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Combined Application of various Sources of Organic Fertilizers with Biofertilizers for Improvement Potato Productivity and Soil Fertility Status

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A FIELD experiments were carried out during two successive seasons 2019 and 2020 in a private farm at Belqas district, Al-Daqahlia Governorate, Egypt to assay the effect of various sources of organic fertilizers (farmyard manure, compost, chicken manure and spent coffee ground) added either solely or combination with biofertilizers (N-fixers and PK-dissolving bacteria) on the growth performance and productivity of potato plants. Results showed that the soil amended with chicken manure (24.7m^3ha^{-1}) and inoculated by dual biofertilizers i.e. *Paenibacillus polymyxa* as nitrogen fixing bacteria and *Enterobacter cloacae* as phosphate and potassium solubilizing bacteria thatintroduced as talc-based formulation containing mixed strains,significantly enhanced remaining nutrientsin the soil post-harvest; Moreover, densities of bacterial population at 90 days'- time interval significantly increased. Also, the highest vegetative growth, yield attributes and tuber quality were recorded for the same treatment. On other hand, this treatment recorded the lowest nitrate content for both seasons. It is worth mentioning that soil amended with spent coffee grounds (27.17m^3ha^{-1}) with bacterial inoculation has a positive effect onimproving soil fertility and potato productivity.

Keywords: Potato; farmyard manure; compost; Chicken manure; spent Coffee ground and biofertilization.

Introduction

Potato (*Solanumtuberosum* L.) is one of most important solanaceous vegetable crops for local consumption and exportation, occupied the fourth number after rice, wheat, and maize in production size (Walker *et al*., 1999). Potato iseconomical food which rich with starch, vitamin C&B, minerals and essential amino acids (Khurana and Naik2003). Data obtained from the Egyptian agricultural quarantine statistics, Ministry of Agriculture and Land Reclamation, Egypt, revealed that the cultivated area of potato in 2019/2020 were about 192.31ha., which yielded about 5.8 million ton of tubers with an average of about 30.38 ton/ ha. Egypt imports 135.000 ton ofpotatofrom European Union as a seed to be cultivated. Egypt exported from it about 678.000 ton. Several reviews indicated that potatoes produced with organic fertilizers are healthier than potatoes produced using conventional methods. This is because organic potatoes contain fewer nitrates (Lairon, 2009) than potatoes produced with conventional practices. When using excessive of mineral fertilizers for long time periods, soil and pollution become potential threat less affecting negatively soil productivity and possessing serious health and environmental problems (Cockburn *et al*., 2011). For these reasons, several countries around the world changed their agricultural additives towards using safe organic and biological fertilizers (El-Sayed *et al*., 2015).

Organic fertilization improves physical, chemical and biological properties of soil, adjusts

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soil pH and increases solubility of macro and micro-nutrients in soil. Adding organic fertilizers can; enrich soil with nutrients needed for plant growth (Zaki *et al.* 2021) by increasing available phosphorus, potassium, calcium, and the other micro-elements contents, via its effect on soil pH, encouraging proliferation of microorganisms, increasing microbial population and stimulating activities of microbial enzymes (Abou-Hussein *et al.,* 2001). The use of various fresh or composted organic wastes has a role in potato production and soil fertility by improving organic matter, nutrient content, water hold capacity as well as aggregation of soil (Abdeldaym *et al*., 2018 and Shehata *et al.,* 2019). Zaki *et al*. (2021) confirmed that application of organic additives has a positive effect on production and nutritional value of groundnut crop. Organic manures (such as compost and FYM) are vital organic resources and used for sustainable agriculture. Itis rich in nitrogen and other nutrients that can decrease the consumption of chemical fertilizer. These organic manures used for many centuries to increase soil fertility (Durzi, 2012). Hany and Darwesh, (2020) reported that inoculation by *E. ludwigii* (KP325139.1) combined with compost could compensate 50% of chemical fertilizer with significant increment in growth, yield and fruit quality of apple. As well, increasing soil content of most nutrients.

Using chicken manure as an organic fertilizer improves soil properties and crop production (Baddour *et al*., 2017). Chicken manure is a better amendment than many animal wastes because of its high concentration of macro nutrients (Dikinya and Mufwanzala, 2010). Spent coffee grounds (SCG), has a high humidity content (80% - 85%), fine particle size, organic load and acidity (Mussatto *et al*., 2011). The consumption of coffee produces high amounts of spent coffee grounds usually mixed with ordinary wastes which may cause environmental problems. On the other hand, this residue is rich in nitrogen, phosphorus and potassium (Mussatto *et al*., 2011 and Cruz *et al*., 2012), and may therefore be used in agriculture as fertilizer or probably as a soil conditioner (Kondamudi *et al*., 2008). Beside of being rich with bioactive compounds (e.g., phenolics, carotenoids, flavonoids, xanthines, diterpenes, melanoidins, vitamin precursors, etc.) (Stylianou *et al*., 2018).SCG (as organic fertilizer) versus NPK (as traditional fertilizer) increases the concentrations of several essential elements, which could reduce the use of chemical fertilizers, work on improvement of environmental sustainability. So,SCG as organic amendment give rise to the production of a food product that could be classified as ecological and, at the same time, improves its nutritional value (Cervera-Mata *et al*., 2019). References to its use as organic fertilizer in domestic cultures, especially in gardens, are common and there are numerous recommendations about its use as organic fertilizer in agriculture (Kasongo *et al.,* 2011; Gomes *et al.,* 2013 and Yamane *et al*., 2014). However, scientific evidence of its safety or even efficiency still unknown

Biofertilizers include efficient strains of nitrogen-fixing bacteria, phosphate and potassium solubilizing bacteria that increase absorption of available nutrients by plants (Shaaban *et al*., 2015), improve crop efficiency decrease pollution and achieve sustainable agriculture (Rahimi *et al.,* 2019). Preparation of talc-based formulation as bacterial carrier was carried out to make the use of bacterial strains easier and also to improve their stability, vitality and durability in the rhizosphere. The bacterial survive in talc powder, this may be because talc had very low moisture equilibrium, relative hydrophobicity and chemical inertness; moreover, it reduces moisture absorption and prevents formation of hydrate bridges that give longer storage periods (Kumar, 2014 and Shaaban *et al*., 2015).

The integration effect of manure and soil microorganisms may improve soil aggregation, especially in light textured soils due to decomposition by soil microorganisms, as additional polysaccharides, act as glue between soil particles to increase soil pores to be suitable medium for plant growth due to efficiency of roots making easier absorption of nutrient and increasing nutrient uptake (Widowati *et al.,* 2005). The application of biofertilizers with organic manure improves soil fertility, fertilizers efficiency and crop productivity (Kantikowati *et al.* 2019 and Elbaalawy *et al.* 2020)

Our objective for this study was to determine the effect of different organic fertilizers on soil fertility, quantity and quality of potato plants. In addition to, how biofertilization would impact potato production under different organic regimes.

Material and Methods

Experimental Site

A field experiment was carried out during two successive seasons (2019-2020) at Belqas district, Al-Daqahlia Governorate, Egypt, to study influence of various sources of organic fertilizers with or without biofertilization on soil fertility status as well as growth, yield and quality of potato plant**.**

The experiment treatments

The study experiments comprised of eleven treatments were allocated in a complete randomized block design with three replicates.

(1)-control (100% NPK), (2)-50%NPK Without organic addition, (3)- 50%NPK + Farmyard manure (FYM), (4)-50%NPK + Compost, (5)- 50%NPK + Chicken manure, (6)- 50% NPK + Spent Coffee Ground (SCG),(7)- 50%NPK+Biofertilizer without organic addition,(8)-50%NPK + FYM+biofertilizers,(9)- 50% NPK+ Compost+biofertilizers,(10)- 50% NPK + Chicken manure+biofertilizers and(11)- 50%NPK + SCG+biofertilizers. Soil sample was collected from the experimental field at the beginning of the experiment, air dried and sieved in a 2-mm sieve. The chemical analysis was carried out according to the procedures outlined by Richards (1954), while mechanical and physical analysis was carried out according to Jackson (1958). Analyses were performed both prior to planting and after harvesting. The chemical, mechanical and physical properties of the collected soils are given in Table 1.

The used fertilizers

Biofertilizer

Paenibacilluspolymyxa and *Enterobacter cloacae* were used in the present experiment. *E.cloacae* LC07192 was provided from Microbiology Lab, Faculty of Science, Zagazig Univ., Egypt. While *P.polymyxa* was provided from the Microbiology Dept. Soils, Water and Environment Res. Inst., Agric. Res. Center, Giza, Egypt.

Preparation of talc-based formulation of bacteria

Bacterial strain was inoculated into the nutrient broth medium by loopand incubated in a rotary shaker at 150 rpm for 48 h at room temperature. One kg of talc powder was taken in a sterilized metal tray and its pH was adjusted to 7 by $CaCO_3$ at the rate of 15 g kg^{-1}. Ten grams of carboxymethyl cellulose (CMC) was added to 1 kg of talc and then autoclaved the mixture for 30 min on each of two consecutive days. The bacterial strains were grown and mixed equally (v/v), finally mixed with talc powder (Nandakumar *et al*., 2002). The 400 mL of 48 h grown bacterial suspension containing 21×10^7CFU ml^{-1} for two strains were mixed with carrier-cellulose mixture under aseptic conditions. After drying (approximately to 35% moisture content) for overnight, it was packed in polypropylene bag sealed and stored at room temperature. At the time of application, the population of bacteria in the formulation was 13×10^7CFU g^{-1} for two mixed strains of talc powder.

Inoculation process

Tubers of potato (*Solanum tubersum* L.); cv. spunta (imported from Holland) were used in the present investigation and obtained from Agric. Res. Center (ARC), Ministry of Agriculture and landreclamation. Potatotubers were cut (approximately 35 g pieces). Pieces of potato tuber were successfully washed with water and air dried then mixed with talc-based formulation by dual strains according to treatments.

Organic Fertilizers

Farmyard manure (FYM) and chicken manure was taken from a private station of animal production, while compost was taken from company for organic manures Egyptian Company for Solid Waste Recycling. El Minia Egypt (ECARU). The fresh spent coffee ground (SCG)

TABLE 1. Some physiochemical properties of the experimental soil at depth (0-30 cm) before plantation in 2019 and 2020 seasons.

Season	Physical properties				Organic matter	EC	pH	SP (%)	Nutrient content ($mgkg^{-1}$)		
	Clay	Silt	Sand	Texture	($g\ kg^{-1}$)	dSm^{-1}			N	P	K
1st season	29.9	36.9	33.2	Sand clay loam	9.3	1.89	7.88	53.5	27.7	5.07	231
2nd season	29.2	37.3	33.5	Sand clay loam	9.8	1.86	7.85	53.5	27.2	5.12	224

was collected from various coffee establishments in the Mansoura city, followed by filtration and air drying. Organic manures were added to the soil before cultivation at a rate of (49.4, 32.11, 24.7 and 27.17m^3ha^{-1}) for FYM, compost, chicken manure and SCG respectively. FYM was utilized at its recommended dose of 49.4 $m^3ha^1$and the equivalent amounts from compost, chicken manures and SCG were calculated according to their N content and weight of 1 m^3 of each. (1m^3 FYM, compost, chicken manure and SCG weighed 700, 780, 575 and 550 kg) orderly.The chemical analyses of used organic manure are shown in Table 2.

Chemical Fertilizers

100% Recommended dose were applied at a rate of 296.4kg N+185.25 kg P_2O_5+ 237.12K_2O) ha^{-1} to control treatment, on other hand, rest of treatments were treated with50% NPK in form of ammonium sulphate (20.5 % N), calcium super phosphate (15.5 % P_2O_5) and potassium sulphate (48 % K_2O).

Cultivation Process

Cultivation process was performed in first week of January for two seasons. Each treatment was replicated three times; the plot area was 10.5 m^2, which contained three rows, 5m long and 0.7 m wide. Pieces of tubers were planted at 25 cm apart between each other, depth (10-15cm) on one side of ridges. Other field practices for potato growing were followed according to the recommendation of the Ministry of Agriculture and Land Reclamation.

Sampling and Determinations

Microbial count determination in soil

The rhizosphere soil samples were collected at the initial (before treatment) and at different time intervals 30, 60 and 90 DAS (Days after sowing). Bacterial population count was performed by dissolving 10 gram of soil in Erlenmeyer flaskfilled with 90 ml of 0.85% sterile NaCl. Then put in a 120 rpm shaker for 30 minutes to obtain 10^{-1} dilution. Serial dilutions were made up to 10^{-7}. Then 1 ml. of each dilution was dropped in a sterile petri dish then respective media was poured over. Enumeration of total bacteria, nitrogen fixing bacteria, PSB (Phosphorous solubilizing bacteria), KSB (Potassium solubilizing bacteria) was done on nutrient agar medium (Difco Manual, 1974), Norris glucose nitrogen free medium (Lin *et al.*, 2002), NBRIP medium (national botanical institute's phosphate growth medium, Nautiyal, 1999) and Alexandrov medium (Hu *et al*., 2006), respectively. The number of viable cells was measured by CFU (colony forming unit/ soil (g).

Vegetative growth parameters

Samples were randomly taken from plots at 60 days after planting to determine vegetative growthparameters (plant height (cm), number of branches and leaves/plant, fresh and dry weight of shoots and dry weight of shoots (g)/plant).

Tuber yield and its components

Number and weight of tubers/plant were determined. Weight yield/fed (ton) was calculated.

Determination of photosynthetic pigment content

Three plant samples were randomly taken from each plot for determination chlorophyll a, chlorophyll b and carotenoid on the 4^{th} leaf from the plant apex. According to Metzner *et al*. (1965).

Tuber Quality

At harvest, fresh weight of tubers was taken from each plot to determine their contents of total carbohydrate, N, P, K, protein and nitrate. Carbohydrates were estimated according to anthrone method (Sadasivam and Manickam, 1996). The modified Micro-kjeldahl apparatus was employed for total N-determination as described by Jones *et al*. (1991). Protein content was calculated by multiplying N content by 6.25 (Ranganna, 1977). Total phosphorus content was estimatedspectrophotomitrically by model no. UV2100 S/N: BH 16041603003. Powersource AC220V/50Hz. FUSE: 250V/ 3.15A FAST-ACTING. according to Peters *et al*.(2003). Total potassium content was determined by photometerically by JENWAY PFP7 model according to Peters *et al.* (2003). Nitrate content was determined according to Cheng and Tsang (1998).

Statistical Analysis

The eleven treatments of two seasons (2019-2020) each were arranged in a complete randomized block design with three replicates. Data were analyzed with statistical analysis software; CoState (2005). All multiple comparisons were first subjected to analysis of variance (ANOVA). Comparisons among means were made using Duncan's multiple range test at a P level of 0.05.

TABLE 2. Chemical analysis of the organic manures used.

Organic manure	FYM	Compost	Chicken manure	SCG
Nitrogen (%)	**1.45**	**1.74**	**2.93**	**2.80**
Phosphorous(%)	**1.07**	**1.61**	**2.11**	**1.81**
Potassium(%)	0.89	1.14	1.73	1.70
Organic matter(%)	40.17	50.44	62.33	56.50
Fe(mg/kg)	27.55	48.65	57.00	51.50
Cu(mg/kg)	17.44	22.65	30.00	17.00
Zn(mg/kg)	11.55	13.54	21.00	10.50
(C/N ratio)	20.10	18.75	15.71	16.17

FYM= Farmyardmanure**,**SCG = Spent Coffee Ground

Results and Discussion

Remaining nutrients in the soil postharvest

Data presented in (Table 3), revealed that the available nutrients contents in the rhizosphere after harvesting potato plants, increased significantly due to the application of organic amendments and./or inoculation by dual bacterial strains i.e., Nitrogen fixing bacteria (*Paenibacillus polymyxa*), phosphate and potassium solubilizing bacteria (*Enterobacter cloacae*). In this concern, the highest increases in available nutrients were attained for the application of chicken manure in presence of the biofertilizers. For nitrogen content increased by (3.10 and 3.23%), phosphorous by (8.33 and 8.33%), potassium by (6.49 and 6.55%) and OM by (24.49 and 32.26 %) in the 1st and 2nd seasons, respectively comparing with control (100%NPK). While, pH values were slightly decreased to pH in soil (7.81 for 1st season and 7.78 for 2nd season). These results are in harmony with those outlined by Abou-Zeid and Bakry (2011) and AbdEl-Nabi *et al*. (2016) on potato. Integrated SCG with dual strains enhanced remaining nutrient compared with control for N content increased by (2.41 and 2.54%), P by (5.83 and 5.00%), K by (4.76 and 4.80), OM by (17.35 and 24.73%) in the 1st and 2nd seasons, respectively. Adding organic manure as a soil amendment was more benefit for soil fertility status, due to its contents of macro- (N, P and K) and micronutrients (Fe, Zn and Cu). Also, the beneficial effect of organic manures, on an increase of available nutrient contents in the soil may be attributed to their slow release of these fertilizers during the mineralization and decomposition processes as well as minimizing their possible loses by leaching (Mohammed, 2004 and Rashwan *et al.,* 2018).

Microbial population in the rhizosphere of potato plants

Data in Fig. (1) illustrated the periodical changes of total bacteria, nitrogen fixing bacteria, phosphate and potassium dissolving bacteria within the rhizosphere of potato plants. Probably, organic fertilization encourages proliferation of soil microorganisms (Bakry *et al.*, 2009). Concerning inoculation treatments, it was observed that microbial densities of the above mentioned microbial groups gradually increased with increasing the incubation period to reach their maximum values at 90 days. This is probably because these amendments influence positively plant root exudates and nutrients that stimulate microbial communities. These results are in accordance with Abdel-Magid *et al.* (1996) who reported that the total CFU counts of soil microorganisms' increase with addition organic fertilizers. On other hand, un-inoculated treatments reach their maximum values at 60 days then the population decreased thereafter and this may be attributed to the decrease in optimum temperature during winter season (Kaur *et al.*, 2017) and/or decrease in the easily oxidized organic fractions of the organic amendments (Abdelhafez *et al.*, 2018; Elcossy *et al.,* 2020 and Mohamed *et al.*, 2021). Rhizosphere of potato plants inoculated with biofertilizersin presence of organic fertilizers gave higher densities of bacteria population than the corresponding ones recorded in presence of organic fertilizers solely. It is well known that *E. cloacae* and *P. polymyxa* not only provide plants with nitrogen but also produce a variety of growth-promoting substances (Attar *et al*., 2015 and Widowati *et al*., 2019) and root exudates which in turn stimulate microbial activities. The results showed that the introduced inoculum able to survive and colonize the root zone of potato plants (Abdel-Ati *et al*., 1996 and Saleh *et al*., 1998). The obtained results indicated that microbial population was affected by biofertilizer inoculation and the stage of plant growth.Increasing bacterial population is due to establishment of bacterial population with nutrients availability (Houlden *et al*., 2008).

The interaction between different types of organic treatments and biofertilizers showed that rhizosphere of potato plants amended with chicken manure and received biofertilizers gave the highest densities of bacterial population at 90 days' time interval (97.19 $\times 10^7$, 24.00$\times 10^5$, 90.16$\times 10^4$ and 50.07$\times 10^4$) CFU g^{-1} soil for total bacteria, nitrogen fixing bacteria, Phosphorous solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB) respectively compared with other treatments. Similar results were recorded by Mandic *et al*. (2011), Abou-Zeid and Bakry (2011) on potato and Gao *et al*. (2020) on maize. The positive action of chicken manure may be due to the beneficial effect on microflora and phytohormones (Mandal *et al.,* 2007 and Zhong *et al.,* 2010). The increase in

TABLE 3. Influence of application various sources of organic fertilizers either solely or combined with biofertilizers on remaining nutrients (mg kg^{-1}), organic matter percentage and pH value in the soil postharvest during the two seasons 2019-2020.

Treatments		Nitrogen		Phosphorous		Potassium		OM		pH	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (100% NPK)		29.00	28.77	6.00	6.00	231	229	0.98	0.93	7.88	7.87
50% NPK Without inoculation	Without organic addition	28.70	28.50	5.12	5.16	225	223	0.98	0.99	7.88	7.85
	FYM	29.10	28.90	6.10	6.00	229	227	1.02	1.04	7.85	7.84
	Compost	29.43	29.30	6.18	6.15	236	231	1.05	1.07	7.83	7.82
	Chicken manure	29.55	29.39	6.30	6.26	239	235	1.13	1.14	7.83	7.82
	SCG	29.50	29.36	6.27	6.23	237	234	1.10	1.11	7.85	7.84
50%NPK With inoculation	Without organic addition	28.80	28.60	5.50	5.60	229	227	1.02	1.03	7.86	7.84
	FYM	29.30	29.10	6.15	6.10	232	230	1.10	1.11	7.83	7.83
	Compost	29.60	29.40	6.32	6.29	241	236	1.17	1.19	7.81	7.81
	Chicken manure	29.90	29.70	6.50	6.50	246	244	1.22	1.23	7.80	7.78
	SCG	29.70	29.50	6.35	6.30	242	240	1.15	1.16	7.81	7.79
$LSD_{at\ 5\%}$		0.069	0.084	0.112	0.108	1.121	0.807	0.025	0.027	0.030	0.029

FYM= Farmyardmanure, SCG = Spent Coffee Ground, OM = Organic matte bacterial population from 30 DAS to 90 DAS may be due to talc-based formulation as bacterial carrier which makes the use of bacterial strains easier and improve their stability, durability and vitality in the rhizosphere was observed within the population (Jambhulkar and Sharma, 2014; Kumar, 2014 and Shaaban *et al*., 2015). Moreover, the shelf life of bacteria varies depending upon bacterial genera, carriers and their particle size

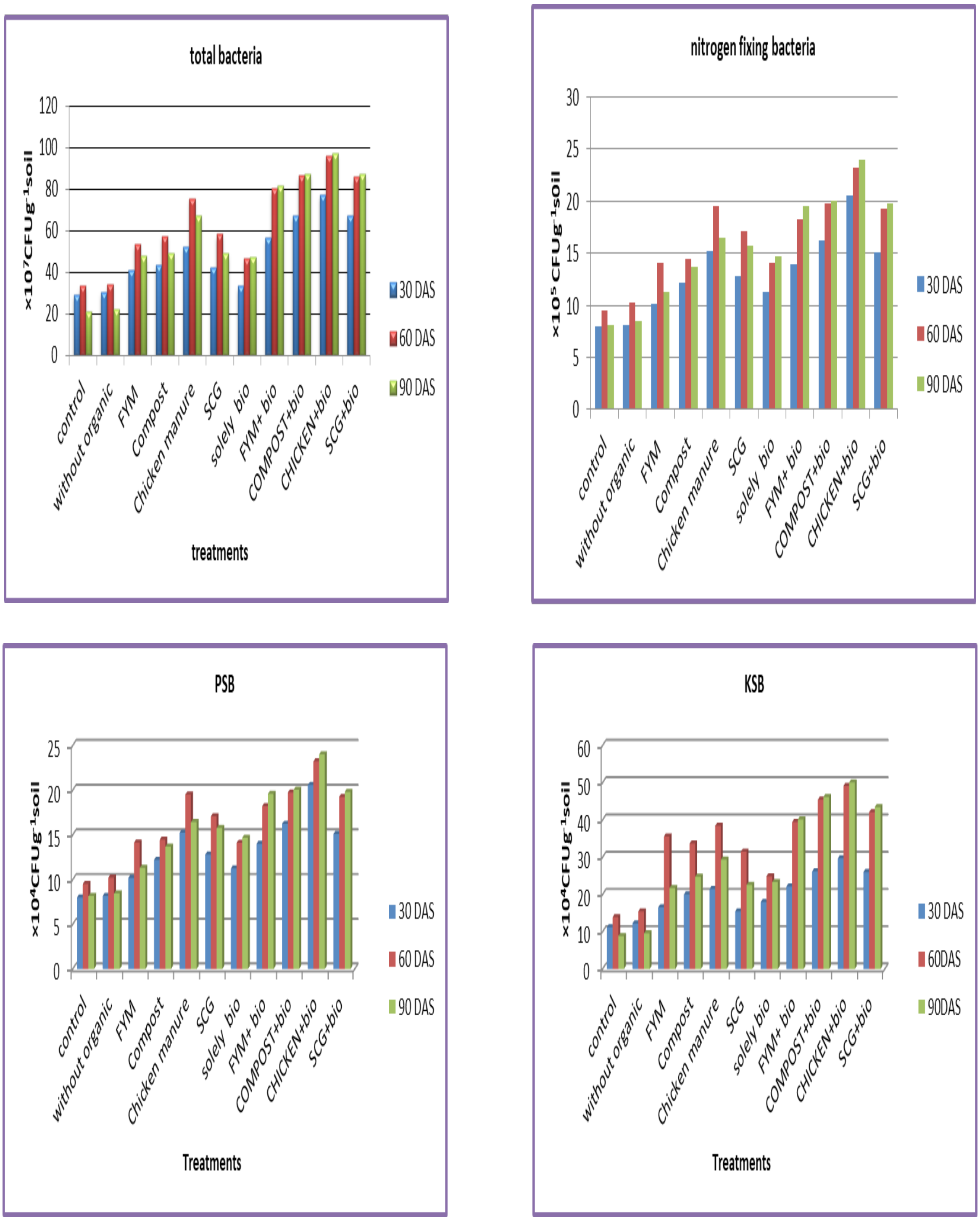

Fig. 1. Influence of application various sources of organic fertilizers either solely or combined with biofertilizers on bacterial population in the rhizosphere zone. (Average of the two seasons) .

(Bora *et al*., 2004 and Sivakumar *et al*., 2012).

Vegetative growth parameters

Data presented in (Table 4) showed that growth parameters of potato plant at the vegetative growth stage (60 days after planting) recorded in both seasons of 2019 and 2020 as affected by application of different organic fertilizers (farmyard manure, compost, chicken manure and spent coffee ground) either solely or in combination with biofertilizers (*P. polymyxa*and *E. cloacae*). With respect to integration chicken manure and biofertilizers, this treatment significantly enhanced growth parameters. Plant height recorded increasing in height comparing with control by (1.07 and 3.76%) in 1st and 2nd seasons respectively. Also, it significantly increased the number of branches by (8.33 and 8.00%), leaves number by (1.79 and 4.69%), fresh weight by (1.28 and 2.79%) and dry weight by (3.91 and 4.52%) for 1st and2nd seasons respectively. These results were in line with those obtained by Kantikowati et al. (2019) and Zaki et al. (2019).

The positive action of chicken manure on vegetative growth may be due to the fact that it contains a large percentage of organic matter besides being rich in macro and micronutrients that improve plant vegetative growth (Bhangoo *et al*., 1988). On the other hand, bacterial inoculation probably enhanced plant growth through the production of hormones, especially IAA (Sheng and Huang, 2001) which increased cell division and elongation. *E. cloacae* is not only a N fixer (Mauricio *et al*., 2009) but also has the capability of phosphate and potassium solubilizing ability (El-Saied *et al.*, 2020). Phosphorus and nitrogen have important roles in the molecular structure of nucleic acids resulting in increased protein synthesis and protoplasm formation (Mengel and Kirkby, 1987 and El-Shanshoury, 1995).

Tuber yield and its components

Effects of different types of organic fertilizers added as either solely or combination with biofertilizers on yield of potato during two successive seasons were represented in (Table 5). As for the synergetic effect of various organic fertilizers and biofertilizers (*P. polymyxa* and *E. cloacae*) on yield parameters, values revealed that chicken manure combined with inoculated bacteria recorded enhancing in number of tubers/plant by (5.26 and 3.00%); weight of yield/plant by (4.35 and 4.43%); and this consequently increased weight yield/ha. by (4.34 and 4.36%) for 1st and 2nd seasons respectively comparing with those received recommended dose of NPK. These results were consistent with the findings of El-Sayed *et al*. (2014), Kantikowati *et al*. (2019) and Zaki *et al*. (2019). The positive effect of chicken manure could be due to a higher content of organic matter and nitrogen as well as some nutrients which led to significant improvement in the nutritional status of potato and this, in turn, was reflected on potato yield (Kannaiyan, 2002). Also, solubilization of P and K in soil by *E.cloacae* probably took place and this consequently increased P and K availability in soil (Park *et al*., 2003). Furthermore, nitrogen fixation increased by *P. polymyxa* affecting positively vegetative growth and yield of potato plants (Premsekhar and Rajashree, 2009). It is worth to mention that plots received SCG combined with inoculated bacteria gave positive effects on yield attributes. This improvement could be related to the richness of fresh SCG in mineral nutrients, especially N (Table 2) (Gomes *et al*., 2013).

Photosynthetic pigments content

Regarding to (Table 6) represented application of different types of organic fertilizers in conjunction with or without biofertilizers on photosynthetic pigments during two seasons. Results showed that, soil amended with chicken manure and biofertilizers (*P. polymyxa* and *E. cloacae*) exhibited significantly higher contents of chlorophyll a, chlorophyll b and carotenoid contents by (11.43 and 5.16%, 26.32 and12.60% &18.97 and 11.17%), respectively for 1st and 2nd seasons comparing with control (100% NPK). These results have been matched with Abd El-Nabi *et al*. (2016) and Singh *et al.* (2018). While, combining SCG with bacteria inoculation increased chl a content by (5.71 and 4.39%), chl b by (19.21 and 10.04%) and carotenoid by (11.03 and 6.33%)for 1st and 2nd seasons,respectively comparing with 100%NPK. The improvement in chlorophyll contents may be a result of promotion of cytokinins secreted by N_2 fixatives to delay senescence of plant tissues through their effect in reducing chlorophyll loss (Gaballah, 1995). Also, phosphate solubilizing bacteria stimulate chlorophyll synthesis through stimulation of pyridoxal enzyme formation that plays an important role in amino levulinic acid synthetase as a primary compound in chlorophyll synthesis (Al-Fraihat *et al.,* 2011 and Hassan and

TABLE 4. Influence of application various sources of organic fertilizers either solely or combined with biofertilizers on the vegetative growth parameters of potato plants during the two seasons 2019-2020.

Treatments		Plant height (cm)		No. of Branch		No. of leaves		F. wtshoot (g/plant)		D. wt shoot (g/plant)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (100% NPK)		93.50	106.50	12.00	12.50	56.00	64.00	78.00	80.75	20.73	22.12
50% NPK Without inoculation	Without organic	64.75	70.00	5.50	6.00	35.50	39.00	39.19	43.27	10.05	10.18
	FYM	82.50	81.50	8.00	8.00	43.00	48.50	53.37	57.54	14.50	15.12
	Compost	87.00	88.75	9.50	9.45	45.75	51.00	61.44	63.50	15.57	15.79
	Chicken manure	90.50	93.80	10.00	11.50	48.00	54.70	68.80	68.77	17.00	16.83
	SCG	88.50	89.50	10.00	10.50	46.00	53.50	67.21	68.00	16.75	16.35
50%NPK With inoculation	Without organic addition	77.00	73.50	6.50	6.50	37.75	42.50	44.82	47.12	12.14	13.14
	FYM	88.90	91.00	10.80	12.00	46.50	55.50	68.91	70.18	17.08	17.50
	Compost	90.75	97.50	10.80	12.00	53.00	58.75	73.50	77.14	19.21	20.31
	Chicken manure	94.50	110.50	13.00	13.50	57.00	67.00	79.00	83.00	21.54	23.12
	SCG	92.75	108.00	11.50	13.00	53.50	63.50	78.17	81.90	21.27	22.81
LSD at 5%		1.469	1.578	0.577	0.667	0.769	1.095	0.644	0.550	0.450	0.402

FYM= Farmyard manure,SCG = Spent Coffee Ground

TABLE 5. Influence of application various sources of organic fertilizers either solely or combined with biofertilizers on tuber yield and its components of potato plants during the two seasons 2019-2020.

Treatments		Number of tubers/ (plant)		Weight tubers/ plant (g)		Weight yield/ha. (ton)	
		1st	2nd	1st	2nd	1st	2nd
Control	(100% NPK)	4.75	5.00	575.00	587.50	34.09	34.83
50% NPK Without inoculation	Without organic	3.15	3.35	441.00	459.00	26.13	27.22
	FYM	3.50	3.65	469.00	487.00	27.81	28.87
	Compost	4.00	4.00	483.50	495.00	28.65	29.34
	Chicken manure	4.15	4.20	505.75	510.75	29.99	30.28
	SCG	4.00	4.15	488.85	500.00	28.97	29.64
50%NPK With inoculation	Without organic addition	3.25	3.50	469.00	471.00	27.81	27.91
	FYM	4.50	4.65	498.00	493.50	29.52	29.24
	Compost	4.75	4.75	525.50	537.50	31.15	31.86
	Chicken manure	5.00	5.15	600.00	613.50	35.57	36.35
	SCG	4.80	5.00	560.00	571.75	33.19	33.89
LSD at 5%		0.0971	0.118	5.187	7.268	0.269	0.405

FYM= Farmyard manure,SCG = Spent Coffee Ground

TABLE 6. Influence of application various sources of organic fertilizers either solely or combined with biofertilizers on photosynthetic pigments during the two seasons 2019-2020.

Treatments		Chl a (mg/g)		Chl b (mg/g)		Total chlorophyll (mg/g)		Cartenoid (mg/g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (100NPK)		0.805	0.775	0.380	0.365	1.185	1.14	0.580	0.537
50% NPK Without inoculation	Without organic	0.521	0.449	0.192	0.187	0.713	0.636	0.310	0.277
	FYM	0.602	0.537	0.254	0.271	0.856	0.808	0.361	0.319
	Compost	0.641	0.582	0.307	0.288	0.948	0.870	0.418	0.371
	Chicken manure	0.711	0.673	0.372	0.331	1.083	1.004	0.473	0.436
	SCG	0.685	0.641	0.338	0.305	1.023	0.946	0.441	0.409
50% NPK Withinoculation	Without organic addition	0.571	0.482	0.216	0.191	0.787	0.673	0.327	0.283
	FYM	0.736	0.703	0.361	0.330	1.097	1.033	0.509	0.473
	Compost	0.821	0.778	0.404	0.371	1.225	1.149	0.583	0.520
	Chicken manure	0.897	0.815	0.480	0.411	1.377	1.226	0.690	0.597
	SCG	0.851	0.809	0.453	0.393	1.304	1.202	0.644	0.571
$LSD_{\text{at 5\%}}$		0.011	0.014	0.016	0.016	0.020	0.019	0.015	0.015

Chl a = chlorophyll a, Chl b = chlorophyll b, FYM= Farmyard manure , SCG = Spent Coffee Ground

Ali, 2013).

The quality of tubers

Results in (Table 7) showed the effect of different types of organic fertilizers with or without biofertilizers (*P. polymyxa* and *E. cloacae*) on potato tubers quality. Plots that received chicken manure in combination with biofertilizers exhibited significantly higher chemical constituents in potato tubers than those received the recommended NPK doses by (3.03 and 3.40 %, 5.63 and 10.96%, 4.04 and 9.72% & 3.05 and 3.40%) for N, P, K and protein content in 1st and 2nd seasons, respectively, as well as enhanced total carbohydrate by (3.54 and 4.60%). Similar findings were recorded on peache (Fayed *et al*., 2019) and potato (Zaki *et al*., 2019). Increase in nutrient concentration as a result of biofertilizers application may be due application of free living N- fixing bacteria that increasing available nitrogen and consequently nutrient absorption by providing fixed nitrogen to plants as well as release certain chemical substances that enhance the availability of other nutrients for plants (El-Naqme *et al*., 2019 and Khan *et al.,* 2019). Moreover, *E. cloacae* secretes organic acids which increase the solubility of phosphate and potassium (El- Mokadem and Sorour, 2014).

Regarding to nitrate content in potato tubers, Chicken manure + mixed strains gave decreasing in nitrate content compared with 100%NPK application during two seasons respectively by (60.71 and 57.69 %). These results were in the same line with El-Sayed *et al*. (2014) and Zaki *et al*. (2019) on potato plant. On the other hand, SCG combined with biofertilizers gave tubers containing less nitrate by (57.14 and 53.85%) compared by control. It was observed that organic potatoes contain significantly lower levels of nitrate than conventionally produced tubers (Table 7). In addition, biofertilizers inoculation proved to be very effective in increasing potato quality by reducing nitrate content compared to un-inoculated ones.

Conclusion

Combining organic manure (chicken manure at rate 24.7m^3/ha.) with dual bacterial inoculation (*Paenibacillus polymyxa* as nitrogen fixer and *Enterobacter cloacae* as phosphate and potassium dissolving bacteria) as biofertilizers exhibited an enhancement in growth and potato productivity with best quality traits. This treatment also had a ppositive consequences on soil fertility. Therefore, it will be recommended a substitute to the use of classical fertilizers. On the other hand, combining spent coffee ground with biofertilizers gave improved results.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest

There is no conflict between the authors of this study.

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Consent for publication

All authors declare their consent for

TABLE 7. Influence of application various sources of organic fertilizers either solely or combined with biofertilizers ontuber quality of potato plants during the two seasons 2019-2020.

Treatments		N (%)		P (%)		K (%)		Protein (%)		Nitrate (%)		Total carbohydrate (%)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Control (100%NPK)		2.31	2.35	0.710	0.730	2.23	2.47	14.44	14.69	0.28	0.26	47.13	46.97
50% NPK Without bacteria inoculation	Without organic	1.85	1.82	0.310	0.340	1.19	1.25	11.56	11.38	0.27	0.25	34.81	35.62
	FYM	1.96	2.00	0.480	0.520	1.36	1.42	12.25	12.50	0.22	0.21	37.00	38.11
	Compost	2.02	2.11	0.520	0.590	1.64	1.69	12.63	13.19	0.20	0.20	38.64	39.22
	Chicken manure	2.14	2.24	0.570	0.660	1.96	1.81	13.38	14.00	0.17	0.16	41.51	42.36
	SCG	2.03	2.19	0.520	0.610	1.78	1.75	12.69	13.69	0.18	0.17	39.18	39.86
50% NPK Withbacteria inoculation	Without organic	1.90	1.91	0.400	0.440	1.27	1.34	11.88	11.94	0.24	0.24	35.23	36.72
	FYM	2.19	2.29	0.590	0.690	1.94	1.93	13.69	14.31	0.15	0.14	44.15	43.92
	Compost	2.27	2.37	0.640	0.720	2.13	2.20	14.19	14.81	0.15	0.13	45.53	45.74
	Chicken manure	2.38	2.43	0.750	0.810	2.32	2.71	14.88	15.19	0.11	0.11	48.80	49.13
	SCG	2.30	2.37	0.700	0.740	2.26	2.55	14.38	14.81	0.12	0.12	47.00	46.81
LSD $_{at\ 5\%}$		0.015	0.040	0.017	0.016	0.049	0.047	0.056	0.098	0.010	0.013	1.43	1.41

FYM= Farmyard Manure ,SCG = Spent Coffee Ground publication.

Author contribution

All authors of this study shared in all stages from the beginning with idea, design and experimental work up to interpretation of data

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