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Response of soybean plants [*Glycine max* (L.) Merr.] to some bio, organic and mineral fertilizers.

Zeinab A.M. Elsherif, Azza M. Salama, Dalia M.A. Nassar and Ramadan A. Sakr

Department of Agricultural Botany, Faculty of Agriculture, Cairo University, Giza, Egypt.

ABSTRACT

The present investigation was carried out at the Agricultural Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt during the two growing seasons of 2019 and 2020. This work was designed to study the effect of some fertilizers as single or combined treatments on morphological, seed yield and chemical characters of soybean plants grown under sandy soil conditions. P and K fertilizers were used as a basal dressing for all the treatments.

Results indicated that *Bradyrhizobium japonicum* as bio-inoculum was efficient for increasing the studied morphological characters, yield components and chemical constituents of soybean plants than those of untreated ones. Application of either compost or algae extract or mineral nitrogen as a single treatment or combined with bio-inoculum (half dose of each + bio-inoculum) mostly had considerable effects on the studied characters than those of bio-inoculum as a single treatment. The combined treatment of bio-inoculum with half dose of any fertilizer positively affected morphology, productivity and chemical constituents of soybean plant than those of each fertilizer used as a full dose. The combination of ½ mineral nitrogen + bio-inoculum was the reliable treatment than the others for increasing most of the studied morphological traits; stem length, shoot fresh weight, shoot dry weight per plant, also, yield components; number of pods, number of seeds, seed yield per plant as well as the percentages of chemical constituents in air-dried seeds N, P, K, total carbohydrates, essential oil and crude protein. The highest increase induced in stem diameter due to the treatment of ½ mineral nitrogen + bio-inoculum could be attributed mainly to the prominent increases in thickness of cortex, phloem and xylem tissues as well as pith diameter.

Key words: soybean, bio-inoculum, algae extract, compost, nitrogen, morphology, anatomy, yield, seed oil and crude protein.

Introduction

Soybean [*Glycine max* (L.) Merr.] is a legume crop belonging to the family Fabaceae. Soybean is native of southeastern Asia. It is a very nutritious food being very rich in protein (32 – 42%). It has the highest lysine content (6-8%). It is an excellent food for diabetics, infants and invalids (**Bendre and Kumar,1980).** It is also rich in oil, calcium, phosphorous, iron, potassium, magnesium and vitamins. It is used for food products, paints, varnishes, soaps and animal nutrition, to which they contribute by their seeds, hulls and the green parts (**Pandey,1980**).

In Egypt, cultivation more areas of newly reclaimed lands have been increased during the present decade. It is necessary to increase crop productivity per unit area which could be achieved by using high yielding cultivars, balanced use of fertilizers and adoption of appropriate agricultural treatments. Among these practices the use of fertilizer substances as a possible tool to improve soil fertility as well as induce favorable changes in growth and yield of cultivated plants. However, soybean has been cultivated in Egypt on a large scale as a food source. The acreage of soybean during 2020 season was about 25,000 feddan as reported by Ministry of Agriculture and Land Reclamation, Egypt.

Recently, a great attention has been focused on the possibility of using natural and safety substances in order to improve plant growth as well as minimize both agricultural costs and the pollution of environment. In this respect, bio-fertilizers were useful for recycling elements, reserving natural resources and protection from increasing pollution due to extensive use of mineral fertilizers (**Gupta *et al*. 1999**). The increase in China aster vegetative growth by use of bio-fertilizers might be related in stimulating nutrient uptake and biosynthesis of plant growth regulators, thereby improving the growth and development process of the plant (**Kumar *et al.* 2003**). The efficiency of inoculation by *Bradyrhizobium japonicum* on nodulation and nitrogen fixation in soybean was reported by many investigators (**Bai *et al*., 2002 and Redzepovic *et al*., 2004**). Algae extracts have been reported to support plants in many ways by enhancing flowering, fruit set and crop yield, in addition to improving root structure, enhancing ability to tolerate plant disease and climatic stresses. There are also benefits that relate to improve soil structure, water holding capacity and soil microbiology (**Khan *et al*., 2009; and Arioli *et al*., 2015**).

Organic inputs release important soil nutrients such as nitrogen, phosphorous, magnesium and calcium, in addition to adding nutrients that are absent in inorganic fertilizers, create a favorable environment for root development and enhance plant root accessibility to phosphorus by making the nutrient available (**Fairhurst, 2012**).

Nitrogen is an essential nutrient for plants which has a major impact on the growth and development (**Mahmet, 2008 and Yagoub *et al*., 2012**). According to **Adisarwanto (2010)** nitrogen is one of the chlorophyll constituents which play an important role in photosynthesis. Limited nitrogen will affect the activity of plant metabolism.

The present work was carried out to throw some light on the effect of two bio-fertilizers (bio-inoculum and algae extract), organic manure (compost), and mineral nitrogen (ammonium sulphate) fertilizer on botanical, productive and chemical characters of soybean plants [*Glycine max* (L.) Merr.] grown under sandy soil conditions with the hope of improving the qualities of this important crop.

Materials and Methods

This study was performed at the Agricultural Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt during the two growing seasons of 2019 and 2020. Soybean cultivar “Giza 111” was used in this study.

Seeds were secured from Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. The seeds were sown on May 12^{th}, 2019 and 2020, in plastic pots (30 cm diameter) filled with sandy soil transported from the 6^{th} of October city, Giza governorate. Mechanical and chemical analysis of the soil used for sowing soybean plants were performed according to **Marshal *et al.*, (1996) and George *et al.*, (2013)** at Reclamation and Development Center Desert Soils, Faculty of Agriculture, Cairo University, Giza, Egypt (Table,1).

P and K traditional fertilizers were used as a basal dressing for the all used treatments. Each pot received the following basic rates: 4.1 g/pot calcium super phosphate (15.5% P_2O_5) added two weeks before sowing and 1.1g/pot potassium sulphate (48% K_2O) added two weeks after sowing and repeated one month later.

Table 1. Mechanical and chemical analysis of the soil used for sowing soybean plants during the two experimental growing seasons of 2019 and 2020.

<table>
<tr><th colspan="11">Mechanical analysis %</th></tr>
<tr><th colspan="3">Coarse sand</th><th colspan="2">Fine sand</th><th colspan="2">Silt</th><th colspan="2">Clay</th><th colspan="2">Texture class</th></tr>
<tr><td colspan="3">71.23</td><td colspan="2">22.50</td><td colspan="2">4.15</td><td colspan="2">2.12</td><td colspan="2">Sand</td></tr>
<tr><th colspan="11">Chemical analysis</th></tr>
<tr><th>pH</th><th>EC</th><th>O.M</th><th colspan="4">Soluble anions (meq/ L)</th><th colspan="4">Soluble cations (meq/ L)</th></tr>
<tr><th colspan="3">(dS/m)</th><td>CO_3^{--}</td><td>HCO_3^-</td><td>CL^-</td><td>SO_4^{--}</td><td>Ca^{++}</td><td>Mg^{++}</td><td>K^+</td><td>Na^+</td></tr>
<tr><td>7.8</td><td>0.4</td><td>0.4</td><td>0.00</td><td>1.2</td><td>1.1</td><td>1.00</td><td>1.7</td><td>1.3</td><td>0.2</td><td>1.8</td></tr>
<tr><th colspan="6">Available macronutrients(mg/kg)</th><th colspan="5">Available micronutrients(mg/kg)</th></tr>
<tr><td colspan="2">N</td><td colspan="2">P</td><td colspan="2">K</td><td colspan="2">Cu</td><td colspan="2">Fe</td><td>Mn</td></tr>
<tr><td colspan="2">20.6</td><td colspan="2">0.3</td><td colspan="2">115</td><td colspan="2">0.4</td><td colspan="2">5.4</td><td>1.7</td></tr>
</table>

E.C.: Electrical conductivity; O.M.: Organic matter.

Fertilizers added

Bio-fertilizers; *Bradyrhizobium japonicum* L. (bio-inoculum) was obtained from Production Unit for bio-fertilizers, Agricultural Research Center, Giza, Egypt. One gram of vermiculite contains 10^{-7}– 10^{-8} cells of *Bradyrhizobium japonicum* L. The extract of the blue green algae *Spirulina platensis* (Algae extract) was massively produced at Algae Biotechnology Unit, National Research Center (NRC) in continuous cultures.

Organic fertilizer; The organic manure (compost) was obtained from Miegos Company, Cairo, Egypt.

Mineral fertilizer; Ammonium sulphate (20.5%N) as a source of mineral nitrogenous fertilizer (MN).

The different fertilization treatments can be summarized as the following:

1. Untreated plants: without adding nitrogenous fertilization source.
2. *Brady rhizobium japonicum* (bio-inoculum): 20 g/Kg seeds was mixed with seeds immediately before sowing.
3. Algae extract: 2 cm^3 / Liter of water was sprayed on the plants 30 &45 days after sowing.
4. Compost: 100 g/pot was added 15 days before sowing.
5. Mineral nitrogen fertilizer (MN): 5.4 g/pot ammonium sulphate (20.5%N) was added in four split doses during sowing and then after 7, 15 and 21 days from sowing.
6. 1/2 algae extract +bio-inoculum: 1 cm^3 algae extract/ Liter of water was sprayed on the plants 30,45 days after sowing + seeds were mixed with bio-inoculum during sowing.
7. 1/2 compost + bio-inoculum: 50 g compost/pot was added 15 days before sowing + seeds were mixed with bio-inoculum during sowing.
8. 1/2 MN + bio-inoculum: 2.7 g/ pot ammonium sulphate (20.5%N) was equally divided and added during sowing and then one week later+ seeds were mixed with bio-inoculum during sowing.

The experiment layout was arranged in a randomized complete block design with three replicates. Each block contained eight fertilization treatments that distributed randomly each replicate contained six pots, each pot containing two plants.

Recording of data:

After 130 days from sowing (at harvest time) during each growing season a random sample of 15 plants for each treatment (5 plants from each replicate) were taken for recording the following morphological characters and seed yield components:

Morphological characters:

- Main stem length (cm).
- Number of secondary branches/plant.
- Shoot fresh weight (g)/plant, Fresh weight of main stem, lateral branches and leaves/plant.
- Shoot dry weight (g)/plant, Samples were oven dried at 70 ºC until constant weight was reached.

Seed yield components:

- Number of pods/plant.
- Number of seeds/plant.
- Weight of 100 seeds (g).
- Seed yield /plant (g).

Anatomical studies:

The anatomical studies were performed on plant material (main stem) for treatments which exhibited remarkable effect on the studied characters. Investigated specimens included the sixth basal internode of the main stem. Six random plants per treatment, 2 from each replicate, through the 2nd season (60 days after sowing) were subjected to anatomical studies. Microtechnique procedures were carried out according to **Sass (1967).** Specimens were kept for killing and fixation in formalin- acetic acid-alcohol solution (F.A.A.). The fixed specimens were then washed in 50% ethyl alcohol, dehydrated in normal butyl alcohol series and finally embedded in paraffin wax of 56-58 °C. Sections, 20-micron thickness, were cut using a rotary microtome. Sections were stained with (Crystal violet – Erythrosine) combination, then cleared in xylene before mounting in Canada balsam. Thereafter, the prepared slides were subjected to the microscopic analysis and photomicrographed.

Chemical constituents:

At harvest time (130 days from sowing) in both growing seasons, 3 samples,5g/each of air-dried seeds of each treatment were prepared and percentages of nitrogen (N), phosphorous (P), potassium (K), total carbohydrates and oil were performed at Soil,Water and Environment Research Institute, Agricultural Research Center (ARC), Giza, Egypt. Nitrogen (%) was determined by using the modified- micro-kjeldahl method as described by **Peach and Tracy (1956).** Phosphorous (%) was determined calorimetrically blue color method in sulphuric acid according to **Jackson (1973).** Potassium (%) was determined by using the flame photometer apparatus (CORNING M 410, Germany). Total carbohydrates (%) were determined using the method described by **Duboies *et al.*, (1956).** Protein percentage was calculated by multiplying N% by 6.25 according to **Helrich (1990)**. Oil content percentage in air dried seeds was determined according to applied technique described by **Acree and Teranishi (1993)**.

Statistical analysis

The obtained results were subjected to appropriate analysis of variance as reported by **Snedecor and Cochran (1980)**. The least significant differences (L.S.D.) at 5% were calculated for each investigated character under different assigned treatments.

Results and Discussion

Morphological characters

Data of morphological characters are presented in Table (2). Data exhibited that the individual treatments of the adopted fertilizers as well as the combined treatments (half dose of each fertilizer with bio-inoculum) significantly gave higher results for the studied characters than those of untreated plants.

Data revealed that the application of bio-inoculum alone significantly recorded increases of 8.40, 42.90, 15.80 and 29.40% over untreated plants for stem length, number of secondary branches/plant, shoot fresh weight and shoot dry weight/ soybean plant, respectively, in the 1st season. Data of the 2nd season recorded increases of 8.20, 36.40, 20.20 and 27.00% more than untreated plants for aforementioned characters, respectively. Plants treated with mineral nitrogen as a single treatment (full dose) recorded significant increase in all studied morphological characters of soybean plant comparing with those of untreated plants or other single treatments, which recorded 126.80 cm for stem length, 7.60 secondary branches/plant, 145.66 g for shoot fresh weight and 43.16 g for shoot dry weight in 1st season. As well, in 2nd season recorded 129.27 cm for stem length, 8.70 secondary branches/plant, 158.00 g for shoot fresh weight and 45.00 g for shoot dry weight. This positive effect of mineral nitrogen was generally followed by algae extract then compost treatment.

Concerning the combined treatments, the results cleared that combination treatment of half dose of mineral nitrogen with bio-inoculum had pivotal effect on plant morphology. It significantly increased most of the morphological characters of soybean plant in comparison with other treatments in both growing seasons. However, this combined treatment recorded 126.80 and 130.27 cm for stem length, 7.53 and 9.10 for secondary branches/plant, 186.33 and 191.66 g for shoot fresh weight/plant and 52.00 and 54.00 g for shoot dry weight/plant in 1st and 2nd seasons, respectively. This positive effect was followed by ½ algae extract + bio-inoculum as a combined treatment.

In this concern, the increase in plant vegetative growth by use of bio-fertilizers might be related to stimulating nutrient uptake and biosynthesis of plant growth regulators, thereby improving the growth and development process of the plant **(Kumar *et al*, 2003).** The increase in plant growth parameters due to rhizobium inoculation was attributed to fixing high amount of nitrogen **Abd El-Fattah and Arisha (2000).** Similar trend of effect was shown by **El-Sagan and Rashad (2020)** and **Mohamed (2020)** on broad bean. The stimulative effect of MN fertilizer on plant growth was also recorded by **Begum *et al*. (2015); Niranjan *et al* (2015) and Raghuveer and Hosmath (2017)** on soybean.

Table 2. Morphological characters of soybean plant, at 130 days old, as affected by bio-, organic and mineral fertilizers during the two seasons of 2019 and 2020.

Treatments	Stem length (cm.)		Number of secondary branches/plant		Shoot fresh weight /plant(g)		Shoot dry weight /plant(g)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Untreated plants (No added N source)	87.20	90.60	3.73	5.50	64.20	82.33	16.46	20.23
Bio-inoculum	94.53	98.07	5.33	7.50	74.33	99.00	21.30	25.70
Algae extract	115.53	119.33	6.13	7.90	99.56	110.33	32.73	35.16
Compost	112.53	116.67	6.40	8.10	89.45	106.33	26.66	29.30
Mineral nitrogen	126.80	129.27	7.60	8.70	145.66	158.00	43.16	45.00
½ algae extract + bio-inoculum	126.27	129.53	7.77	9.10	165.60	176.66	47.70	49.66
½ compost + bio-inoculum	116.40	122.00	6.97	7.90	135.33	149.70	38.66	40.60
½ mineral nitrogen + bio-inoculum	126.80	130.27	7.53	9.10	186.33	191.66	52.00	54.00
LSD 5%	2.66	1.79	0.55	0.52	10.09	8.16	4.22	4.26

Anatomical studies

The histological characters were microscopically measured in transverse sections through the median portion of the 6th basal internode of soybean main stem and the microphotographs were taken (Table 3 & Fig. 1)

It is realized from (Table 3 and Fig. 1) that stem diameter decreased in untreated plants compared to other used treatments, recording 2507.0 µ. This reduction in stem diameter was reflected in decreased thickness of epidermis, cortex, vascular cylinder and pith diameter which recorded 17.0, 49.0, 556.0 and 1265.0 µ, respectively. It was recorded that treating soybean plants with *Bradyrhizobium* as an individual treatment increased diameter of the sixth basal internode on main stem than that of untreated internode. The thickness of epidermis (18.0µ), cortex (64.0µ), vascular cylinder (680.0µ) and diameter of pith (1433.0µ) of bio-inoculated internode recorded higher values than those of untreated one.

The combined treatment of half dose of algae extract + bio-inoculum increased the internode diameter (being 3432.0 µ) more than that of untreated or bio-inoculated internode due to increasing thickness of the studied tissues; epidermis, cortex, fiber tissue, phloem and xylem as well as diameter of pith, recording 22.0, 86.0, 50.0, 123.0, 704.0 and 1447.0µ, respectively.

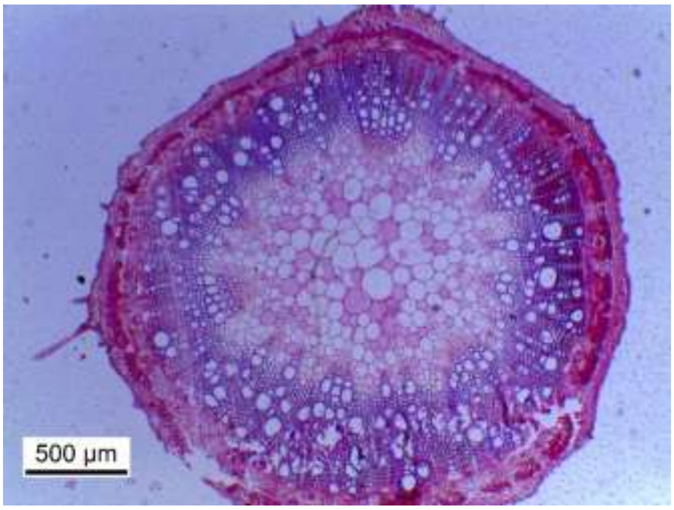
The highest values of the studied anatomical characters were determined in the stems which received the combined treatment of half dose of mineral nitrogen with bio-inoculum comparing with other adopted treatments. This might explain the ability of this combined treatment (½ mineral nitrogen +bio-inoculum) to stimulate internode diameter being 4018.0 µ. This was due to increasing thickness of epidermis, cortex, fiber tissue and vascular cylinder as well as pith diameter, being 23.0, 111.0, 52.0, 943.0 and 1860.0 µ, respectively.

It is clear also that the prominent increase in the thickness of vascular cylinder could be attributed to increasing thickness of phloem and xylem tissues (being, 155.0 and 736.0 µ, respectively). The positive effects of some adopted treatments on structure of main stem might facilitate the translocation of more water, nutrients, minerals and metabolites throughout the plant tissues. This might improve the growth of the treated plants.

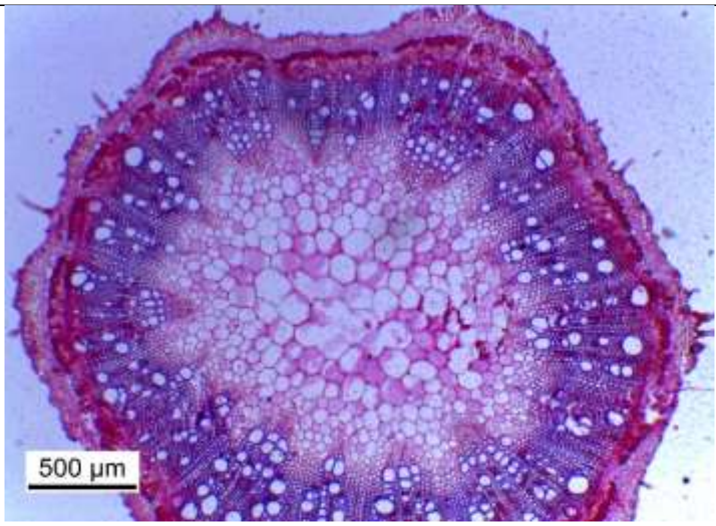
In this concern, **Abdel-Fattah *et al.* (2011)** on soybean plant, stated that inoculation of plants by *Bradyrhizobium japonicum* combined with 20 kg MN/fed increased thickness of both xylem and phloem and decreased pith diameter of main stem. **Intedhar and Majeed (2015)** on pepper plant, indicated that seaweed extract (6 ml/l) increased thickness of cortex and vascular cylinder of stem. **Marhoon and Abbas (2015)** on sweet pepper (*Capsicum Annuum* L.) plant, reported that the increment in stem diameter of seaweed treated plants may be resulting from the important action of cytokinin's in enhancing cell division and improving the cambium activity that led to form new vascular bundles and increase the stem diameter. **Salama and Yousef (2015)** on basil plant (*Ocimum sanctum* L.) recorded that foliar applications with seaweed extract (1.5 ml/l) increased main stem diameter as well as thickness of cortex, phloem and xylem tissues more than those of the control. **Salama *et al*. (2019)** on common bean plants, reported that foliar application with 1ml/l algae extract mixed with 6 ml/ l amino acid increased main stem diameter as well as thickness of cortex, phloem and xylem tissues and vessel diameter more than control.

Table 3. Mean values of some histological traits (in micron) of 6th basal internode of soybean main stem, as affected by bio-inoculum, ½ algae extract + bio-inoculum and ½ mineral nitrogen +bio-inoculum at the age of 60 days from sowing during the second season of 2020.

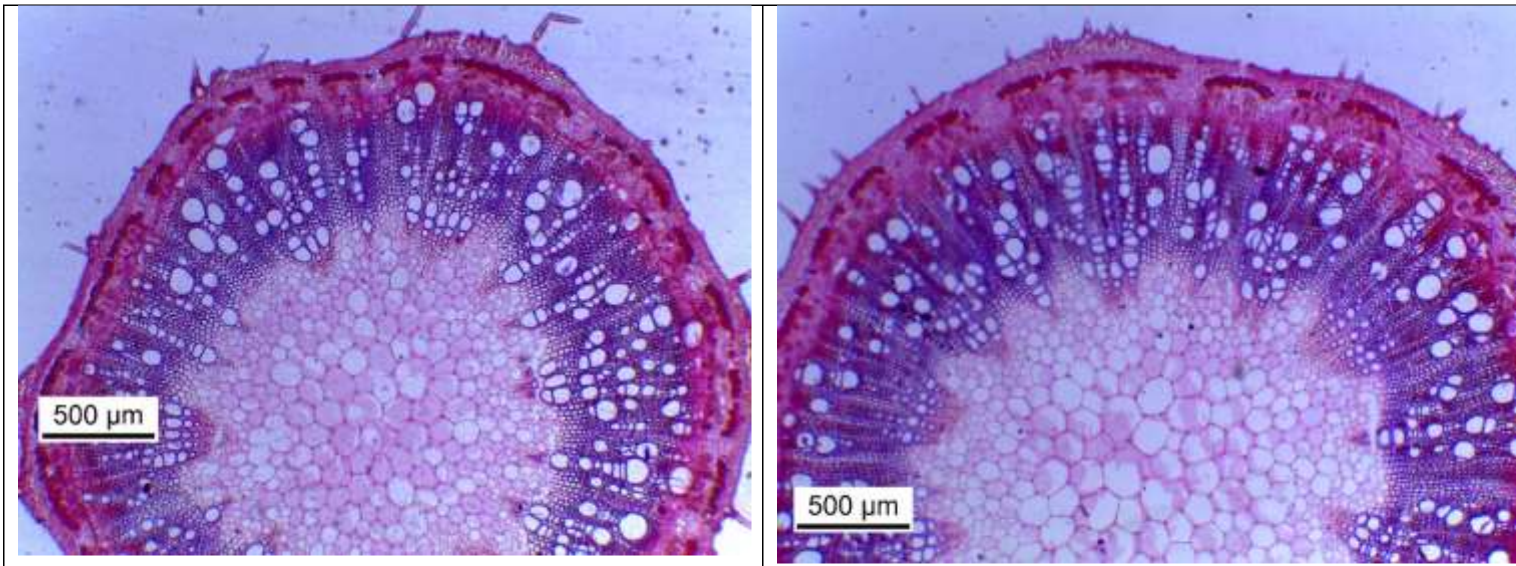
Characters	Treatments			
	Untreated (No added N source)	Bio-inoculum	½ algae extract + bio-inoculum	½ mineral nitrogen + bio-inoculum
Diameter of whole section	2507.0	2978.0	3432.0	4018.0
Thickness of epidermis	17.0	18.0	22.0	23.0
Thickness of cortex	49.0	64.0	86.0	111.0
Thickness of fiber tissue	42.0	41.0	50.0	52.0
Thickness of vascular cylinder	556.0	680.0	877.0	943.0
Thickness of phloem tissue	80.0	71.0	123.0	155.0
Thickness of xylem tissue	434.0	569.0	704.0	736.0
Diameter of pith	1265.0	1433.0	1447.0	1860.0



A



B



C D

Fig. 1. Transverse sections in the sixth basal internode of soybean main stem, at the age of 60 days from sowing during the 2nd season of 2020, as affected by bio-inoculum, ½ algae extract + bio-inoculum and ½ mineral nitrogen +bio-inoculum. (40 X)

A- Untreated
B- Treated, bio-inoculum
C- Treated, ½ algae extract + bio-inoculum
D- Treated, ½ mineral nitrogen + bio-inoculum

Seed yield components

The studied of seed yield characters included number of pods /plant, number of seeds /plant, weight of 100 seeds and seed yield /plant.

As shown in Table (4), untreated plants statistically exhibited lower values than other adopted treatments for number of pods/plant (77.07 and 83.40), number of seeds/plant (164.16 and 200.16), weight of 100 seeds (6.58 and 7.96g) and seed yield/plant (10.80 and 15.94 g) in 1st and 2nd seasons, respectively.

Concerning the single treatments, bio-inoculum statistically recorded lower values in number of pods/plant (94.73 and 101.80), number of seeds/plant (215.04 and 244.32) and seed yield/plant (21.23 and 23.62 g) in both seasons, respectively comparing with other single treatments. Mineral nitrogen as a single treatment produced the higher value of number of pods/plant (129.33 and 133.80), number of seeds/plant (362.12 and 401.40) and seed yield/plant (33.47 and 32.96 g) in 1st and 2nd seasons, respectively comparing with those of other single treatments. No significant differences were detected between the effects of algae extract and compost treatments on all seed yield characters in both growing seasons. In this regard, **Sohrabi *et al*. (2012)** reported that application of 100 kg N ha^{-1} to soybean plants during reproductive stage gave the maximum number of seeds pod^{-1} and seed yield.

The combined treatment of *Bradyrhizobium* with half dose of mineral nitrogen generally gave the highest values as compared with other treatments for number of pods/plant (139.07 and 147.00), number of seeds/plant (399.13 and 441.00) and seed yield/plant (40.93 and 46.16 g) in 1st and 2nd seasons, respectively. **Koushal and Singh (2011)** observed that the highest number of pods /soybean plant (80.40) was recorded in the treatment where 50% recommended N applied through urea + 50 % N through FYM + Phosphorous solubilizing bacteria (PSB) and the lowest of these were found in the control treatment.

Table 4. Seed yield characters of soybean plant of 130 days old, as affected by bio-, organic and mineral fertilizers during the two seasons of 2019 and 2020.

Treatments	Number of pods/plant		Number of seeds/plant		Weight of 100 seeds(g)		Seed yield/plant (g)	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Untreated plants (No added N source)	**77.07**	**83.40**	**164.16**	**200.16**	**6.58**	**7.96**	**10.80**	**15.94**
Bio-inoculum	**94.73**	**101.80**	**215.04**	**244.32**	**9.87**	**9.67**	**21.23**	**23.62**
Algae extract	**110.40**	**116.80**	**301.39**	**350.40**	**9.66**	**9.38**	**29.13**	**32.88**
Compost	**111.80**	**118.40**	**305.21**	**331.52**	**8.98**	**9.53**	**27.39**	**31.60**
Mineral nitrogen	**129.33**	**133.80**	**362.12**	**401.40**	**9.24**	**8.21**	**33.47**	**32.96**
½ algae extract + bio-inoculum	**125.13**	**132.80**	**334.10**	**398.40**	**12.22**	**11.67**	**40.82**	**46.50**
½ compost + bio-inoculum	**126.53**	**133.60**	**312.53**	**347.36**	**12.64**	**13.33**	**39.50**	**46.32**
½ mineral nitrogen + bio-inoculum	**139.07**	**147.00**	**399.13**	**441.00**	**10.25**	**10.47**	**40.93**	**46.16**
LSD 5%	**4.87**	**6.23**	**41.32**	**51.92**	**1.51**	**1.07**	**2.94**	**3.18**

Chemical constituents

Percentages of N, P, K, total carbohydrates, essential oil and protein in air- dried seeds of soybean are presented in Table (5).

Seed mineral:

Plants inoculated by *Bradyrhizobium jabonicum* non-statistically increased nitrogen percentage than those of untreated plants, being 5.82 and 5.92% for untreated plants as well as 6.10 and 6.22% for bio-inoculated plants in both seasons, respectively (Table, 5).

Application of mineral nitrogen as full dose statistically gave the higher percentages of nitrogen (6.79 and 6.86%) than those of other single treatments in both seasons. Spraying plants with algae extract significantly increased nitrogen percentage in seeds comparing with bio-inoculated or untreated plants, being 6.39 and 6.37% in the two seasons, respectively. The increase of macro elements in soybean seeds resulted from the application of algae extract may be attributed to the beneficial effects of algae extract as natural regulators or as an organic bio stimulator, which improve plant vigor **(Galbiattia *et al*. 2007).** In addition, seaweed extract contains auxins, cytokinins, mineral elements and vitamins which induce many processes due to having an influence on the content of some macronutrients (**Wierzbowska and Bowszys, 2008).** Also, **Rathore *et al*. (2009)** reported that application of seaweed extract increased uptake of N in soybean plant.

As to the effects of the combined treatments (half dose of each fertilizer + *Bradyrhizobium jabonicum*), ½ mineral nitrogen + bio-inoculum (6.97 and 7.12%N) regardless significancy increased nitrogen% of seeds during the two seasons than those of ½ algae extract + bio-inoculum (6.60 and 6.68%N) or ½ compost + bio-inoculum (6.83 and 6.86%). However, the treatment of ½ mineral nitrogen + bio-inoculum was the reliable treatment for increasing nitrogen% in soybean seeds among all single or combined treatments (Table, 5).

All treatments statistically gave similar percentages of phosphorous in air-dried seeds of soybean in both seasons Table (5). The highest percentages of P were recorded when plants treated with ½ mineral nitrogen + bio-inoculum reaching 0.59 and 0.62% in both seasons respectively, followed by treatment of compost as full dose (0.55 and 0.58%), then ½ algae extract + bio-inoculum (0.54 and 0.57%), in the same order. In this concern, **Rathore *et al*. (2009)** reported that application of seaweed extract increased P uptake in soybean. **Zadapea *et al.* (2009)** showed that spraying wheat plants with the Kappaphycus alvarezii extract increased P concentration in grains. **Sosnowski *et al.* (2014)** found that application of the seaweed extract to alfalfa plants increased P content in aerial biomass.

Concerning the effect of different fertilizers on potassium percentages, data in Table (5) revealed that there are no significant differences among most of the adopted treatments during the two seasons. However, regardless significancy plants treated with ½ mineral nitrogen + bio-inoculum recorded the highest value (0.55 and 0.58%) followed by plants treated with mineral nitrogen or algae extract as a single dose (0.48 and 0.51%) and the lowest value observed in untreated plants (0.43 and 0.38%) in both seasons, respectively. In this respect, **Rathore *et al*. (2009)** found that application of seaweed to soybean plants increased uptake of K. **Zodapea *et al*. (2009)** observed the promotive effect of *Kappaphycus alvarezii* extract as spray treatment on concentration of K in wheat (*Triticum aestivum*) grains. Also, **Sosnowski *et al.* (2014)** found that application of seaweed extract increased K content in alfalfa aerial biomass.

It is obvious that untreated plants significantly showed the lowest percentages of carbohydrate 12.46 and 12.27% in the 1st and 2nd seasons, respectively as compared with those of other treatments (Table ,5). Bio-inoculum showed significant remarkable elevation in total carbohydrate percentages as compared with untreated plants, recording 13.56 and 14.37% in both seasons, respectively. Compost treatment showed significant increase in this respect than those of bio-inoculum plants recording 14.37 and 15.23% in the two growing seasons, respectively. Full dose of mineral nitrogen as a single treatment significantly gave higher carbohydrate percentages, over all adopted single treatments being 18.17 in the first season and 20.48% in the second one. However, the highest percentages of 19.09 and 21.71% were recorded with ½ MN + bio-inoculum in 1st and 2nd seasons, respectively.

As regard to percentage of oil in air-dried seeds, it is clear from Table (5) that the untreated plants statistically gave the lowest percentages of seed oil recording 12.15% in 1st season and 12.23% in 2nd one comparing with all other treatments. Bio-inoculated plants recorded significant increase in seed oil % compared with untreated plants, being 12.67 and 13.23% in the two growing seasons, respectively. In this concern, **Kaschuk *et al.* (2010)** on soybean plants, found that inoculation with rhizobial had no significant effect on seed lipids mass. Mineral nitrogen as full dose significantly increased seed oil percentage than other single treatments where it recorded 18.11 and 19.21% in both seasons, respectively. Plants sprayed with algae extract exhibited significant increase in seed oil% as compared with compost as full dose. Data recorded 14.00 and 13.07% in 1st season and 14.80 and 14.19% in 2nd season for algae extract and compost, respectively. Statistically, the highest percentage of seed oil (18.92 and 20.93%) was recorded in 1st and 2nd seasons, respectively with ½ mineral nitrogen + bio-inoculum comparing with other used treatments.

Concerning the percentage of protein in soybean air-dried seeds, data in Table (5) proved that there were no significant differences between the untreated plants (36.38 and 37.01%) and those inoculated with *Bradyrhizobium japonicum* (38.13 and 38.91%) in both seasons, respectively. The untreated plants achieved the lowest percentages among the various tested treatments. The full dose of mineral nitrogen statistically gave higher percentages of protein in air dried seeds comparing with other single treatments, being 42.41 and 42.88% for 1st and 2nd seasons, respectively.

Concerning the effects of the combination treatments, it was clear that, ½ mineral nitrogen + bio-inoculum gave the highest percentage of protein in seeds (43.56 and 44.51%) in both seasons, respectively with significant differences than most of the adopted treatments. However, **Elsheikh and Ibrahim (1999)** reported that *Bradyrhizobium* strains significantly increased the crude protein content in seeds of guar (*Cyamopsis tetragonoloba* L.). **Egamberdieva *et al*. (2004)** revealed that inoculation with *Bradyrhizobium japonicum* increased protein content in soybean seeds. **Kaschuk *et al.* (2010)** on soybean, found that inoculation with rhizobial improved seed protein by 7%.

It is realized that the treatment of half dose of any fertilizer with bio-inoculum significantly increased the percentages of the studied chemical constituents in seeds than those of each fertilizer as a single treatment (full dose) with more positive effects on morphology and productivity of the plant.

Table 5. Nitrogen, phosphorous, potassium, total carbohydrates, oil and crude protein percentage of soybean air-dried seeds, at harvest time (130 days old), as affected by bio-, organic and mineral fertilizers in the two growing seasons of 2019 and 2020.

Treatments	N%		P%		K%		Total carbohydrates%		Seed oil%		Crude protein%	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Untreated plants (No added N source)	5.82	5.92	0.41	0.43	0.43	0.38	12.46	12.27	12.15	12.23	36.38	37.01
Bio-inoculum	6.10	6.22	0.53	0.56	0.46	0.49	13.56	14.37	12.67	13.23	38.13	38.91
Algae extract	6.39	6.37	0.50	0.53	0.48	0.51	14.00	14.31	14.00	14.80	39.94	39.84
Compost	6.11	6.23	0.55	0.58	0.47	0.50	14.37	15.23	13.07	14.19	38.22	38.96
Mineral nitrogen	6.79	6.86	0.52	0.55	0.48	0.51	18.17	20.48	18.11	19.21	42.41	42.88

½ algae extract + bio-inoculum	**6.60**	**6.68**	**0.54**	**0.57**	**0.44**	**0.47**	**18.52**	**21.07**	**15.79**	**16.71**	**41.28**	**41.75**
½ compost + bio-inoculum	**6.83**	**6.86**	**0.45**	**0.47**	**0.45**	**0.46**	**17.85**	**18.68**	**14.60**	**15.41**	**42.69**	**42.89**
½ mineral nitrogen + bio-inoculum	**6.97**	**7.12**	**0.59**	**0.62**	**0.55**	**0.58**	**19.09**	**21.71**	**18.92**	**20.93**	**43.56**	**44.51**
LSD 5%	**0.29**	**0.31**	**Ns**	**Ns**	**Ns**	**0.17**	**0.63**	**0.47**	**0.49**	**0.42**	**1.76**	**1.91**

Conclusion

In the light of the obtained results, it could be concluded that combined treatment of half dose of mineral nitrogen plus *Bradyrhizobium jabonicum* proved to be more effective in promoting morphology, productivity and chemical constituents of soybean plants grown under sandy soil conditions. These findings emphasize the magnitude of the role of inoculation with *Bradyrhizobium japonicum* in mitigating environmental pollution while providing safe production.

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