of maturity were determined according to Page *et al.* (١٩٨٢) and Iglesias-Jimenez and Perez-Garcia (١٩٨٩).

Plant materials:

- Total-N content in plant tissues was measured according to **Jackson (١٩٧٣)**.
- Total chlorophyll content in leaves was determined according to **Arnon (١٩٤٩)**.
- Crude protein in potato tubers was calculated by multiplying of N-concentration by ٦,٢٥.

All data of the plant parameters were statistically analyzed according to Sendecor and Cochran (١٩٨٠).

RESULTS AND DISCUSSION

Physico-chemical, microbiological and maturity/stability characteristics of compost:

The most important factors affecting the successful use of compost for agricultural and horticultural purposes are its degree of stability and maturity. Application of unstable or immature compost may inhibit seed germination; reduce plant growth and damage crop by competing for oxygen or causing phytotoxicity to plants due to insufficient biodegradation of organic matter (Cooperband, ٢٠٠٠). Therefore, it should be practice the comprehensive figure about the physico-chemical and microbiological characteristics as well as maturity/stability indices of compost prior to its uses in agriculture and horticulture production. These practices are presented in Tables (٢) and (٣). As seen in Table (٢), the tested physical parameters of enriched compost exerted relevant values for the finished compost. The reasonable values of bulk density and water holding capacity (٥٧١,٠ kg/m٣ and ١٩٢,٥٢٪, respectively) are indicative for well decomposition process. These findings are in accordance with those attained by Abdel-Wahab *et al.* (٢٠٠٩) who reported that such physical properties may provide a primary indication about materials degradation, transportation, handling and its application. With respect to chemical properties of enriched compost, also same Table exhibited that compost has a neutral pH (٧,٢٨) and relatively high EC (٣,٩٦) referring to the occurrence of degradation and mineralization of organic materials (Bentio *et al.,* ٢٠٠٣ and Abdel-Wahab, ٢٠٠٨). The current compost has a valuable nutrient content, particularly fertilizer's elements (N, P and K were ١,٤٢, ١,١٢ and ١,٦٤٪, respectively). This fertilization value may be contributed efficiently in system of integrated fertilization management. Additionally, enriched compost contains appreciable content of micronutrients beside the relatively high CEC value (١١٨,٥ meq/١٠٠g compost). These findings indicate that this compost contains humified organic compounds which acting to maintain these nutrients in available forms, particularly phosphorus and micronutrients (Manna *et al.,* ٢٠٠٣ and Abdel-Wahab, ٢٠٠٨).

In respect of microbiological properties of tested compost, obtained results exhibited that this compost have valuable high numbers of the main groups of microorganisms, which emphasized by the activity of dehydrogenase (١٧٠,٠ mg TPF/١٠٠g) and nitrogenase (٨٢,٥ nmole $C_٢H_٤$/g/h) enzymes. These findings are indicative of this compost has a high biological activity, which may provide the manured plants with beneficial microorganisms, which may providing plants with promoting substances and suppressing soil borne diseases (Hoitink and Changa, ٢٠٠٤).

Table (٢): Physico-chemical and biological analyses of enriched compost

Character	Value
Bulk density (kg/m^٣)	٥٧١,٠
Water holding capacity (%)	١٩٢,٥٢
pH (١:١٠ extract)	٧,٢٧
E.C. (dS/m)	٣,٩٦
Organic carbon (%)	٢٠,٨٥
Total nitrogen (%)	١,٤٢
Total phosphorus (%)	١,١٢
Total potassium (%)	١,٦٤
N-$NH^+_٤$ (ppm)	١٩٦,٥
N-$NO^-_٣$ (ppm)	٢٣٢,٥
Total soluble-N (mg kg$^{-١}$)	٤٢٩,٠
Available-P (mg kg$^{-١}$)	٣٤٥,٤
Available-K (mg kg$^{-١}$)	٥٨٧,٦
DTPA-extractable Fe (mg kg$^{-١}$)	٢٣٥,٧
DTPA-extractable Mn (mg kg$^{-١}$)	٦٢,٣
DTPA-extractable Zn (mg kg$^{-١}$)	٧١,٦
CEC (c mol/kg)	١١٨,٥
DHA-ase activity (mg TPF/١٠٠ g)	١٧٠,٠
Total count of bacteria (cfu/g)	٣,١ x ١٠^٧
Total count of fungi (cfu/g)	٢,٥ x ١٠^٥
Total count of actinomycetes (cfu/g)	٨,٥ x ١٠^٦

Table (٣): Maturity and stability characteristics of enriched compost

Parameter	Value
Color	Dark brown
C/N ratio	١٤,٦٨
Final C/N / Initial C/N	٠,٣٨
CEC/Organic-C	٥,٦٨
pH of saturated sample at ٥٥°C	٧,١٢
$E_{٤}/E_{٦}$:	
in aqueous extract	٤,١٠
in alkaline extract	٢,١٥
Seed germination index (%):	
for cress seeds	٨٦,٥
for barley seeds	٩٢,٧
$NH_{٤}/NO_{٣}$ ratio	٠,٨٥
Accumulative $CO_{٢}$ mg/g:	
after ١st day	٢,٣٨
~ ٢nd ~	٢,٣٦
~ ٣rd ~	٢,٢٥
~ ٤th ~	١,٩٤
~ ٥th ~	١,٧٢
$N_{٢}$-ase activity (nmole $C_{٢}H_{٤}$/g/h)	٨٢,٥
Phosphate dissolving bacteria (cfu/g)	٣,١ x $١٠^{٧}$

Some maturity and stability indices of the tested compost are given in Table (٣). It is apparent that the color of tested compost is dark brown and it has crumble structure, which is recommended for mature compost according to Iglesias-Jimenez and Iglesias-Jimenez and Perez-Garcia (١٩٨٩). C/N ratio of the tested compost considered in acceptable level for mature compost according to Vuorinen and Saharinen (١٩٩٧) who suggested a C/N ratio between ١٥–٢٠ is ideal for ready use of compost without any restrictions. Also, the final C/N ratio to initial C/N ratio was ٠،٣٨, which is indicative of the tested compost is acceptable to use in agriculture (Van-Heerden *et al.,* ٢٠٠٢ and Abdel-Wahab, ٢٠٠٨).

Other chemical properties such as soil reaction of saturated sample incubated at ٥٥°C, values of E٤/E٦ and CEC referred to that tested compost may considered mature as in accordance with (Bentio *et al.,* ٢٠٠٣ and Abdel-Wahab *et al.,* ٢٠٠٩).

Data in Table (٣) also exerted that phytotoxicity test gave values were much more than ٥٠٪ (value suggested by Zucconi *et al.,* ١٩٨١) for the germination index of cress and barley. These results clearly indicated that tested compost are free from phytotoxin and may considered mature. In this concern, Bernal *et al.* (١٩٩٨) elicited that mature compost could be safely be used with plants without occurring phytotoxicity, which may be resulted from raw materials or produced during the early period of composting where its degraded during the process giving mature compost.

For microbiological properties (Table ٣) data exhibited that accumulative $CO_{٢}$-evolution for five days as stability index gave low values and its changes were not sensible during incubation period, which is indicative of well stability (Wu and Ma, ٢٠٠١). In addition, the positive values of phosphate dissolving bacteria, nitrogenase activity and nitrification index ($NH_٤/NO_٣$ ratio) confirmed the maturity of the tested compost because such biological processes occurred in the later stages of composting (curing and maturity stages) (Hoitink and Boehm, ١٩٩٩).

Effect of different strategies of fertilization on the vegetative growth and productivity of potato plants grown in sandy soil:

a)Vegetative growth:

The vegetative growth parameters of potato plants grown in sandy soil as affected by different rates of enriched compost, rhizobacteria and graded levels of N-fertilizer are presented in Table (٤). The growth aspects of potato plants had greatly affected by all fertilization strategies independently. Irrespective of N-fertilization and biofertilization, all growth aspects of potato plants under investigation exhibited marked response for increasing the rate of addition from enriched compost. Obviously, the highest vigor of potato plants was attained as a result of addition of highest rate of compost (١٥ ton/fed) as compared with the lowest rate of addition (٥ ton/fed), which considered the traditionally rate added to sandy soil. For instance, topdressing the sandy soil with ١٥ ton from enriched compost resulted in significantly increased all the growth aspects to reach ١١,٩١ g/plant, ٢,١٩ g/plant, ٧,٠٠ mg/g and ٨٣,٩٦ $cm^٢$ for shoot dry weight, root dry weight, chlorophyll content and leaf area, respectively. The corresponding values attained as a result of manuring with the lowest rate of compost (٥ton/fed) were ٩,٥٤, ١,٧٤, ٥,٤٣ and ٧٣,٥٣, respectively. The distinct response of potato growth to compost addition clearly reflected the prominent role of enriched organic materials in establishment of rich media for healthy growth, which originated from strengthened root architecture, which formed due to promoting humic substances and other decomposed organic materials, which act to improve soil physico-chemical properties and increase nutrients availability, either that its contain or those added as fertilizer (Tejada *et al.,* ٢٠٠٦ and Abdel-Wahab *et al.,* ٢٠٠٩).

Additionally, obtained results revealed that enriched compost have essential role in enhancement of photosynthesis capacity, which evident by enhancing the chlorophyll content and leaf area of potato plants. The promotive effect of composted organic materials on boosting the plant vigor was proved by many investigators (Hussein and Radwan, ٢٠٠٢; El-Egami, ٢٠٠٤ and El-Saiid, ٢٠١١).

Table (٤): Effects of bio, organic and nitrogen fertilization on the vegetative growth features of potato plants after ٦٠ days of cultivation

a)Main Effect :

Treatments	Shoot D.W (g/plant)	Root D.W (g/plant)	Chl. Cont. (mg/ g leaves)	Leaf area (Cm٢)
	Overall means of Rhizobacteria (Rh)			
+ Rh.	١١,٣٢	٢,٠٦	٦,٣٧	٨٠,٣٠
- Rh.	١٠,١١	١,٧٨	٥,٩٣	٧٧,٦٩
LSD at ٠,٠٥	٠,٣٣	٠,٠٩	٠,١٦	١,٩٩
	Overall means of N-fertilization levels (N)			
N١	٧,٤٤	١,٣٤	٥,٢٩	٦٨,٦٢
N٢	٩,٣٣	١,٧١	٥,٩١	٧٧,٣٥
N٣	١١,٧٧	١,٩٤	٦,٢٩	٨٢,٩٥
N٤	١٣,٤٥	٢,٧٠	٧,١١	٨٧,٠٦
LSD at ٠,٠٥	٠,٤٦	٠,١٢	٠,٢٢	٢,٨١
	Overall means of compost levels (C)			
C١	٩,٥٤	١,٧٤	٥,٤٣	٧٣,٥٣
C٢	١٠,٥٣	١,٨٤	٦,٠٤	٧٩.٥٠
C٣	١١,٩١	٢,١٩	٧,٠٠	٨٣,٩٦
LSD. at ٠,٠٥	**٠,٤٠**	**٠,١١**	**٠,١٩**	**٢,٤٣**

b) Interaction Effect :

Treatments	Shoot D.W (g/plant)		Root D.W (g/plant)		Chl. Cont. (mg/ g leaves)		Leaf area (Cm٢)	
	+ Rh.	**- Rh.**	**+ Rh.**	**- Rh.**	**+Rh.**	**- Rh.**	**+ Rh.**	**- Rh.**
٥ Ton compost/fed (C١)								
N١	٧,٣٠	٦,٥٩	١,٢٠	١,١٢	٤,٩٦	٤,٧٣	٦٤,٨٨	٦٢,٦٢
N٢	٨,٥٧	٨,٠٣	١,٧٠	١,٤٧	٥,٣٦	٥,١٢	٧٠,١٢	٦٧,٥٠
N٣	١١,٢٣	٩,٨٨	٢,٠٥	١,٧٥	٥,٩١	٢,١٢	٧٩,٧٥	٧٥,٣٢
N٤	١٢,٥٨	١١,٣٨	٢,٤٨	٢,١٤	٦,٢٨	٥,٩٥	٨٥,٢٨	٨٢,٧٦
١٠ Ton compost/fed (C٢)								
N١	٧,٨٥	٧,١٠	١,٣٦	١,١٩	٥,١٠	٤,٨٠	٦٨,٥٥	٦٦.٧٥
N٢	٩,٣٣	٨,٥٢	١,٨٣	١,٥٣	٥,٩٥	٤,٤٥	٨١,٣٦	٧٦,٩٠
N٣	١٢,٩٦	١٠,٥٩	٢,٠٢	١,٥٧	٦,٥٦	٥,٨٢	٨٥,١١	٨٢,٤٨
N٤	١٤,٠٨	١٢,٨٦	٢,٨٣	٢,٣٩	٧..٥٦	٦,٩٦	٨٨,٤٥	٨٦,٤٠
١٥ Ton compost/fed (C٣)								
N١	٧,٨٣	٧,٩٧	١,٧٩	١,٣٧	٦,١٩	٥,٩٧	٧٥,٥٥	٧٣,٣٩
N٢	١١,٨١	٩,٧٢	٢,٠٤	١,٦٨	٦,٩٦	٦,٦١	٨٥,٧٩	٨٢,٤٤
N٣	١٤,٧٢	١٣,٥٢	٢,٣٤	١,٩٤	٧,٣٣	٧,٠٣	٨٨,١٨	٨٦,٨٦
N٤	١٥,٦٠	١٤,١٧	٣,١٤	٣,٢٣	٨,٣٢	٧,٥٨	٩٠,٥٨	٨٨,٨٦
LSD. at ٠,٠٥ (C x Rh x N)	**١,١٣**		**١,٣٠**		**٠,٥٥**		**٢,٨٨**	

Concerning the main effect of rhizobacteria, data in Table (٤) showed that inoculation of potato tubers with rhizobacteria increased significantly all aspects of vegetative growth as compared with un-inoculated treatments. The distinct simulative effects of rhizobacteria on the vegetative growth of potato plants may be correlated with remarkable changes in root architecture in terms of root dry weight (٢,٠٦ g for inoculated treatment against ١,٧٨ g for un-inoculated one). These findings are in harmony with El-Tahlawy (٢٠٠٦) and Bertrand *et al.* (٢٠٠٨). In addition, inoculation with rhizobacteria has clear promotive effect on the chlorophyll content (٦,٣٧ mg/g) and leaf area (٨٠,٣٠ cm^{٢}) of potato plants reflecting the marked pronounce of photosynthesis efficiency. These findings are in accordance with Hewedy *et al.* (٢٠٠٨) who reported that the enhancement of chlorophyll contents of lupin and chickpea plants in response to PGPR's co-inoculation may be elucidated by the ability of rhizobacteria to improve the nutrients status in plant tissues, particularly nitrogen, phosphorus and iron which are the more essential nutrients for chlorophyll assimilation in sandy soil.

Concerning the main effect of graded levels of chemical N-fertilizer on vegetative growth of potato plants, data in Table (٤) exerted that increasing the applied dose of N-fertilizer gave gradual significant increases in all aspects of vegetative growth. Obviously, the highest values of growth aspects of potato plants were attained as a result of addition of the highest level of N-fertilizer (١٨٠ kg/fed). For instance, application of ١٨٠ kg N/fed to potato plants resulted in a beast plant vigor in terms of shoot dry matter (١٣,٤٥ g/plant), root dry matter (٢,٧٠ g/plant), chlorophyll content (٧,١١ mg/g) and leaf area (٨٧,٠٦ cm^{٢}). In fact, nitrogen usually is the most limiting essential nutrient for potato growth, especially in sandy soil (Errebhi *et al.,* ١٩٩٨). The marked response of potato plants to graded levels of mineral N-fertilizer was observed by many investigators (El-Saiid, ٢٠١١).

In respect of interaction effect between the different strategies of fertilization on the growth aspects of potato plants, data in Table (٤) revealed that the highest values of plant vigor were always attained in case of co-operation between fertilization strategies. However, in case of manuring with ١٥ ton compost/fed, there is no significant difference between addition of ١٣٥ or ١٨٠ kg N/fed either in presence or absence of rhizobacteria with exception with chlorophyll content.

b) Chemical composition of potato shoot:

NPK concentrations of potato shoot as affected by different strategies of fertilization under sandy soil conditions are presented in Table (٥). Irrespective of organic and mineral fertilization, rhizobacteria of potato tubers resulted in significantly increased N-concentration of potato shoots, while its no significant increases in their concentrations of PK.

In respect of the main effect of organic or mineral fertilization, data clearly exerted that increasing the applied dose of compost and/or mineral N-fertilizer increased significantly the concentration of NPK in potato shoots. Increasing NPK concentrations with increasing the rate of compost reflects the essential role of composted materials in enhancement of nutritional status through its content of nutrients in terms of fertilizer value (Table ٢) beside its ability for increasing the nutrient availability in soil and efficiency of the applied fertilizer (Abdel-Wahab *et al.,* ٢٠٠٩ and El-Saiid, ٢٠١١).

Table (٥): Concentration of essential macronutrients of potato shoots as affected by different strategies of fertilization

a)Main Effect :

	Shoot

Treatments	N (%)	P (%)	K (%)
	Overall means of Rhizobacteria (Rh)		
+ Rh.	١,٩٣٢	٠,٣٤١	٣,٢٣١
- Rh.	١,٨٩٣	٠,٣٣١	٣,١٩٤
LSD at ٠,٠٥	٠,٠٢١	N.S	N.S
	Overall means of N-fertilization levels (N)		
N١	١,٧٩٤	٠,٢٧٨	٢,٨٦٣
N٢	١,٨٧٢	٠,٣٢٤	٢,٩٥٧
N٣	١,٩٦٠	٠,٣٥٧	٣,٣٧٧
N٤	٢,٠٢٣	٠,٣٨٣	٣,٦٥٣
LSD at ٠,٠٥	٠,٠٣٠	٠,٠٣	٠,١٠٢
	Overall means of compost levels (C)		
C١	١,٨٥٢	٠,٣٠٥	٢,٩٧٢
C٢	١,٩٢٤	٠,٣٣٥	٣,١٤٩
C٣	١,٩٦٢	٠,٣٦٧	٣,٥١٧
LSD. at ٠,٠٥	٠,٠٢٦	٠,٠٢٠	٠,٠٨٨

b) Interaction Effect :

Treatments	Shoot					
	N (%)		**P (%)**		**K (%)**	
	+ Rh.	**- Rh.**	**+ Rh.**	**- Rh.**	**+ Rh.**	**- Rh.**
٥ Ton compost/fed (C١)						
N١	١,٧٦٠	١,٧٦٣	٠,٢٧٠	٠,٢٥٣	٢,٧٧٧	٢,٧٢٠
N٢	١,٨٤٠	١,٧٨٠	٠,٢٩٠	٠,٢٧٧	٢,٩٤٠	٢,٨٥٠
N٣	١,٩٠٠	١,٨٨٧	٠,٣٣٧	٠,٣١٧	٣,٠٣٣	٣,٠١٣
N٤	١,٩٥٣	١,٩٣٠	٠,٣٥٧	٠,٣٤٣	٣,٢٣٠	٣,٢١٧
١٠ Ton compost/fed (C٢)						
N١	١,٧٩٣	١,٧٧٠	٠,٢٧٧	٠,٢٧٠	٢,٨٦٠	٢,٨٩٧
N٢	١,٨٨٣	١,٨٩٠	٠,٣٣٠	٠,٣٢٣	٢,٧١٠	٢,٨٦٠
N٣	٢,٠٠٧	١,٩٨٣	٠,٣٥٧	٠,٣٦٠	٣,٣٤٧	٣,٢٨٧
N٤	٢,٠٥٠	٢,٠١٣	٠,٣٩٠	٠,٣٧٧	٣,٦١٧	٣,٦١٣
١٥ Ton compost/fed (C٣)						
N١	١,٨٣٧	١,٨٤٠	٠,٣٠٧	٠,٢٩٣	٢,٩٨٣	٢,٩٤٣
N٢	١,٩٣٣	١,٩٠٧	٠,٣٧٠	٠,٣٥٧	٣,٢٥٣	٣,١٣٠
N٣	٢,٠٤٧	١,٩٣٧	٠,٣٨٣	٠,٣٩٠	٣,٨٤٠	٣,٧٤٠
N٤	٢,١٧٧	٢,٠١٧	٠,٤٢٧	٠,٤٠٧	٤,١٨٣	٤,٠٦٠
LSD. at ٠,٠٥ (C x Rh x N)	٠,٠٧٣		٠,٠٧٠		٠,٢٤٩	

On the other hand, the distinct response of potato plants to gradual increases of applied N-fertilizer reflected the essential role of mineral N-fertilizer in nutritional status of potato plants (El-Egami, ٢٠٠٤ and El-Saiid, ٢٠١١). In this respect, El-Sersawy *et al.* (١٩٩٧) reported that increasing N-levels had positive effect on root growth and the absorption sites, which enhance the absorption of nutrients.

Potato yield and its components:

Potato tubers yield and some its components as affected by different strategies of fertilization are presented in Table (٦). Data clearly revealed that potato yield and its components exhibited remarkable response to all fertilization strategies used as main effect and their interaction, reflecting the high needful of potato plants to fertility media under sandy soil conditions.

Regardless of compost manuring and/or N-fertilization, tuber bacterization with the mixture of rhizobacteria increased significantly the productivity and yield components of potato as compared to uninoculated tubers. The promotive effect of such PGPR's on enhancing the potato yield and its components may be elucidated by well habitation of these effective rhizobacteria in potato rhizosphere and consequently they can promote the plant growth and yield *via* several mode of actions, which enhanced the nutrients availability and their uptake (Tilak *et al.,* ٢٠٠٥ and Hewedy *et al.,* ٢٠٠٨). Furthermore, these rhizobacteria has good ability to tri a natural bioprotection against several soil pathogens (El-Sayed, ٢٠٠٧), leading to increase the tuber yield of inoculated potato plants.

Concerning the main effect of N-fertilization levels, data in Table (٦) demonstrated that application of graded levels of N-fertilizer to potato plants increased significantly the potato yield and its components. For instance, fertilization with ٩٠, ١٣٥ and ١٨٠ kg N/fed led to increase the potato tuber yield by ١٧,٢٧, ٣٩,٣٧ and ٦٦,٠٣٪, respectively, over the lowest level of N (٤٥ kg N), which considered as control. These findings confirmed the essential role of nitrogen in achievement of satisfied potato yield, particularly under sandy soil conditions, which it common having poor fertility and needing special fertilization strategy (El-Egami, ٢٠٠٤). The positive response of potato plants to applied N-levels was evinced by many workers (El-Egami, ٢٠٠٤ and El-Saiid, ٢٠١١).

Table (٦): Effects of bio, organic and nitrogen fertilization on potato yield and its components

a)Main Effect :

	Tuber			**Potato yield**
Treatments	**Number/plant**	**Size/plant (cm')**	**Weight/plant (g)**	**(ton/fed)**
	Overall means of Rhizobacteria (Rh)			
+ Rh.	٦,٨٦١	٨٩٤,٠٠٠	٥٥٦,٩٢٨	٧,٥٥٣
- Rh.	٦,٤٤٤	٨٦٨,٥٠٠	٥٣١,٣٢٨	٧,١٥٦
LSD at ٠,٠٥	٠,٣٣٥	٠,٤٠٣	٧,٨٥٩	٠,١٩٥
	Overall means of N-fertilization levels (N)			
N١	٥,٠٥٦	٢٠,٦٠٦	٣١٤,٨٢٨	٥,٦٢٨
N٢	٥,٧٧٨	٢٣,٢٥٠	٤٤٤,٦٥٠	٦,٦٠٠
N٣	٧,١٦٧	٢٥,٥٥٦	٦٦٢,٠٨٩	٧,٨٤٤
N٤	٨,٦١١	٢٨,٥٠٦	٧٥٤,٩٤٤	٩,٣٤٤
LSD at ٠,٠٥	٠,٤٧٤	٠,٥٦٩	١١,١١٠	٠,٢٧٦
	Overall means of compost levels (C)			
C١	٥,٥٠٠	٢٢,١٣٧	٤٧٨,٧٣٣	٦,٥٤٢
C٢	٦,٧٥٠	٢٤,٨٦٢	٥٤٢,٢١٣	٧,٣٤٢
C٣	٧,٧٠٨	٢٦,٤٣٨	٦١١,٤٣٧	٨,١٧٩
LSD. at ٠,٠٥	**٠,٤١٠**	**٠,٤٩٣**	**٩,٦٢٥**	**٠,٢٣٩**

b)Interaction Effect :

	Tuber			**Potato yield**
Treatments	**Number/plant**	**Size/plant ($cm^{٣}$)**	**Weight/plant (g)**	**(ton/fed)**

	+ Rh.	- Rh.	+ Rh.	- Rh.	+Rh.	- Rh.	+ Rh.	- Rh.
٥ Ton compost/fed (C١)								
N١	٤,٠٠٠	٣,٦٦٧	١٨,٨٣٣	١٨,٢٠٠	٢٧٧,٤٦٧	٢٣٨,٩٦٧	٤,٨٦٧	٤,٦٦٧
N٢	٤,٦٦٧	٤,٣٣٣	٢١,٠٦٧	٢٠,٧٣٣	٤٠١,١٣٣	٣٧٧,٠٠٠	٦,١٠٠	٥,٦٣٣
N٣	٦,٠٠٠	٦,٣٣٣	٢٣,٥٦٧	٢٢,٨٣٣	٥٩٧,٠٦٧	٥٧٧,٢٣٣	٧,٢٦٧	٧,٠٦٧
N٤	٧,٦٦٧	٧,٣٣٣	٢٦,٥٦٧	٢٥,٣٠٠	٧٠٢,٣٣٣	٦٥٧,٦٦٧	٨,٤٦٧	٨,٢٦٧
١٠ Ton compost/fed (C٢)								
N١	٥,٣٣٣	٤,٦٦٧	٢٠,٨٠٠	٢٠,٢٣٣	٣٣٥,٩٣٣	٣١٥,٣٦٧	٥,٩٣٣	٥,٤٣٣
N٢	٦,٣٣٣	٥,٦٦٧	٢٣,٣٦٧	٢٣,٢٠٠	٤٦٢,٠٦٧	٤٤٢,٠٣٣	٦,٩٠٠	٦,٢٣٣
N٣	٧,٦٦٧	٧,٠٠٠	٢٦,٩٣٣	٢٦,٠٦٧	٦٥٦,٦٠٠	٦٤٢,١٠٠	٨,١٦٧	٧,٦٦٧
N٤	٨,٦٦٧	٨,٦٦٧	٢٩,٧٣٣	٢٨,٥٦٧	٧٤٧,٦٠٠	٧٣٦,٠٠٠	٩,٣٦٧	٩,٠٣٣
١٥ Ton compost/fed (C٣)								
N١	٦,٦٦٧	٦,٠٠٠	٢٣,٠٠٠	٢٢,٥٦٧	٣٨٠,١٣٣	٣٤١,١٠٠	٦,٦٣٣	٦,٢٣٣
N٢	٧,٠٠٠	٦,٦٦٧	٢٥,٩٦٧	٢٥,١٦٧	٥٠٣,٥٣٣	٤٨٢,١٣٣	٧,٥٦٧	٧,١٦٧
N٣	٨,٣٣٣	٧,٦٦٧	٢٧,٢٠٠	٢٦,٧٣٣	٧٦٥,٢٦٧	٧٣٣,٢٦٧	٨,٦٦٧	٨,٢٣٣
N٤	١٠,٠٠٠	٩,٣٣٣	٣٠,٩٦٧	٢٩,٠٠٠	٨٥٣,٠٠٠	٨٣٣,٠٦٧	١٠,٧٠٠	١٠,٢٣٣
LSD. at ٠,٠٥ (C x Rh x N)	١,١٦١		١,٣٤٤		٢٧,٢٢٠		٠,٦٧٥	

In respect of main effect of compost manuring on potato tuber yield and its components, data in Table (٦) exerted that potato yield increased significantly with increasing the rate of compost application. In other words, topdressing sandy soil with compost at levels of ١٠ and ١٥ ton/fed increased significantly potato tuber yield by ١٢,٢٣ and ٢٥,٠٥٪, respectively, over the lowest compost rate (٥ ton/fed). This distinct response of potato yield and its components to graded rates of enriched compost emphasized its essential role in establishment of fertile media for growing potato plants leading to healthy vegetative growth and consequently sustain these plants to give high quality and quantity of potato yield. The prominent role of organic materials in enhancement of plant productivity was proved by many investigators (Jayathilake *et al.,* ٢٠٠٦; Abdel-Wahab, ٢٠٠٨ and El-Saiid, ٢٠١١).

Concerning the interaction effect between the bio, organic and mineral fertilization, results displayed that potato yield and its components were greatly responded to joint application of organic and mineral fertilization. Obviously, the highest yield of potato tuber was attained in case of soil manuring with ١٥ ton/fed, then the fertilization of potato plants with ١٨٠ kg N/fed practiced. Moreover, There is no significant differences between inoculated and un-inoculated treatments, particularly with highest rate of compost (١٥ ton/fed). These results may be elucidated by the presence of rhizobacteria in enriched compost with humified organic substances and nutritional elements, which act to provide the introduced microorganisms with enriched media for their proliferation and survival (Tejada and Gonzalez, ٢٠٠٤ and Abdel-Wahab, ٢٠٠٨). Also, this enriched compost able to improve the efficiency of applied nitrogen fertilizer (Montemurro *et al.,* ٢٠٠٦ and Abdel-Wahab, ٢٠٠٨).

c)Some chemical constituents of potato tuber:

Results presented in Table (٧) show the effect of different strategies of fertilization on protein, phosphorus and potassium concentration of potato tubers.

Irrespective of organic or mineral fertilization, tuber inoculation with mixture of PGPRs increased significantly protein and potassium, while it has no significant effect on phosphorus concentration. Indeed, used rhizobacteria can achieve many beneficial mechanisms to their colonized plants such nitrogen fixation, supplying with growth promoting substances and enhancing nutrient uptake, which reflected on increasing the nutrient status in rhizosphere and in plant tissues (Mantelin and Touraine, ٢٠٠٤, Tilak *et al.,* ٢٠٠٥ and Abdel-Wahab *et al.,* ٢٠٠٦).

Concerning the main effect of compost manuring, data exerted that increasing the compost rate resulted in significantly increased the concentration of protein and potassium in potato tubers, while it has no significant effect of phosphorus. Same trend was obtained for the main effect of N-fertilizer levels on protein, phosphorus and potassium concentrations of potato tubers. Similar tendency was obtained by El-Egami (٢٠٠٤) and El-Saiid (٢٠١١).

Table (٧): Content of protein, phosphorus and potassium in potato tubers as affected by different strategies of fertilization

a)Main Effect :

	Tuber		
Treatments	**Protein content (%)**	**K (%)**	**P (%)**
	Overall means of Rhizobacteria (Rh)		
+ Rh.	١٠,١٩١	١,٦٢٨	٠,٢٢٨
- Rh.	٩,٩٥٣	١,٥٧٥	٠,٢١٤
LSD at ٠,٠٥	٠,١٦٤	٠,٠٢١	N.S
	Overall means of N-fertilization levels (N)		
N١	٨,٨٧٤	١,٤٠٥	٠,١٧٣
N٢	٩,٣٢١	١,٥٦١	٠,٢٠٨
N٣	١٠,٣٢٨	١,٦٦٩	٠,٢٣٦
N٤	١١,٧٦٤	١,٧٢٢	٠,٢٦٩
LSD at ٠,٠٥	٠,٢٣٢	٠,٠٣٠	N.S
	Overall means of compost levels (C)		
C١	٩,٤٥٠	١,٤٧٣	٠,١٨٧
C٢	١٠,١٨٢	١,٦٠٨	٠,٢٢٢
C٣	١٠,٥٨٣	١,٧٢٥	٠.٢٥٦
LSD. at ٠,٠٥	٠,٢٠١	٠,٠٢٦	**N.S**

b) Interaction Effect :

Treatments	**Tuber**					
	Protein content (%)		**K (%)**		**P (%)**	
	+ Rh.	**- Rh.**	**+ Rh.**	**- Rh.**	**+ Rh.**	**- Rh.**

٥ Ton compost/fed (C١)						
N١	٨,٦٨٠	٨,٥٦٠	١,٣١٧	١,٢٩٣	٠,١٥٧	٠,١٤٧
N٢	٨,٩٢٣	٨,٧٩٣	١,٤٦٠	١,٤٥٠	٠,١٨٧	٠,١٨٠
N٣	٩,٦٦٠	٩,٤٢٧	١,٥٥٣	١,٥٣٣	٠,١٩٠	٠,١٩٧
N٤	١٠,٩٦٠	١٠,٥٩٧	١,٦٣٧	١,٥٣٧	٠,٢٢٠	٠,٢١٧
١٠ Ton compost/fed (C٢)						
N١	٩,٠١٧	٨,٨٢٠	١,٤٦٣	١,٣٩٠	٠,١٨٧	٠,١٤٠
N٢	٩,٥٠٣	٩,٢٣٠	١,٦٠٠	١,٥٢٧	٠,٢١٧	٠,١٩٧
N٣	١٠,٦٦٠	١٠,٥٥٣	١,٦٩٠	١,٦٧٠	٠,٢٥٣	٠,٢٤٣
N٤	١٢,٠٨٠	١١,٥٩٣	١,٧٨٣	١.٧٣٧	٠,٢٧٣	٠,٢٦٣
١٥ Ton compost/fed (C٣)						
N١	٩,١٩٠	٨,٩٧٧	١,٥١٧	١,٤٥٠	٠,٢١٠	٠,١٩٧
N٢	٩,٨١٧	٩,٦٥٧	١,٦٧٧	١,٦٥٠	٠,٢٣٧	٠,٢٣٠
N٣	١٠,٩٨٧	١٠,٦٨٣	١,٨٠٧	١,٧٦٠	٠,٢٧٣	٠,٢٦٠
N٤	١٢,٨١٣	١٢,٥٤٣	٢,٠٣٧	١,٩٠٣	٠,٣٣٧	٠,٣٠٣
LSD. at ٠,٠٥ (C x Rh x N)	٠,٥٦٩		٠,٠٧٣		**N.S**	

At a given interaction treatments, data presented in Table (٧) revealed that the best results were attained in case of combination between the highest levels of N-fertilizer and compost in presence of rhizobacteria. However, these obtained results are in need to be repeated to reach the level of recommendation.

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استجابة البطاطس للاستراتيجيات المختلفة من التسميد

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تم اجراء تجربة حقلية في ارض رملية بمحطة البحوث والتجارب الزراعية بالأسماعيلية خلال الموسم الشتوى ٢٠١١/٢٠١٠ لدراسة تأثير الاستراتيجيات المختلفة من التسميد (الكمبوست ، التسميد الحيوى و المستويات المتدرجة من التسميد النيتروجينى المعدنى) على النمو الخضرى ومحصول وبعض مكونات محصول نباتات البطاطس تحت نظام الرى بالتنقيط.

تم أختبار الكمبوست المستخدم من حيث الخواص الطبيعية والكيماوية والميكروبيولوجية وكذلك مدى النضج والثبات. اشارت النتائج الى أن هذا الكمبوست ذو قيمة مقبولة من حيث خواصه الطبيعية والكيماوية (مثل الكثافة الظاهرية وقدرة الاحتفاظ بالماء درجة الحموضة ودرجة التوصيل الكهربى) والقيمة السمادية (محتواه من العناصر الكبرى والصغرى). ايضا فقد وجد ان هذا الكمبوست له قيمة حيوية عالية (ذو كفاءة عالية فى اثراء التربة بالميكروبات المفيدة). كذلك كل اختبارات النضج والثبات اظهرت ان الكمبوست المستخدم على درجة مقبولة من النضج ويمكن اضافته للتربة الزراعية بدون مشاكل.

اشارت نتائج التجربة الحقلية الى ان قياسات النمو و محصول درنات البطاطس ومكونات محصول البطاطس اظهرت استجابة كبيرة للتسميد العضوى والتسميد النيتروجينى المعدنى او التسميد الحيوى كل بمفرده وكذلك الاضافة المشتركة منهم. أن تسميد التربة بـ ٩٠ ، ١٣٥ و ١٨٠ كجم ن/فدان ادت الى زيادة فى محصول درنات البطاطس بـ ١٧,٢٧ ، ٣٩,٣٧ و ٦٦,٠٣% على التوالى اعلى من استخدام المعدل المنخفض من التسميد النيتروجينى (٤٥ كجم ن/فدان). ومن ناحية أخرى، أدى التسميد العضوى لنباتات البطاطس بالمعدل ١٠ و ١٥ طن/فدان الى زيادة محصول الدرنات ب ١٢,٢٣ و ٢٥,٠٢% أعلى التوالى اعلى من استخدام المعدل المنخفض من الكمبوست (٥ طن/فدان).

بالنسبة لحالة العناصر الغذائية فى كل من المجموع الخضرى ودرنات نباتات البطاطس، أظهرت النتائج الى أن زيادة معدل الاضافة من الكمبوست او التسميد النيتروجينى المعدنى أدى الى زيادة معنوية فى تركيزات النيتروجين والفوسفور والبوتاسيوم فى المجموع الخضرى لنباتات البطاطس. كذلك ادى التلقيح بالريزوبكتيريا الى حدوث زيادة معنوية فى تركيز كل من البروتين والبوتاسيوم فى درنات البطاطس.

بالنسبة للتداخل بين استراتيجيات التسميد تحت الدراسة، اشارت النتائج الى أن أعلى قيم للمجموع الخضرى، ومحصول الدرنات والمحتوى من العناصر كان فى حالة التسميد العضوى بـــ ١٥ طن كمبوست/فدان مع التسميد النيتروجينى المعدنى بمعدل ١٨٠ كجم ن/فدان فى وجود أو غياب الريزوبكتيريا.

قام بتحكيم البحث

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