Enhancing Potato Production by Applying Commercial Seaweed Extract (TAM®) Biostimulant under Field Conditions

Gamal, A.G. Ammar [1], Mohamed Ashour [2] Shimaa M. Hassan [3] *

1.Biotechnology Unit., Plant Production Department, Arid Lands Cultivation Research Institute, City of Scientific Research and Technological Applications, Alexandria 2193, Egypt; gammar@srtacity.sci.eg (A.G.A.G.)
2.National Institute of Oceanography and Fisheries, NIOF, Cairo 11516, Egypt, microal-gae_egypt@yahoo.com (M.A.); ah831992@gmail.com (A.E.A)
3.Department of Vegetable crops, Faculty of Agriculture (El-Shatby), Alexandria University, Alexandria 21545, Egypt; shaymaa.hassan@alexu.edu.eg (S.M.H.).
*Corresponding author: shaymaa.hassan@alexu.edu.eg

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ABSTRACT: Potato (*Solanum tuberosum L.*) represents a major globally consumed starchy vegetable crop that possesses a great stature and impact on feeding the world. Several studies have been performed to increase potato production, following different approaches. Biostimulants are magic biomolecules that carry unique traits, allowing them to perfectly fit the mission of augmenting crops' immunity for surviving various provenances of cruel stresses. The current work proposed a modern trend, aiming to take advantage of a research based, new commercially-produced biofertilizer; TAM® (True-Algae-Max), in a trial to evaluate its potentiality for substituting conventional N, P, and K fertilization practice. TAM® is a seaweed extract, distinguished to own an abundancy in biomolecule constituents like; Milbemycin-oxime; 5-Silaspiro [4.4] nona-; Rhodopin; Nonadecane, while also been recognized for its richness in other nutritious biomolecules. Spunta cultivar was treated with three treatments; (1) T1: NPK100%, (2) T2: NPK50%+TAM2.5 mL L^{-1}, and (3) T3: NPK50%+TAM 5 mL L^{-1}, to figure out the best doses for boosting potato yield production, quality, besides biochemical and physiological traits. Resulted data endorsed that TAM® could successfully enhance potato production under field conditions, and intensify its fundamental elements constitution. It is apparently that biomolecules-rich biologically-derived fertilizers would, undoubtedly, stand for novel reliable supplements, in the coming future of producing safe crops, to secure clean global alimentary needs, following environ-mentally friendly managements.

Keywords: Seaweed biostimulants; TAM®; Potato; Biofertilizers; Functional biomolecules; Plant growth promotion; Nutrient deficiency

INTRODUCTION

Potato (*Solanum tuberosum L.*) occupies the first world-widely staple source of starchy foods and the fourth dietary important crop after wheat, maize, and rice (**Statista, 2019**). While global production has estimated a sum of over 370 million metric tons in 2019 (**Statista, 2019**, **FAO, 2021(b**) the Food and Agriculture Organization of the United Nations (**FAO, 2008)**, has specified the year "2008" to celebrate the importance of potato crop, as being one of the most significantly consumed plants worldwide, and as a food security crop that provides a main supplement of complex carbohydrates on the international dining tables (**FAO, 2019(a)**.

Utilization of plant biostimulants nowadays as effective biomolecules, has been experiencing much scientific interest all over the world, with greater attention than any time ever before(**Khan*et al*., 2009, Ali *et al*., 2021**). This is because it provides one of the advances and most innovative technologies, used recently -with safe outlines- for boosting plant production, under harsh conditions, in parallel with striking world population that claims for sustained food resources(**Khan *et al*., 2009, Jardin, 2015**). It is highly expected that biostimulants would be acting as the "codeword" in the future of organic agriculture business and markets, at least for establishing a pioneer production of new Biofertilizers that can compete with classically applied ones in the fertilizers' industry, through which worldwide governmental strategies will follow to secure riskless food and feed sources for their nations, as a novel trend for finer and healthier style of living (**Kaur, 2020, Buono, 2021**).

Biomolecules found in biological stimulants, and plant growth promotors (PGPs), sourced from bioagents, include plenty of beneficial substances. Numerus biological origins are prominent with compounds like proteins, organic and humus bountiful substances, while other bioactive molecules have been detected in seaweed and plant extracts, which were found to be rich sources of phytohormones, beneficial plant-growth-promoting microorganisms(**Santini*et al* .,2021**), and mycorrhizal fungi as well (**Jardin , 2015**, **Rouphael*et al*., 2015, Shukla *et al*., 2021**). Such vital elements, are famous to be environmentally friendly, when being compared with traditionally practiced fertilizers, and have shown amazing capabilities in balancing the harmony of different antioxidant machinery, redox potential, and secondary metabolism in plants, leading to maximizing plant yields, thorough supportation of defense strategies, and supplementation with essential promotors, to afford various serious stresses (**Hasanuzzaman,2020,Khan et al.,2009,Patel and Mukherjee,2021**). Yet, physiological, biochemical, and molecular mechanisms, lying under the plant–biostimulant relationship symphony, within different environmental conditions, are so far unrevealed, and still have a lot to tell. Necessarily, encouragements for extra investigations are representing top-priorities to interpret the key-operating mechanisms, and the administrative functions of biostimulants (**Buono,2021**).

Unquestionably, involving seaweed foliar sprays in the modern organic agriculture programs, as parallel alternatives to conventional fertilizers, gives them a superior ad-vantage to sustain the obvious soars in extreme disease infections, and an unwanted fortuitously environmental stresses that occur as a direct result of climatic shifts(**EL Boukhari*et al*., 2020**). This feature has been very handy, while for a lot of farming practices, traditional chemicals proved out to be a nuisance issue **(Hasanuzzaman ,2020**).

Lately, our team has investigated the impact of applying TAM® as a reliable supplement for crops like cucumber (**Hassan *et al*., 2021(a)**, and pepper (**Ashour *et al*.,2021**). A part from that, previous investigated TAM® practices have been carried out under controlled greenhouse conditions. In this context, the innovative trend in the contemporary research work aimed mainly to complementary inspire the growth and yield production of potato plant (*Solanum Tuberosum* L., Spunta cv.), and at the same time, to evaluate its performance under normal field conditions, in order to exploiting the beneficial attributed magic properties of TAM® seaweed liquid extract, as a novel turn for practicing biostimulants application, in the form of foliar spray, along with comparative doses from classical N, P, and K, fertilizing protocol.

MATERIALS AND METHODS

Experimental Site

Two field experiments were conducted during the autumn seasons of 2017and 2018, at the Abu Al-Ela village, Al-Nahda area, Alexandria Governorate, Egypt, to investigate the effects of covenantal mineral N, P, and K fertilizers, and seaweed liquid extract (TAM®) on vegetative growth and morpho-physiological traits, mineral contents of leaves, tubers yield and quality characteristics, as well as tuber nutritional quality of potato (*Solanum Tuberosum*, Spunta cv.) which were obtained from Agro Food Co., Egypt.

Seaweed Liquid Extract Methods

TAM® is a commercial seaweed liquid extract, submitted as a patent (**Garcés-Fiallos*et al*., 2021**). The preparation of TAM® was followed as been described previously by (**Ashour et al., 2020**). In details, three seaweeds species, *Ulva lactuca* (Chlorophyceae), *Janiarubens*, and *Pterocladiacapillacea* (Rhodophyceae), were employed in preparing and producing TAM®. The selected species were collected in the 2016 summer season from the rocky site (31° 16′ 16.0″ N, 30° 10′ 28.0″ E) of Abu-Qir Bay, the Mediterranean Coast of Alexandria, Egypt. After being harvested, the epiphytic and waste materials were removed, and then samples were washed, air-dried, powdered, and finally kept in plastic bags at room temperature for further analysis. Phytochemical, physical, chemical, and biochemical analyses of crude TAM® were conducted and estimated as previously described by (**Ashour et al., 2020**) and (**Hassan *et al*., 2021(a) Tables 1and 2** .

Table 1.:Physical, chemical and biochemical analyses of Seaweed Commercial Biofertilizer Extract (SCBE) used as foliar spray for Potato plant.

Item	Value
Physical analyses	
Color	Dark brown
Odor	Seaweed
Density	1.20
pH	9.5
Biochemical analyses (% DM)	
Total polysaccharides	15
Total organic matter	8.2
Total dissolved solids	2.6
Chemical analyses	
Macro elements (%)	
Potassium	12
Phosphorus	2
Total nitrogen	0.14
Micro elements (ppm)	
Copper	0.39
Iron	16.18
Magnesium	19.72
Zinc	1.19
Manganese	3.72
Heavy metals (ppm)	
Cadmium	0.00
Chromium	0.00
Lead	0.00
Nickel	0.00
Arsenic	0.55

Table 2.:Phytochemical compounds of (TAM) and related biological activities according to the literature .

RT (min)	Compound name	Formula	Molecular weight	Nature	Biological properties	Literatures
8.99	5-Silaspiro[4.4]nona-1,3,6,8-tetraene, 3,8-bis(diethylboryl)-2,7-diethyl-1,4,6,9-tetraphenyl-	$C_{44}H_{50}B_2Si$	628.39	silicon-boron compound	Growth and immunity enhancer for Fish and plant; Antifungal for plant pathogen	[73,74,72,1]
16.31	Nonadecane	$C_{19}H_{40}$	268.31	alkane	Antioxidant; Anticancer; Antimicrobial Anti-inflammatory	[64,63,65–67]
19.45	Rhodopin	$C_{40}H_{58}O$	554.45	carotenoid	Antioxidant	[61,62]
20.07	Milbemycin B, 5-demethoxy-5-one-6,28-anhydro-25-ethyl-4-methyl-13-chloro-oxime	$C_{32}H_{44}ClNO_7$	589.28	Macrocyclic lactones	Antiparasitic; Antihelmintic; Insecticidal	[68,69,70]
20.90	Tridecanoic acid, methyl ester	$C_{14}H_{28}O_2$	228.21	Fatty acid methyl esters (FAMEs)	Surfactants; Herbicidal; Antioxidant; Antimicrobial	[56–58,17]
21.63	Oleic Acid	$C_{18}H_{34}O_2$	282.26	Fatty acid	Anti-inflammatory; Enhancing insulin production	[52–55]
23.74	γ-Linolenic acid, methyl ester	$C_{19}H_{32}O_2$	292.24	FAMEs	Surfactants; Herbicidal; Antioxidant; Antimicrobial	[56–58,17]
24.02	9,12-Octadecadienoic acid, methylester, (E,E)-	$C_{19}H_{34}O_2$	294.26	FAMEs	Surfactants; Herbicidal; Antioxidant; Antimicrobial	
24.37	Phytol	$C_{20}H_{40}O$	296.31	Diterpene alcohol	Antioxidant; Antinociceptive	[59,60]

Experimental Design

Potato tuber seeds were planted on 25th of September in both seasons (2o17 and 2018). The experimental layout was, a randomized complete blocks design (RCPD), with three replicates. Each replicate included 3 plots . Each main plot contained three rows, each row was 4 m long, and 0.7 m wide, making a total main plot area of 8.4 m^2.

Soil Analysis

Preceding the initiation of each experiment, in both seasons, soil samples were collected, from the experimental site before planting , at 15-30 cm depth, and analyzed at Faculty of Agricultural in Alexandria University analysis lab, for some soil's physical and chemical properties according to the published procedures (**A.O.A.C, 1995**, **A.O.A.C International Arlington, 2019**), and are presented in **Table 3.**

Table 3: Soil physical and chemical properties of the experimental sites in the two growing autumn seasons of 2017and 2018

Properties	Season 2017	Season 2018
Physical properties		
Clay (%)	20.5	19.9
Silt (%)	15.4	14.6
Sand (%)	64.1	65.5
Soil texture	Sandy clay loam	Sandy clay loam
Chemical properties		
PH	8.3	8.00
E.C (ds/ M^{-1})	0.88	0.80
O.M. (%)	2.45	2.56
Soluble cations (m.eq/l)		
Ca^{++}	4.00	3.89
Mg^{++}	6.05	6.00
K^{+}	1.20	1.10
Na^{+}	3.01	3.2
Soluble anions (m.eq/l)		
CO_3^{-2}	0.0	0.0
HCO_3^{-}	6.0	5.88
CL^{-}	2.05	2.00
SO_4^{-2}	1.41	1.7

In the current experiment, two levels of crude TAM® foliar application (2.5 ml L^{-1} and 5 ml L^{-1}) were applied as a 50 % replacement of the recommended NPK classical chemical fertilizer that added during the growing seasons. two treatments were applied three times every week after the fourth week from planting until harvest to compare a control 100 % NPK mineral fertilizer as follows; (1) T1: NPK100%, (2) T2: NPK50%+TAM2.5 mL L^{-1}, and (3) T3: NPK50%+TAM5 mL L^{-1}. The recommended NPK100% mineral fertilizer protocol consists of 300 kg fed^{-1} of Ammonium Nitrate (33.5% N), added in three-time intervals 4, 7, and 10 weeks after planting, Phosphorus fertilizer was mixed during soil preparation 150 kg fed^{-1} of calcium super phosphate (15.5% P2O5), as one dose at soil preparation time, 80 kg fed^{-1} of Potassium Sulphate (48% K2O), added in two-time doses; i.e., after 7, and 10 weeks from planting. Other recommended agricultural practices were followed as commonly used in the commercial production for potato plant, and according to the Egyptian Ministry of Agriculture and Land Reclamation outlined potato fertilization program guidelines.

Tested Parameters

Vegetative growth characters

A random sample of five potato plants was taken from the first ridge of each plot, after 90 days of planting, to measure plant height, number of branch $plant^{-1}$, and plant fresh weight.

Mineral contents of leaves

Random samples of the youngest expanded mature leaves of potato plants, were randomly collected from each plot, then washed with distilled water, weighed, and hence after, oven dried at 70 °C till constant weight. The dried leaf materials were grinded and homogenized, wet digested; using concentrated sulfuric acid and H_2O_2, and the total nitrogen, and phosphorus of leaves of potato were determined calorimetrically; using spectrophotometer at 662 and 650 nanometers wavelength; according to **(Evenhuis, 1976andMurphy and Riley,1962)**.

Tubers' yield and quality characters

Harvesting potato plants was performed at 90 days after planting by the 20th of January. The harvested tubers from the 2nd and the 3rd ridges of each experimental unit were weighed, then graded into three sizes according to their diameter; small (< 30 mm), medium (30 - 60 mm) and large (> 60 mm). Total tuber yield ton fed^{-1} was calculated for small, medium, and large . Total potato yield has been also calculated as well. In addition, other yield and quality characters like tuber weight, tuber length, and tuber diameter were measured.

Tuber nutritional quality

Tuber sample from each plot was saved, to determine tuber dry matter contents, total sugar, (mg. g^{-1}.d.w) according to (**Malik and Singh,1980**), and starch percentage as described by (**A.O.A.C, 1990)** Moreover, total phenols measurement for the total free and conjugated phenols was determined according to **Snell and Snell, 1953**.

Statistical analysis

All obtained data of the present study were, statistically, analyzed according to the technique of analysis of variance (ANOVA)for the RCBD as published by (**Gomez and Gomez, 1984**) using the (**SPSS, 1997**) software package. The comparisons among means of the different treatments were carried out, by using the revised L.S.D. test (**Al-Rawi and Khalaf-Allah, 1980**) at (P>0.05).

RESULTS

Vegetative growth characters

Results in Table 4 refer to the vegetative growth parameters of potato, as affected by the ratio between conventional NPK100% fertilization (T1), and TAM® levels (T2 and T3), among in 2017 and 2018 cultivating seasons, under field conditions respectively. During the two cultivating seasons 2017 and 2018, plant height recorded 72.9 cm and 74.73 cm, respectively for the control treatment (NPK100%). On the other hand, it recorded 72.19 cm, and 73.90 cm, after being treated with T2 while recorded 74.39 cm, and 73.65 cm, when treated with T3, during the same cultivating seasons respectively, with no significant difference. In both seasons 2017 and 2018, number of branches recorded 4.83, and 4.50, for T1, 4.66 and 4.83 for T2, and 4.50 and 4.67 for T3, respectively, without any significant difference.

Plant fresh vegetative weight (g) was notably affected by applying TAM® and NPK. In 2017 season, T1 recorded 404.33 g, while it reached its highest record among all treatments in the year 2018 (411.00 g). Significantly, readings differed also between the successive cultivating seasons, where T2 reported 375.00 g in 2017, and 378.00 g in 2018, while T3 record 391.33 g in 2017 and 386.33 g in 2018, respectively.

The dry matter (%) was reported to vary among the two seasons of cultivation (2017 and 2018), where T1 showed 20.31% in 2017, while recorded 20.35% in 2018. Continuously, T2 displayed of 17.81%, and 19.41% for the years 2017, and 2018, respectively, while practicing T5 resulted in 19.68%, and 19.01% for the same successive seasons.

Produced results also demonstrated that tuber weight (g) was 235.30 g, and 223.91 g in 2017 and 2018, respectively, when potato was treated with T1, while it was 260.97 g in 2017, and 264.85 g in 2018, when being treated with T2. At the same time ,T3 gave average tuber weight values of 245.54 g, and 248.70 g, respectively over the two successive seasons 2017, and 2018.

In contrast tuber length (cm), treatment T2 recorded the highest value of 12.47 cm in 2018 and 12.07 cm in 2017, while the lowest value (10.94 cm) was recorded in 2017 season by treatment T1 that valued 11.19 cm in 2018. In the same context, treatment T3 valued 11.73 cm in 2017 and 11.81 cm in 2018 season respectively.

Potato tuber diameter (mm) varied significantly affected by treatments over the two cultivating seasons. In 2017, treatment T1 was found to be 66.65 mm, while it reach 66.14 mm in 2018. T2 gave the heist diameter in 2017 (73.99 mm), and (72.45 mm) in 2018 season, while T3 reached 64.30 mm, and 63.82 mm in both 2017 and 2018 seasons, respectively.

Table 4. Potato vegetative growth parameters as influenced by NPK: TAM® concentrations among 2017 and 2018 cultivating seasons

Treatments	**T1****		**T2**		**T3**	
Parameters	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
Plant Height *(cm)*	72.9±1.79a*	74.73±1.39a	72.19±1.15^{a}	73.90±1.15^{a}	74.39±1.13^{a}	73.65±1.21^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-1.10*	*-1.02*	*2.05*	*-1.45*
Branches (No.)	4.83±0.17^{a}	4.50±0.29^{a}	4.66±0.18^{a}	4.83±0.44^{a}	4.50±0.29^{a}	4.67±0.33^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-3.45*	*7.41*	*-6.90*	*3.70*
Plant Fresh Vegetative Weight *(g FW)*	404.33±2.96^{a}	411.00±2.31^{a}	375.00±2.89^{c}	378.00±5.51^{c}	391.33±1.86^{b}	386.33±8.57^{b}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-7.25*	*-8.03*	*-3.22*	*-6.00*
Dry Matter (%)	20.31±0.70^{a}	20.35±0.58^{a}	17.81±0.50^{b}	19.41±0.85^{a}	19.68±0.75^{a}	19.01±0.73^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-12.29*	*-4.60*	*-3.05*	*-6.55*
Tuber Weight (g)	235.30±2.95^{b}	223.91±3.50^{b}	260.97±8.30^{a}	264.85±4.64^{a}	245.54±2.85^{ab}	248.70±7.54^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*10.91*	*18.28*	*4.35*	*11.07*
Tuber Length (cm)	10.94±0.35^{b}	11.19±0.42^{c}	12.07±0.44^{a}	12.47±0.15^{a}	11.73±0.44^{a}	11.81±0.44^{b}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*10.33*	*11.44*	*7.22*	*5.54*
Tuber Diameters (mm)	66.65±0.40^{b}	66.14±1.24^{b}	73.99±1.06^{a}	72.45±1.64^{a}	64.30±1.90^{b}	63.82±0.88^{b}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*11.00*	*9.55*	*-3.53*	*-3.51*

*Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.

**T1: NPK100%, T2: NPK50%+TAM2.5 mL L^{-1}, and T3: NPK50%+TAM5 mL L^{-1}.

Potato yield parameters

As shown in Table 5, potato yield parameters are presented in Ton fed^{-1}, as affected by different treatments of NPK and TAM® and their concentrations, among the two successive cultivating seasons, 2017, and 2018. Accordingly, potato tubers' yield has been categorized depending on size into three groups:

1) Large tubers' yield, which recorded 6.63 ton fed^{-1}, and 6.57 ton fed^{-1} in 2017, and 2018, respectively, for treatment (T1). On the other hand, it record 8.40 ton fed^{-1} in 2017, and 8.36 ton fed^{-1} in 2018, for treatment T2, while it recorded 6.74 ton fed^{-1} in 2017 and 6.70 ton fed^{-1} in 2018, for treatment T3

2) Medium tubers' yield, was 5.82 ton fed^{-1} in 2017, and 5.77 ton fed^{-1} in 2018, when potato was treated with NPK Control treatment .7.19 ton fed^{-1} and 7.31 ton fed^{-1}, were the tubers yield recorded in 2017, and 2018 successive seasons, respectively, when potato was treated by T2, whilst, treatment with T3 gave 7.36 ton fed^{-1} in 2017, and 7.17 ton fed^{-1}in 2018;

3) Small tubers' yield, was 4.59 ton fed^{-1} in 2017, and 4.58 ton fed^{-1} in 2018, for treating potato with T1, and 4.16 ton fed^{-1} in 2017, and 4.19 ton fed^{-1} in 2018, for treating potato with T2, and 4.74 ton fed^{-1}in 2017, and 4.55 ton fed^{-1}in 2018, for treating potato with T3, without any significant differences between treatments.

Finally, the total yield recorded 17.03 ton fed^{-1}, and 16.92 ton fed^{-1} for the successive seasons 2017, and 2018, for T1, 19.75 ton fed^{-1} in 2017, and 19.86 ton fed^{-1} in 2018, for T2 treatment, and 18.85 ton fed^{-1} in 2017, and 18.42 ton fed^{-1} in 2018, when applying T3 (Table 5).

Table 5. Potato yield (ton fed^{-1}) parameters as influenced by NPK:TAM® concentrations among 2017 and 2018 cultivating seasons.

Treatments	**T1****		**T2**		**T3**	
Parameters	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
Large tubers' Yield ton fed^{-1}	6.63±0.17^{b}*	6.57±0.16^{b}	8.40±0.23^{a}	8.36±0.05^{a}	6.74±0.12^{b}	6.70±0.11^{b}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*26.65*	*27.23*	*1.76*	*1.98*
Medium tubers' Yield ton fed^{-1}	5.82±0.10^{b}	5.77±0.11^{b}	7.19±0.25^{a}	7.31±0.19^{a}	7.36±0.09^{a}	7.17±0.28^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*23.67*	*26.63*	*26.59*	*24.32*
Small tubers' Yield ton fed^{-1}	4.59±0.19^{a}	4.58±0.27^{a}	4.16±0.08^{a}	4.19±0.16^{a}	4.74±0.22^{a}	4.55±0.24^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-9.37*	*-8.45*	*3.27*	*-0.66*
Total Yield ton fed^{-1}	17.03±0.31^{b}	16.92±0.46^{b}	19.75±0.52^{a}	19.86±0.12^{a}	18.85±0.30^{a}	18.42±0.63^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*15.93*	*17.38*	*10.65*	*8.88*

*Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.

**T1: NPK100%, T2: NPK50%+TAM2.5 mL L^{-1}, and T3: NPK50%+TAM5 mL L^{-1}.

Potato leaf N, P, and K mineral content

The content of N, P, and K minerals in potato leaves was determined, as influenced by NPK:TAM® concentrations in 2017 and 2018 cultivating seasons, is represented in Table 3. Leaf-N (mg 100 g^{-1} DW) by applying T1 reached 1.93 in 2017, and 2.08 in 2018, while it reached 1.63 and 1.12 when T3 was applied during the two seasons. It also varied significantly to reach 0.95 in 2017 and 0.89 when T3 was applied (Table 6).

Leaf-P (mg 100 g^{-1} DW) recorded no significant differences among treatments over the two cultivating seasons. In 2017, treatment with NPK Control resulted in 0.60, while in 2018, it resulted in 0.69. Subsequently, 0.57, and 0.59, were the values obtained by applying T2 in 2017, and 2018 cultivating seasons.

No significant difference was also found when determining potato leaf-K (mg 100 g^{-1} DW), which recorded 1.56 in 2017, and 1.54 in 2018, for T1. T2, recorded 1.49, and 1.45, for the same successive seasons, while, T3 recorded 1.52 in 2017, and 1.49 in 2018, respectively.

Table 6. Measurements of potato leaf N, P, and K mineral content as influenced by NPK: TAM® concentrations among 2017 and 2018 cultivating seasons.

Treatments	**T1****		**T2**		**T3**	
Parameters	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
Leaf-N (*mg 100 g^{-1} DW*)	1.93±0.04^{a}*	2.08±0.09^{a}	1.63±0.03^{b}	1.12±0.49^{ab}	0.95±0.06^{c}	0.89±0.06^{b}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-15.69*	*-46.00*	*-50.69*	*-57.21*
Leaf-P (*mg 100 g^{-1} DW*)	0.60±0.04^{a}	0.69±0.03^{a}	0.57±0.03^{a}	0.59±0.04^{a}	0.54±0.06^{a}	0.53±0.04^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-4.47*	*-14.08*	*-8.95*	*-19.43*
Leaf-K (*mg 100 g^{-1} DW*)	1.56±0.13^{a}	1.54±0.14^{a}	1.49±0.17^{a}	1.45±0.18^{a}	1.52±0.14^{a}	1.49±0.15^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*-4.49*	*-5.84*	*-2.56*	*-3.25*

*Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.

**T1: NPK100%, T2: NPK50%+TAM2.5 mL L^{-1}, and T3: NPK50%+TAM5 mL L^{-1}.

Nutritional quality of potato tubers

The analyses of potato tubers' nutritional quality, as impacted by applying ratios of NPK:TAM® in 2017 and 2018 cultivating seasons, are shown in Table 5. Significant differences for the percent of total sugar were reported. Total sugar valued 1.42% in 2017, and 1.40% in 2018, when treating potatoes with T1, while higher values of 1.84%, and 1.86%, could be noticed for T2 treatment in 2017, and 2018, respectively, and relatively medium values of 1.62% in 2017, and1.64% in 2018, for T3 were also noticed.

Contrary, Starch content readings displayed no significant differences for treatments over the two cultivating seasons. In 2017, treatment with T1 resulted in 17.55%, and 17.56% for 2017, and 2018, respectively, while treatment T2 resulted in 17.89% in 2017, although the highest value was recorded in 2018 to be 18.83%, at the same time when treatment T3 resulted in 17.84%, and 17.83%, in 2017, and 2018 seasons, repetitively.

Phenol Gallic Acid Equivalents content (mg GAE 100 g^{-1}), significantly varied between treatments over the two seasons. The highest values were produced by applying T3 in 2018 (1.303), while 2017 recorded 1.268, whilst the lowest values were produced by applying T1 in 2018 (0.542), and 2017 (0.562), whereas T2 recorded relatively medium values of 0.995 in 2017, and 0.976 in 2018 (Table 7).

Table 7. Potato tuber nutritional quality analyses as influenced by NPK:TAM® concentrations among 2017 and 2018 cultivating seasons.

Treatments	**T1****		**T2**		**T3**	
Parameters	**2017**	**2018**	**2017**	**2018**	**2017**	**2018**
Total Sugar (%)	1.42±0.04^{b}*	1.40±0.05^{c}	1.84±0.08^{a}	1.86±0.007^{a}	1.62±0.05^{b}	1.64±0.03^{b}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*29.65*	*29.40*	*14.35*	*13.66*
Starch (%)	17.55±0.31^{a}	17.56±0.46^{a}	17.89±0.62^{a}	18.83±0.33^{a}	17.84±0.40^{a}	17.83±0.35^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*1.90*	*7.25*	*1.63*	*1.54*
Phenol (mg GAE 100 g^{-1})	0.562±0.001^{c}	0.542±0.002^{c}	0.995±0.06^{b}	0.976±0.014^{b}	1.268±0.009^{a}	1.303±0.007^{a}
Increase/Decrease Rate (%)	*0.00*	*0.00*	*77.78*	*79.31*	*127.93*	*138.60*

*Values followed by the same alphabetical letter(s) in common, within a particular group of means in each character, do not significantly differ, using Revised L.S.D test at 0.05 level of probability.
**T1: NPK100%, T2: NPK50%+TAM2.5 mL L^{-1}, and T3: NPK50%+TAM5 mL L^{-1}.

DISCUSSION

Results in this research are inspired by practicing new natural PGPs for substituting conventional mineral fertilizers. What distinguishes this research, is that it has been focused on carrying out field trial applications, rather than evaluation under controlled greenhouse conditions. Practicing different combinations between TAM® commercial seaweed extract biostimulant, and NPK conventional mineral fertilizers, to evaluate the potentiality of TAM® bioactive compounds for boosting potato plant production was considered to be the main goal. While plant biostimulants (PBs) have been showing a promising future for sustainable agriculture, seaweed bio-fertilizers are characterized to enhance plant growth, tolerance of abiotic stresses, resulted from being exposed to harsh conditions (**Munjal, 2020, Ali *et al*., 2021**), resistance to serious diseases (**Shukla *et al*., 2021, Patel and Mukherjee,2021**), and soil fertility boosters too (**Kaur, 2020**). Those bioactive compounds found in PBs are classified as effective members of the plant growth promotors (PGPs), recently employed for the sake of green innovation. For example, the new EU regulatory frameworks (2019/1009), stated a novel definition for PBs as follows: "A plant biostimulant shall be an EU fertilizing product, the function of which is to stimulate plant nutrition processes independently of the product's nutrient content, with the sole aim of improving one or more of the following properties of the plant, or the plant rhizosphere: i) nutrient use efficiency; ii) tolerance to abiotic stress; iii) quality traits, and/or; iv) availability of confined nutrients in the soil or rhizosphere" (EU, 2019) (**Buono ,2021, Rouphael and Colla, 2020**). It worth saying that seaweed liquid extract biostimulants have been practiced as PGPs for several plant species with great success. They have been applied on bean (**Kocira*et al*., 2020**) tomato (**Chanda *et al*., 2020**), oilseed rape (**Łangowski*et al*., 2019**), hormone signaling in Arabidopsis (**Ghaderiardakani*et al*.,2019**), and wheat (**Latique*et al* .,2021**).

According to previous studies, TAM® has been known to be rich in nutritious sub-stances, important for improving total yield production and quality for some plant species like hot pepper (*capsicum annum*) (**Ashour *et al*.,2021**) cucumber (*Cucumis sativus*) **Hassan et al .,2021(a)**, and rocket salad (*Eruca vesicaria*) **Hassan *et al* .,2021(b)** . Previously obtained analyses of bioactive compounds in TAM® showed that it includes a wide variety of biostimulants, in addition to phytochemical constituents, and a wealth of requisite biomolecules, distinguished with exceptional bio-logical properties. Among those essential biological elements, were, "5-Silaspiro[4.4]nona-1,3,6,8-tetraene,3,8-bis(diethylboryl)-2,7-diethyl-1,4,6,9-tetraphenyl-", a silicon-boron compound, used as fish and plant growth regulator, as well as immunity enhancer; an alkane compound known as "Nonadecane", which is a fish and plant im-munity enhancer, an antioxidant, antimicrobial, and an anti-inflammatory agent; "Rhodopin", a carotenoid, recognizes as a fish and plant growth enhancer, and as an an-tioxidant; "Milbemycin-oxime", a macrocyclic lactones, proved to have properties for im-proving fish and plant immunity, while also being an antiparasitic, anthelmintic, and an insecticidal compound; "γ-Linolenic acid methyl ester"; "9,12-Octadecadienoic acid me-thyl ester, (E,E)-"; and "Tridecanoic acid methyl ester", which are members of the fatty acid methyl esters (FAMEs), known for their antioxidant effect, and role as herbicides, with an antimicrobial impact, plus their usage as surfactants; "Oleic Acid", a fatty acid, helps stimulating fish and plant immunity, and used as an anti-inflammatory; "Phytol", a diterpene alcohol, used as an antioxidant, and plant growth promotor (**Hassan *et al* .,2021(a), Ashour *et al*., 2020 , Hassan *et al* .,2021(b), Santos *et al* .,2012**).

Findings in this investigation revealed that foliar application of different concentrations from TAM®, in comparison to application of parallel concentrations, and/or combinations with conventional N, P, and K mineral fertilizers, could successfully be reliable for promoting potato growth, and physio-chemical properties, while also, increasing yield and its components, besides enriching potato nutritional quality. Seaweed extracts have been utilized and surveyed for its application feasibility since quite a long period, with focus on potato plant (**Kuisma ,1989**). Our findings are in agreement with studies done on Kelpak® seaweed-derived biostimulant. A study on the effect of the seaweed extracts Kelpak SL (*Ecklonia maxima*, and Bio-algeen S90 (*Ascophyllum nodosum*), and humic and fulvic acids HumiPlant (leonardite extract) on potato early crop yield and yield components recently carried out (**Dziugieł andWadas , 2020**). The study showed that practicing seaweed biostimulant could increase the tuber weight per plant, and the average tuber weight, which consequently led to increase the tuber yield. Another two studies were also conducted following the same trend to evaluate the growth of marketable potato, and quality of new potatoes with the application of seaweed extract, and humic acid **(Wadas and Dziugieł, 2019,Wadas and Dziugieł, 2020(a**). Moreover, the same treatments could be investigated on the assimilation area and chlorophyll content of very early potato cultivars ('Denar', 'Lord', Miłek'), giving almost very close effects (**Wadas and Dziugieł, 2020(b)**. Kelpak® Sea-weed-derived biostimulant was alike evaluated earlier to influence endogenous phyto-hormones like cytokinins, and other bioactive compounds in Eucomisautumnalislately with great results (**Aremu*et al*., 2016**). In a study done by **Al-Juthery*et al*., 2018**.the impact of foliar application of nano-fertilizer seaweed was tested under field conditions to evaluate its potentiality for enhancing potato growth. The study revealed that applying seaweed extract could boost yield and its components, with notable results for higher fruit weight, and biochemical properties like chlorophyll percent, and protein content as well. Our findings are similar to those obtained lately about the impact of seaweed sap foliar application on growth, yield, and tuber quality of potato (**Garai*et al*., 2021**), where outcomes indicated the significant usage of seaweed sap for better potato yielding.

CONCLUSIONS

In the race to come out with the most sustainable environmentally friendly plant fertilizer, PGPs, including seaweed biostimulants, are representing promising solutions to favor plants. TAM® foliar spray application has proven to be very optimistic, while being rich in nutritious biomolecules, which could boost potato production under field conditions. Evaluating TAM® bioactive compounds revealed its ability to, at least, partially substitute conventional NPK chemical fertilization for brighter agricultural futurity.

Patents :Seaweed extract (TrueAlgaeMax, TAM®) is a patent submitted at Egyptian Patents office, Academy of scientific research and technology (submission No.: 2046/2019).

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الملخص العربى

تحسين إنتاج البطاطس من خلال تطبيق مستخلص الأعشاب البحرية التجارية (TAM®) كمنشط حيوي في ظل الظروف الميدانية

جمال عمار[1]، محمد عاشور[2] ،شيماء محمد رجب على حسن[3]

1- وحدة التكنولوجيا الحيوية ، قسم الإنتاج النباتي معهد بحوث زراعة الأراضي القاحلة ، مدينة البحث العلمي والتطبيقات التكنولوجية ، الإسكندرية 21934 ، مصر.

2- قسم تربية الأحياء المائية ، معهد علوم البحار والمحيطات ومصائد الأسماك - القاهرة

3-قسم الخضر ، كلية الزراعة ، جامعة الإسكندرية ، 21545- الشاطبي ، الإسكندرية ، مصر

تمثل البطاطس (*Solanum tuberosum L.*) محصولا رئيسيا من الخضروات النشوية المستهلكة عالميا والتي تتمتع بمكانة كبيرة فى التغذية على مستوى العالم. وقد أجريت عدة دراسات لزيادة إنتاج البطاطس، بإتباع عديد من الوسائل المختلفة. ويمكن تعريف المنشطات الحيوية بأنها جزيئات حيوية سريعة التأثير وفريدة من نوعها، مما يسمح لها بزيادة مناعة المحاصيل المختلفة لمقاومة التأثيرات الشديدة التى تعيق إستمرارها على قيد الحياة. وتم إقتراح التجربة بهدف الإستفادة من الأسمدة الحيوية الجديدة المنتجة تجاريا وهى عبارة عن طحالب بحرية (TAM® (True-Algae-Max)، وأجريت التجربة لتقييم تأثير المستخلص التجارى السائل من الطحالب البحرية وإستخدامه بديلا عن التسميد المعدنى NPK ويعتبر المنتج مستخلص من الأعشاب البحرية ، ويتميز بإحتواؤه على بعض المكونات الحيوية مثل (ميلبيمايسين-أوكسيم. 5-سيلاسبيرورودوبين.و نونيديكين ، وجزيئات حيوية مغذية أخرى. تم إستخدام ثلاث معاملات وهى: T1 : NPK 100%، T2: NPK 50% + TAM 2.5 mL L^{-1}، T3: NPK 50% + TAM 5 mL L^{-1}، والتي تم تطبيقها على صنف بطاطس Spunta لمعرفة أفضل المعاملات التى تؤدى الى زيادة إنتاج المحصول، وتحسن صفات الجودة لنبات البطاطس، إلى جانب الصفات الكيميائية والحيوية والفسيولوجية. وأوضحت البيانات الناتجة أن المستخلص التجارى السائل من الطحالب البحرية قد أدى إلى تحسن إنتاج البطاطس في ظل الظروف الحقلية ويبدو أن هذه الأسمدة الحيوية غنية بالجزيئات الحيوية المشتقة بيولوجيا والتى يمكن إستخدامها بثقة، في المستقبل القريب لإنتاج محاصيل أمنة ، مع توفير الإحتياجات الغذائية النظيفة والمطلوبة عالميا ، من خلال تطبيقات زراعية صديقة للبيئة.