Plant Archives Vol. 19 No. 2, 2019 pp. 2513-2521 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

COMBINED APPLICATION OF DIFFERENT SOURCES OF NITROGEN FERTILIZERS FOR IMPROVEMENT OF POTATO YIELD AND QUALITY

Emad A. Abdeldaym[1], El-Sawy, M.B.I.[2] and M.A.El-Helaly[1]

[1]Department of Vegetable Crops, Faculty of Agriculture, Cairo University, El-Gama St., 12613 Giza, Egypt.
[2]Department of Horticulture, Faculty of Agriculture, Kafrelsheikh University, Kafrelsheikh, Egypt.

Abstract

This investigation was conducted to study the impact of different sources of nitrogen fertilizers on soil nutrient content and quality of potato (*Solanum tuberosum* L.), cultivar "Spunta", at the experimental station of Faculty of Agriculture, Cairo university, Egypt during winter season of 2017- 2018. Treatments of field experiment were organized as randomized complete block design with four replicates. Six treatments were used in this experiment which one control and the remaining treatments consist combination of farm compost, biofertilizer and mineral fertilizer. Combined application of biofertilizer with other sources of nitrogen fertilizers significantly improved dry matter, starch and protein contents of potato tuber. Similar trends were observed in concentrations of N, P, K and Ca in potato tuber. Furthermore, microbial inoculum not only increased nutrient assimilation by potato plant but also increased soil nutrient contents, such as available N (NH_4-N and NO_3-N), available P and exchangeable content. It can be concluded that combination of nitrogen fixer biofertilizers with various sources of nitrogen fertilizers can be better solution for improving nutritional quality and yield of potato in less fertile soils.

Key words : *Solanum tuberosum*, tuber quality, biofertilizer, nutrient concentration.

Introduction

Today, the agriculture facing serious challenges, this is in respect of producing enough to feed escalating world population. This should be accomplished with less reliance on renewable resources (Tilman *et al.,* 2011). The last three decades with increased world growing concern towards the quality, not only the quantity, of agricultural products. Several goods of agricultural practices (GAPs) are already introduced, monitored and regulated to secure, good quality commodities for both local and export markets. Potato (*Solanum tuberosum* L.) is one of most vital *solanaceous* vegetable crops contributing to the world food requirements and occupied the fourth position after rice, wheat, and maize in production size (Walker *et al.,* 1999). Potato is economical food which is rich to starch, vitamin C and B and minerals and appropriate amounts of essential amino acids (Paul Khurana and Naik, 2003). Fertilization is considered one of the most limiting factors in potato production. Several reports compared the organic and synthetic fertilization of potato and revealed that best results are achieved by the last practice in terms of quantity and quality of tubers (Palmer *et al.,* 2013; Singh and Lallawmkima, 2018). Overuse of the mineral fertilizers for long period not only makes soils degraded, polluted and less productive but have also posed severe health and environmental problems (Cockburn *et al.,* 2011). For these reasons, several countries worldwide modified their policies in agriculture and use organic and biological fertilizers as a source of nutrients (Saikia and Upadhyaya, 2011; El-Sayed *et al.,* 2015). On the other hand, the sustainability has become one of the most important aims in agriculture, taking into considerations the economic development, social justice, and environment security. The sustainable agriculture systems are depends on utilization of renewable inputs (fertilizer, pesticides, water etc.) which reduce the environmental damages and achieve a profit for poor farmers. Utilization of organic and biological fertilizers as source of nutrients and satisfy plant requirement could be an unavoidable practice in futures, especially for resource limit countries (Kumar *et al.,* 2013). Additionally, wide range of those fertilizers are available and can be used in agriculture.

Application of different fresh and composted organic wastes play key role in soil potato production and soil fertility (Abdeldaym *et al.,* 2018; Shehata *et al.,* 2018). These wastes can improve organic matter, nutrient content, water hold capacity and aggregation of soil as well as soil borne diseases, in particular phytoparasitic nematode (Abdel-Dayem *et al.,* 2012; Abdeldaym *et al.,* 2014). Biofertilizers is defined as living microorganisms that provide the certain nutrient to plants, by fixing atmosphere N or dissolving soil P, which enhance soil health and crop productivity (Singh and Lallawmkima, 2018). Biofertilizers are available, easy to use, low-price and eco-friendly (Kumar *et al.,* 2013). Application of N fixing bacteria like Azotobacter increase the amount of available N in soil by fixing atmospheric N gas to meet potato requirement (Wu *et al.,* 2005). Likewise, P- K solubilizing biofertilizers may increase available P and K in soil and improve their uptake by plant (Goldstein and Liu, 1987). Therefore, judicious combination of biofertilizers with farm compost and half does of inorganic nitrogen fertilizer had been suggested in this current research for recovering of soil nutrients and for obtaining high potato yield and quality.

Materials and Methods

Two filed experiments were conducted at experimental station of the Faculty of Agriculture, Cairo University, Giza, Egypt during the two successive winter seasons 2017 and 2018. The experimental location lies between latitude 30.0131°N, and 31.2089°E with an elevation of about 694 m below sea level. Soil of experiment was deeply ploughed and divided into plots (6×6 m), each separated by a 50 cm buffer zone. The experiment included 6 treatments Table 1 arranged in a randomized complete block design (RCBD) with four replicates. Seed of potato tubers (*Solanum tuberosum* L., cv. Sponta) were planted on 2nd of January at space 70 cm between rows and 25 cm among plants. The nitrogen fertilizer treatments started before sowing and repeated 2 times post completed planting. Farm compost was made of farm solid wastes such as plant restudies and cow manure. This compost was added completely during land preparation. The chemical characteristics of farm compost are presented in table 3. In case of biological treatments, seed tuber were dipped in Biofertile liquid for 30 min prior to sowing and added biofertilizer 2 weeks after completed planting. The recommended doses of nitrogen (180 ammonium nitrate), potassium (96 kg of potassium sulphate / fed) and phosphors (60 kg of calcium super phosphate /fed) were added according to local good agriculture practice. Soil samples were taken before treatments application to identify the soil physiochemical properties table 3 and after treatment addition to record the variation on soil nutrients content. Potato tuber were harvested on 30th of April. Potato tubers of selected plants were collected from each treatment and weighted to calculate average of tuber yield per plant.

Soil and compost analysis

For determination of soil properties, eight sub-samples were taken from each plot on 28th of December (before sowing tuber) and on 30th of April (after harvesting) using W shape at 0–25 depth by augur, after removing weeds and 5 cm from soil surface. The subs-samples of each plot were homogeneously mixed and 1 kg composite sample obtained over quartering. Composite soil sample of each treatment was air dried, sieved through 2 mm sieves before laboratory analyses. Soil texture was assessed only at the beginning of the experiment by the pipette method (Indorante *et al.,* 1990) and textural class was identified by the USDA soil textural classification system. Soil pH was determined in a soil-water solution at a ratio of 1:2. (w/v) using a pH meter, electrical conductivity (EC) was determined in suspended solution at a ratio of 1:2 (w/v) using EC meter. Total nitrogen (N) and mineral nitrogen (N_{min}) were determined using Kjeldahl digestion method (AOAC, 1990). Organic carbon (OC) was determined using Walkley and Black method (1934). Available phosphorus (P) was estimated by Olsen method (Olsen *et al.,* 1954). Exchangeable K and Ca were extracted in ammonium acetate and measure using a flame-photometer (CORNING M 410, Germany). Compost samples were analyzed before sowing the potato tuber for pH (3:50, w/v), EC (1:10, w/v), organic N measured using micro- Kjeldahl methods with minor modification (AOAC, 1990) and K contents was determined using flam photometer. Organic carbon was analyzed according to the Springer–Klee based method (Ciavatta *et al.,* 1989).

Data collection

Samples of potato tuber were selected randomly from each treatment for analytical analysis. Tuber nitrogen content was determined using Kjeldahl digestion method. Crude protein content was assessed by multiplying the total nitrogen content in the conversion factor (6.25). Phosphorus concentrations was determined colorimetrically as described by Olsen method. Potassium and calcium concentrations in tuber were determined using a flame-photometer (CORNING M 410, Germany). Fresh tuber samples were dried in forced air oven (105^{o}C) till constant (for 72 hrs) the weight to determine dry matter percentage. The starch content (%) was calculated according to Simmonds (1977).

Table 1: Description of treatments used in the experiment.

Treatment	Composition	Rate
T_1	Ammonium nitrate (N), Calcium super phosphate (P) and Potassium sulphate (K) (Control)	N.P.K (90: 60: 96 Kg/ fed)
T_2	Ammonium nitrate (N), Calcium super phosphate (P) and Potassium sulphate (K)	N.P.K (180: 60: 96 Kg/ fed)
T_3	Ammonium nitrate (N), Calcium super phosphate (P) and Potassium sulphate (K) + Biofertile product (*Azospirillum brasilense, Azotobacter chroococcum, Bacillus polymexa,Enterobacter agglomerans, Klebsiella pneumonia and Pseudomonas putida*)	N.P.K (90: 60: 96 Kg/ fed) + Biofertile product (5 L/fed) N.P.K (90: 60: 96 Kg/ fed) + Farm compost (7.5 ton/fed).
T_4	Ammonium nitrate (N), Calcium super phosphate (P) and Potassium sulphate (K) + Farm compost	N.P.K (90: 60: 96 Kg/ fed) + Farm ompost (7.5 ton/ fed) + Biofertile
T_5	Ammonium nitrate (N), Calcium super phosphate (P) and Potassium sulphate (K) + Farm compost + Biofertile product (*Azospirillum brasilense, Azotobacter chroococcum, Bacillus polymexa, Enterobacter agglomerans, Klebsiella pneumonia and Pseudomonas putida*)	product (5 L/fed)
T_6	Farm compost + Biofertile product (*Azospirillum brasilense, Azotobacter chroococcum, Bacillus polymexa, Enterobacter agglomerans, Klebsiella pneumonia and Pseudomonas putida*)	Farm compost (7.5 ton/ fed)+ Biofertil product (5 L/fed)

Data Analysis

Test of normality distribution was done according to Shapiro and Wilk method (1965), by using SPSS software version 10. Computer package. Combined analysis of variances cross two seasons was computed after running Bartelet test according to Snedecor and Cochran (1994). The obtained data from combined analysis were subjected to the statistically analysis of variance and means were compared according to Duncan's multiple range test ($p \leq 0.05$) using MSTATC. Furthermore, principal component analysis (PCA) was used in order to determinate the relationships between observed variables and a new set of non-associated variables (parameters).

Results and Discussion

Meteorological data

The meteorological data was recorded during the experimentation over two seasons, as shown in Fig. 1. The average of maximum temperature was recorded in April (21°C and 23°C at first and second season, respectively) and the average of minimum was in January (4°C and 5°C at first and second season, respectively). The temperature was increased gradually during the harvest periods. The average of rainfall during the potato crop cycle in first year (2017) was 107.5 mm and 102 mm was in second year (2018).

Characterization of experimental land

The analytical data showed that soil of experimental area was characterized by clay-loam texture (sand 45%, silt 26 and clay 29 %,) according to USDA classification, low organic matter (OM) and N_{min} content as well as high alkalinity table 2. Available P content of experimental land was low considering a moderate range of 12-20 mg per kg of soil (Cook, 1988). The electric conductivity (EC) of soil was 0.2 dSm^{-1} which can be defined non saline according to salinity class (Dellavalle, 1992).

Properties of applied compost

Physiochemical properties of used compost in the experiment are shown in table 3. Compost used is presented neutral pH value, high organic carbon (OC) and total N content whereas C/N ratio was lower than critical level (20). Furthermore, this amendment contains on appropriate amount of P, K and Ca for plant growth.

Fertilization effectiveness in soil nutrient content

Application of biofertilizer (biofertile) had variably impacts on soil macronutrient concentration. ANOVA analysis revealed that combined application of biofertile with farm compost and mineral fertilizer (T_5) achieved a highest soil NH_4-N content when compared to all other treatments (Fig. 2A). On the other hand, maximum value of soil NO_3-N content was recorded when combined the biofertile with mineral N fertilizers alone (T_3) if compared to all other treatment (Fig. 2B). The significant effect of biofertile with farm compost and mineral fertilizer on increasing available N (NH_4-N + NO_3-N) in soil at the end of crop cycle could be associated to increase N-fixing bacteria population in soil and slowly release of N from compost (Jnawali *et al.,* 2015 ; Abdeldaym *et al.,* 2018). Furthermore, many researchers suggested that increase the mineral nitrogen in soil inoculated with free living nitrogen fixer bacteria is related to fixing atmospheric nitrogen, converting the N into NH_4-N or NO_3-N during the mineralization processes or excretion of ammonia in

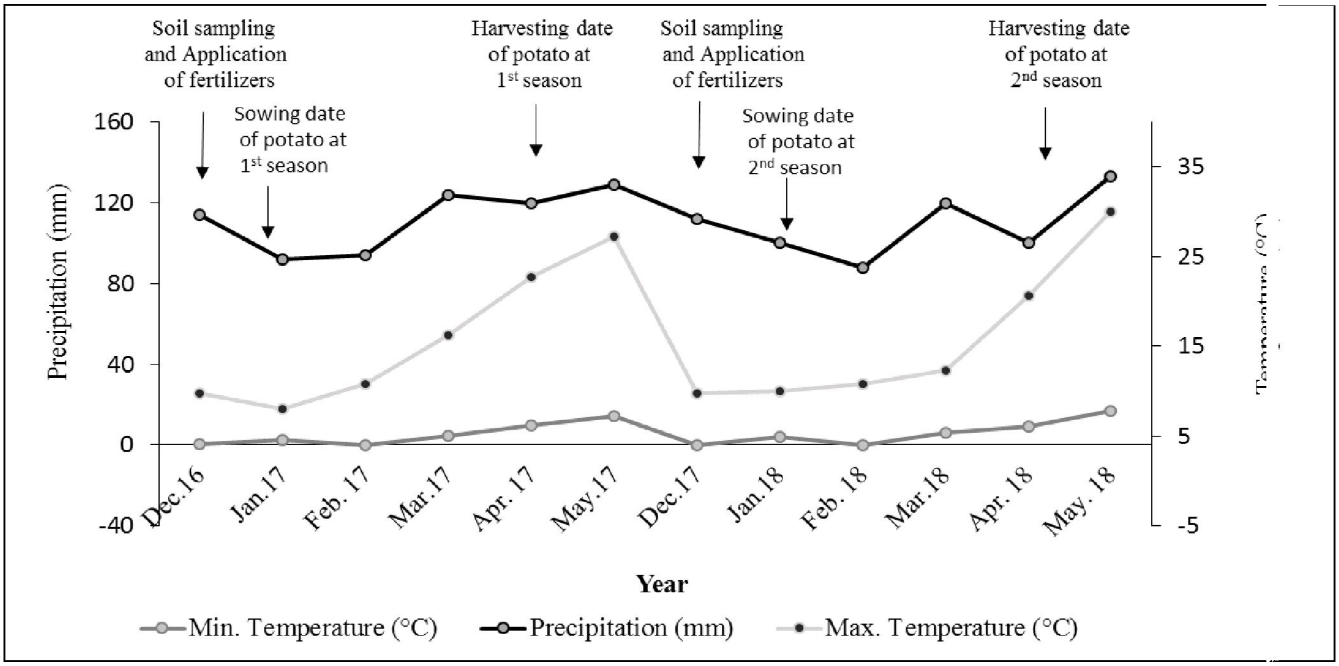

Fig. 1: Climatic condition during potato growth cycle.

Table 2: Physiochemical properties of soils before fertilizers application during 2017 and 2018.

Soil property	2017	2018
Clay (ø<0.002mm)	*29	*29
Sand (ø<0.5mm)	45	45
Silt (0.002mm<ø<0.5mm)	26	26
pH (1:2.5 H_2O)	7.9	8.1
EC (dS.m^{-1})	0.41	0.23
O.C (%)	0.92	0.82
O.N (%)	0.14	0.13
C/N ratio	6.57	6.31
N_{min} (mg.kg^{-1})	33.13	23.37
P_{Av}. (mg.kg^{-1})	2.47	2.38
Exchangeable Ca (cmol.kg^{-1})	16.32	17.5
Exchangeable K (cmol.kg^{-1})	2.57	2.41

*Each data is an average of five replications.

Table 3: Chemical properties of used compost during both seasons.

Farm compost property	2017	2018
Moisture content (%)	*27	*22
pH (3:50, w/v)	7.4	7.3
EC (1:10, w/v, dSm^{-1})	3.2	3.8
O.C %	17.30	18.1
N%	1.5	1.340
C/N ratio	11.5	13.50
P%	0.53	0.42
K%	0.81	0.78
Ca%	0.97	0.84

*Each data is an average of five replications.

the soil rhizosphere (Wu *et al.,* 2005; Jnawali *et al.,* 2015). Highest values of soil P content compared to other fertilizers (2C). This results can explained by the release of organic acids that reduced immobilization of P when mixed with compost in soil (Wu *et al.,* 2019). Particularly, large portion of P fertilizer rapidly immobilized after addition, and becomes unavailable to crops. Therefore, application of organic fertilizers with P fertilizer to reduce the chemical fixation of phosphorus in soil is recommended (Jiménez *et al.,* 2019). However, the maximum value of exchangeable K in soil was observed in T_2 and the lowest value was in T_1 (2D). On contrary, significant reduction of P and K contents in soil fertilized with biofertile and farm compost could be attributed to the high uptake of those elements during the growth cycle or/ and to imbalance between their unavailable form and the available one. Similar findings were observed by Mukhongo *et al.*, (2017) who stated that application of biofertilizers with mineral fertilizers reduced the availability of P and K in soil due to mobilization of those elements by microorganisms of biofertilizers were generally lower than what was applied by NPK alone Rao *et al.*, (1999) reported that nutrients depletion from soil could be occurred when the applied amount of nutrient less than the amount of that required for plants growth.

Fertilization effectiveness in potato production

Fig. 3 Shows a potato production and quality were significantly influenced by different sources of nitrogen fertilizers application. Maximum tuber yield per plant was recorded in T_5 (800 g / plant) in comparison to T_1 (600 g/

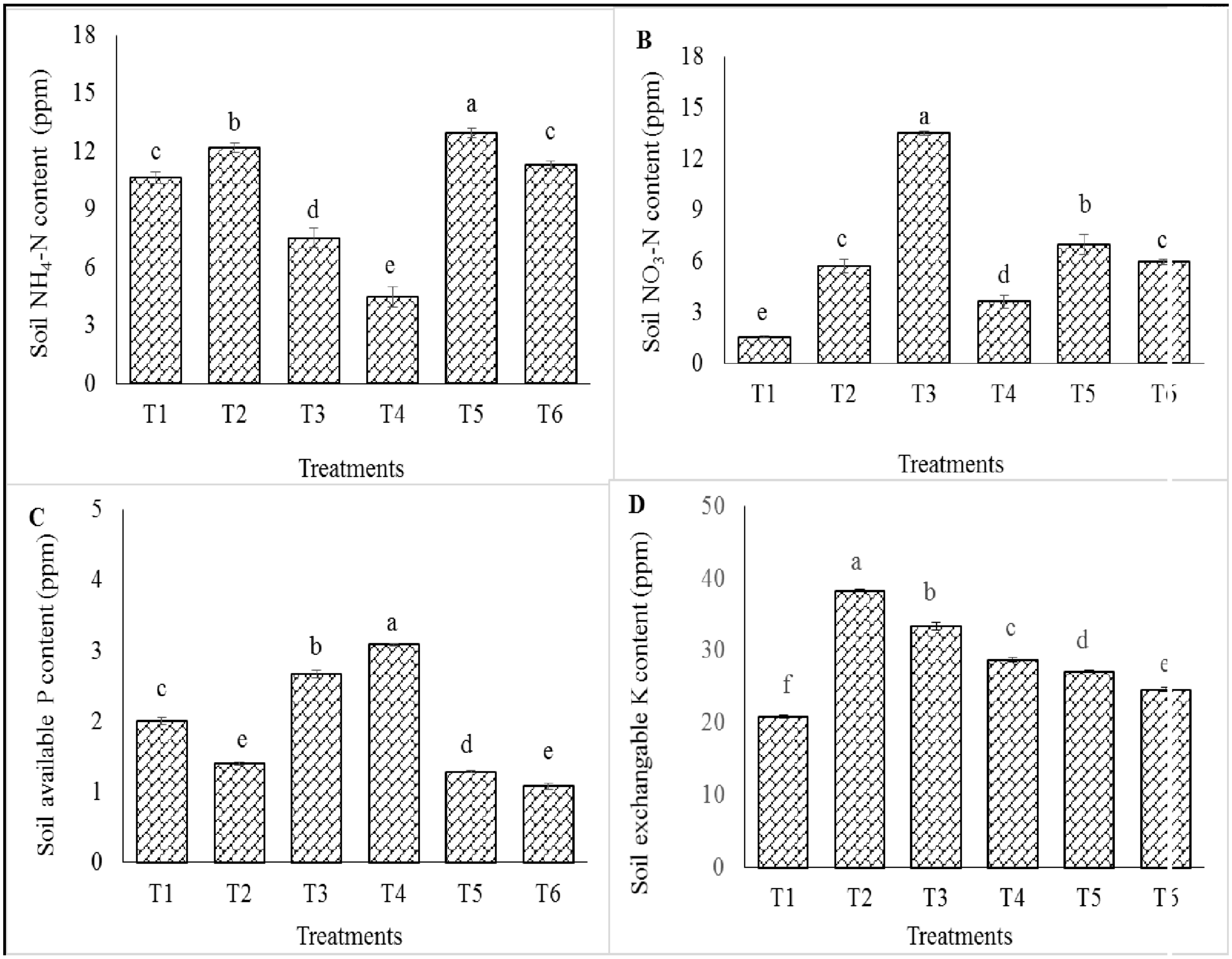

Fig. 2: Effects of biofertilizer (biofertile) along with other fertilizers on (A) NH_4-N, (B) NO_3-N, (C) available P and (D) exchangeable K content in soil. Different letters indicate significant differences at P d”0.05 by Duncan's multiple range test. Bars indicate to standard division (±SD).

plant), as presented in Fig. 3A. On the other hand, the lowest value of tuber yield was observed in T_3 which it was 480 g/plant. This result was harmony with Singh and Lallawmkima (2018) on potato who found that combination between mineral N fertilizers and biofertilizers improved plant growth and total yield. Improvement of total yield could be resulted of efficient utilization of nutrients by the plant that supplied by chemical fertilizer alone in T_2 or in combination with farm compost and biofertile in T_5. Highest potato yield had also been stated by Mohammadi *et al.,* (2013) who had reported that combination of mineral fertilizers (urea) with *Azotobacter* and *Azospirillum* significantly improved the tuber yield than single application. Furthermore, several reports confirmed that the combined application of bio-fertilizer with organic and/ or mineral fertilizers enhanced the vegetative growth, photosynthesis rates, dry matter accumulation, tuber number and tuber weight per plant (Hussain *et al.,* 1993; Yao *et al.,* 2002; Dash and Jena, 2015; Kumar, 2019)

Fertilization effectiveness in tuber quality

Concerning the tubers quality as expressed as percentage of dry matter, starch and crude protein significantly affected by source of fertilizers ($P \leq 0.05$) as shown in Fig.s 3 B, C and D. It was clearly noticed that the maximum tuber quality were recorded in T_5 while the minimum quality was recorded in T_1 (Fig. 3). Highest percentage of dry matter content in potato tubers was achieved by treatments T_5 and T_3 (19.6% and 19.4%, respectively) followed by T_6 and T_2 (18.8 % and 17.91%, respectively) compared to T_1 (16.9 %), as illustrated in Fig. 3B. Similar trend was noted in starch content of potato tuber (Fig. 3C). The maximum concentration of starch in tubers was observed in T_5 and T_3 treatments (13.25% and 13.43%, respectively) and the lowest values were found in T_1 (9.02%). Furthermore, simple regression

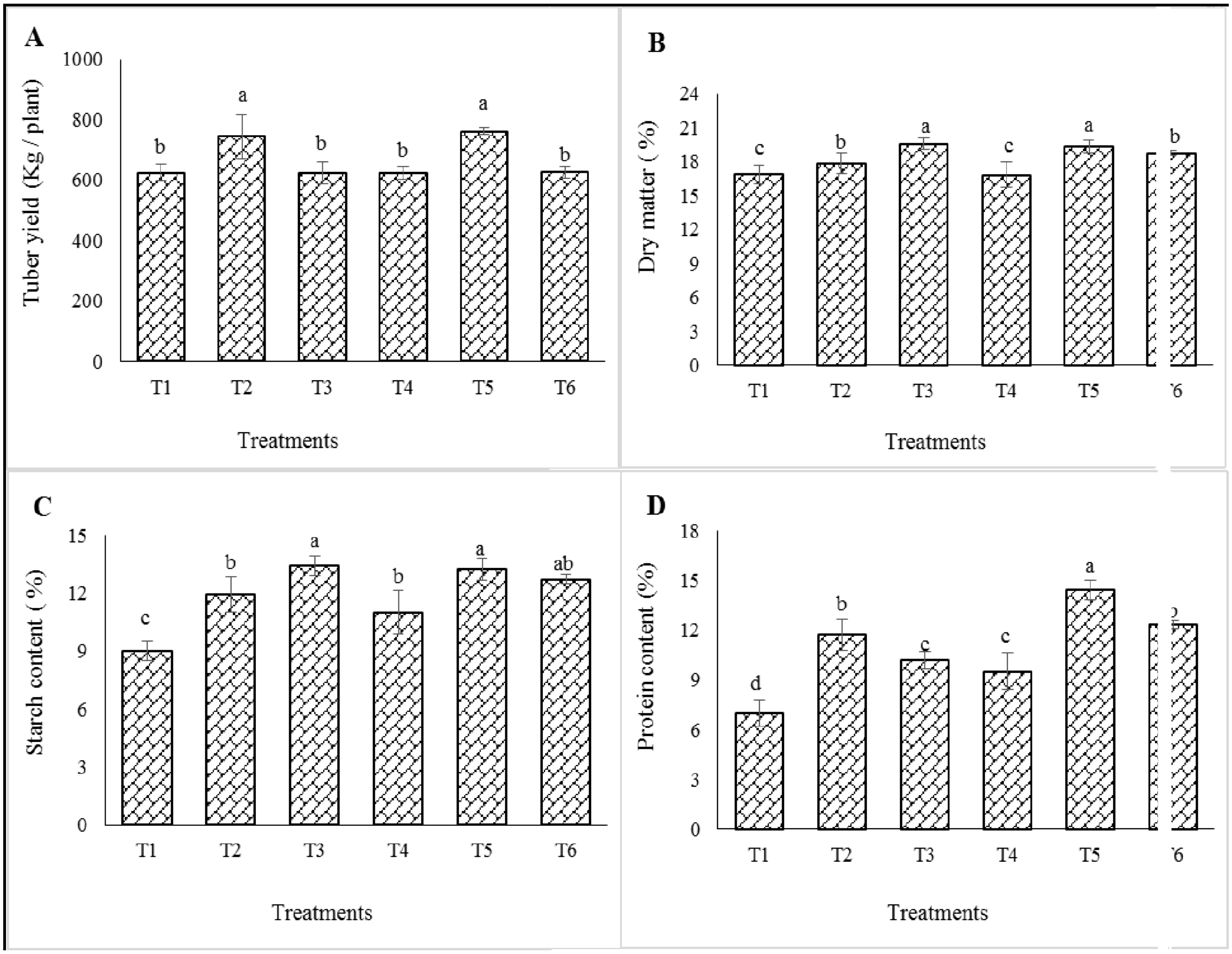

Fig. 3: Effects of biofertilizer (biofertile) along with other fertilizers on (A) tuber yield, (B) dry matter, (C) starch and (D) protein content of potato tuber. Different letters indicate significant differences at $P \leq 0.05$ by Duncan's multiple range test. Bars indicate to standard division (±SD).

analysis showed strong positive correlation between starch content and dry matter ($r^2 = 0.92$; Fig. 4). The high tuber quality could be associated to efficient utilization of nutrients by potato plants for carbohydrates metabolism and proteins synthesis which are responsible to dry matter accumulation. Such results were observed by Jatav *et al.*, (2013). Notably, highest value of protein content in potato tuber was found in T_5 treatment while the lowest value was recorded in treatment T_2 (Fig. 3D). This findings are in agreement with Khan *et al.*, (2019) who found that carbohydrate and protein concentration of different crops significantly increased with inoculation with biofertilizers. Application of nitrogen fixer microorganisms through biofertilizer caused a promotion in nitrogen supply to plant which increase the amount of amino acids and protein synthesis in different parts of plant (Gupta *et al.,* 2012; Jnawali *et al.,* 2015).

Fertilization effectiveness in tuber nutrient content

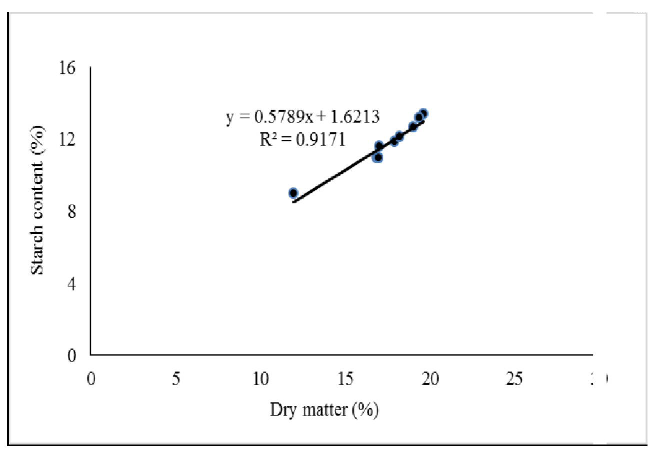

Fig. 4: Simple regression between dry matter (%) and starch content (%).

Different sources of fertilizers and rates greatly effected on chemical composition of potato tuber. Our results revealed that highest values of N, P, K and Ca

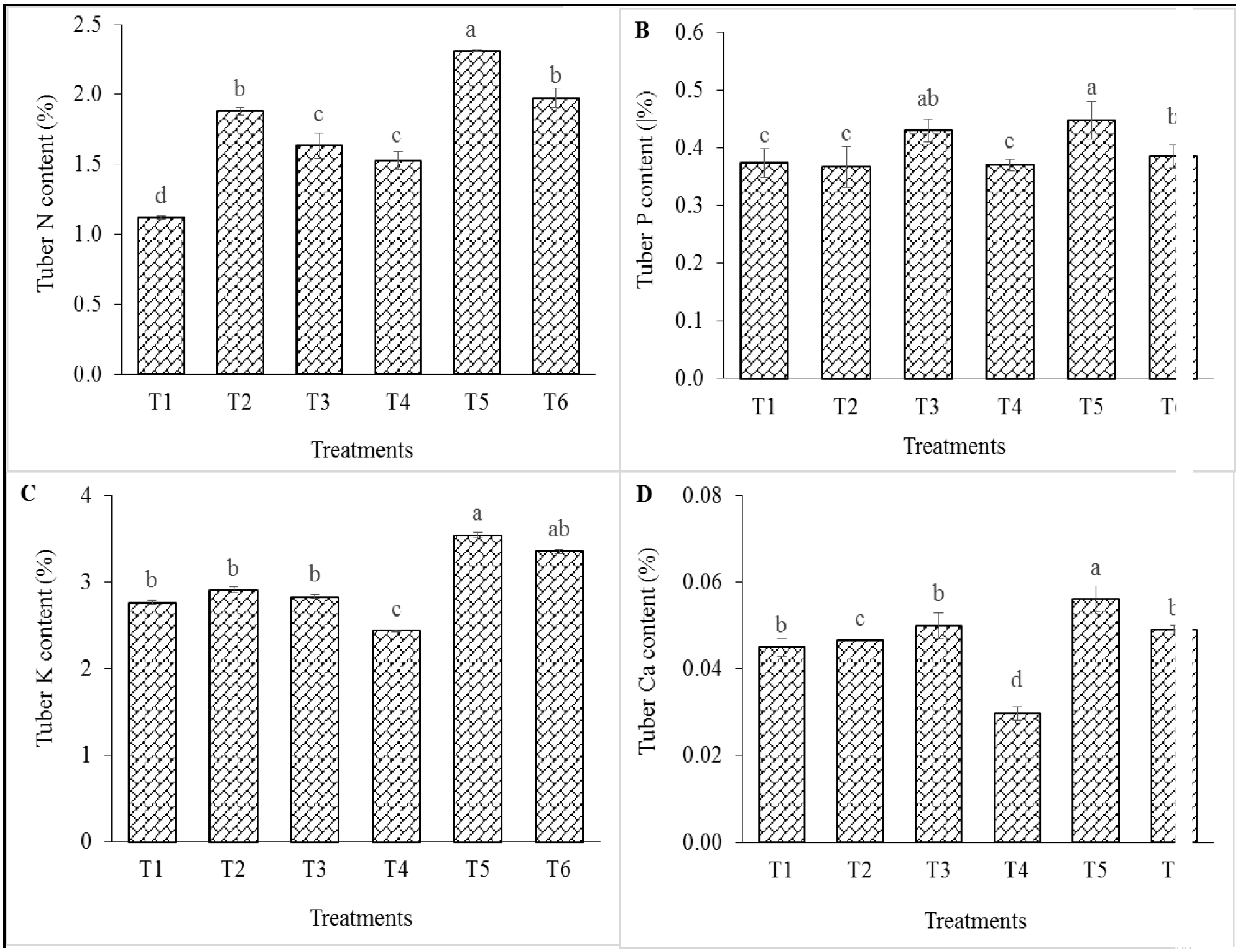

Fig. 5: Effects of biofertilizer (biofertile) along with other fertilizers on (A) total N, (B) P, (C) K and (D) Ca content of potato tuber. Different letters indicate significant differences at P d" 0.05 by Duncan's multiple range test. Bars indicate to standard division (±SD).

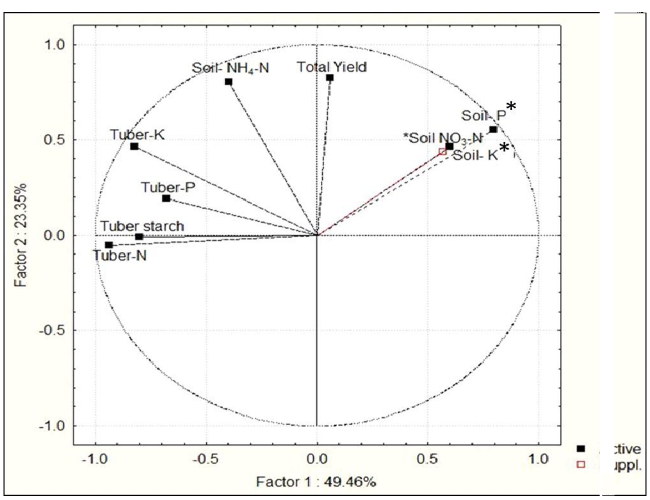

Fig.6: Principal component analysis of tuber chemical composition with nutrients content in soil, (soil-P*) = available P in soil, (soil-K*) = exchangeable K in soil.

contents were recorded in T_5 than other all treatments (Fig. 5). Tuber N content was 2.31% higher when potato plants treated with T_5, as compared to plants treated with T_1 treatment (1.12%) as presented in Fig. 5A. Eidi-zadeh *et al.,* (2010) stated that the Addition of biofertilizer increased the availability of N through transform organic nitrogen into NH_4 increasing N available to the plant. The significant effect of bio fertile on increasing N content is related to nitrogen fixer bacteria presented into biofertile. Moreover, combined application of organic, biological and chemical fertilizers grantee providing nitrogen over plant cycle and reduce nitrogen losses. Such findings were observed with tuber P and K contents (Fig. 5B and C). Application of biofertile with farm compost and mineral fertilizers (T_5) increased tuber P and K by 0.45 % and 3.54 %, respectively, as compared to potato plants supplied by treatment T_1. The lowest values of P and K contents in potato tuber have reported in T_4 (0.37 and 2.43, respectively), without addition biofertile fertilizer.

Furthermore, application of combined fertilizers (T_5) gave significantly highest value of Ca than other all applied fertilizers (Fig. 5D). Several reports confirmed that the addition of bio-fertilizer and manure together caused significant enhances in the population density of soil beneficial microorganism which increased the available nutrients such as nitrogen, transferable phosphor, magnesium, dissolved potassium required for the plants (Mukhongo *et al.,* 2017). Improvement of N and other macronutrients concentration in potato tubers due to application of free living N- fixing bacteria not only associated to providing fixed nitrogen to plants but also to release certain chemical substances which increase the plant development and enhance the availability of other nutrients for plants (Shen *et al.,* 2016; Khan *et al.,* 2019).

Principal component analysis

Principal component analysis shown a soil NH_4-N content correlated positively with protein, nitrogen and starch accumulation in tuber. Similar relations was noted between soil NH_4-N and K accumulation in tuber. Furthermore, tuber K and P concentrations associated positively to available P and K in soil. A slight positive relation was found between total yield and NO_3-N in soil.

Acknowledgements

We would like to thank Vegetable Department, faculty of Agriculture, Cairo University for providing us all facilities and Dr. Abdel-lattif H.A for helping us in analyzing data statistically.

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