



Effect of Effective Microorganisms on Vegetative Growth of Wheat

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ABSTRACT

Background: Environmental pollution has led to climate change and agriculture is an aspect of this pollution, Pesticides, fertilizers and plant growth regulators are pollutants in soil and water. Therefore, beneficial microorganisms found in nature to provide plants with nutrients, resist pests and reduce mineral fertilizers is an ambitious goal for researchers. On the environment. *Pseudomonas* bacteria, baker's yeast and mycorrhizal fungi are known for their ability to increase a group of nutrients' organic and amino acids, as well as plant hormones that stimulate growth.

Methods: A field experiment was conducted at University of Baghdad to assess the impact of beneficial microorganisms on wheat growth traits during winter of 2019-2020, using a randomized complete block design (RCBD) with eight treatments: *Pseudomonas fluorescens* bacteria (Pse), Mycorrhizae *Glomus* spp. (Gl.), *Saccharomyces cerevisiae* yeast (Sa.), Ps+Gl, Gl+Sa, Ps+Sa, Ps+Sa+Gl and control.

Result: Experimental indicated that treatments significantly outperformed in plant height, tiller number, CGR (crop growth rate) and total dry weight. Additionally, the Ps+Sa+Gl treatment demonstrated a significant superiority over all other treatments in terms of plant height and tiller number. These observations suggest that the combination of biological factors within a single treatment resulted in a synergistic interaction, that led to enhancement of the vegetative growth indices in wheat plants.

Key words: CGR, Mycorrhizae, Nutrient availability, *Pseudomonas fluorescens*, *Saccharomyces cerevisiae* yeast.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide, serving as a staple food for a significant portion of the global population. Enhancing wheat production and quality is crucial to meet the increasing demand for food security. In this context, exploring sustainable agricultural practices that improve wheat growth and yield without relying heavily on chemical inputs is of paramount importance. Utilization of beneficial soil microorganisms promote plant growth, enhance uptake, which is helpful in realizing sustainable crop productivity.

After environmental pollution and climate change it is certain that chemical fertilizers and other chemical compounds used in agriculture have contributed to environmental pollution. Usage of biological fertilizers (beneficial soil organisms for plants) known as Bio. Farming technology and testing its formulations represent a promising program to reduce environmental pollution and increase crop productivity. This trend has a very important sustainability aspect in conserving natural resources as well as reducing the cost of cultivation however its effectiveness is still low (Gouda *et al.*, 2018). Mycorrhiza is the symbiotic relationship that arises between soil fungi and plant roots. It enhances the plant's ability to withstand biotic and abiotic stresses, thereby increasing vegetative, fruit and root growth indices (Wahab *et al.*, 2023). Mycorrhizal fungi are one of the most famous fungi that promote plant growth and compensate for 50% of the added chemical fertilizers (Ziane *et al.*, 2017). The fungus supplies the plant with vital nutrients (Sangothari *et al.*, 2024), like phosphorus and nitrogen that it has dissolved from the soil,

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while the plant supplies sugars from photosynthesis and organic molecules (Luo *et al.*, 2023; Zang *et al.*, 2023) and improving soil structure by secreting an exopolysaccharide called Glomalin, it also stimulates the production of plant hormones and the effectiveness of some enzymes in plants (Bitterlich *et al.*, 2018; Zhang *et al.*, 2023). El-Latif and Mohamed (2011) indicated that some strains of *Saccharomyces cerevisiae* yeast have the ability to dissolve inorganic phosphate compounds by producing citric acid. Integrated biological fertilization of wheat plants with *Saccharomyces cerevisiae* yeast along with nitrogen fertilizer (50% and 75% of the recommended fertilizer rate) led to a significant increase in chlorophyll a and b, increased plant uptake of NPK nutrients and an increase in plant height (Hamed *et al.*, 2022). The yeast also has the ability to extract potassium from complex compounds through the organic acids it secretes (Mohamed *et al.*, 2017) and it increases

vegetative growth indices (Mahmoud *et al.*, 2020). The benefits of *Pseudomonas spp* bacteria can be summarized as they belong to the group of phosphorus-solubilizing bacteria (PSB) in the soil (Iftikhar *et al.*, 2023), increase nutrient availability (Bargaz *et al.*, 2023), fix atmospheric nitrogen, oxidize sulfur, enhance root permeability, reduce the effect of growth inhibitors (such as ethylene), increase the activity of plant growth regulators (cytokinins, auxins, gibberellins), act as biofertilizers and increase root infection by mycorrhiza, both external and internal types (Abed *et al.*, 2016). By using these bacteria as bio-inoculants, one can improve plant growth indicators (Resmi *et al.*, 2024), soil nutrient availability, minimize the use of chemical fertilizers, lessen pollution to the environment and advance sustainable agriculture.

Among the benefits of these bacteria is their high pathogenicity to white ants (Etesami and Adl, 2020); (Kamil *et al.*, 2023) found that the fungus *Glomus spp.* and the bacterium *Pseudomonas spp.*, plant growth promotion (Aljuboori *et al.*, 2022; Dey *et al.*, 2024).

MATERIALS AND METHODS

A field experiment was conducted in the fields of the College of Agricultural Engineering Sciences at University of Baghdad during the winter season of 2019-2020 with the aim of determining the effect of some beneficial microorganisms on vegetative growth traits of wheat variety 'IBA 99'. The experiment was conducted using a randomized complete block design (RCBD) with three replications. Each replicate consisted of 8 treatments, including the addition of *Pseudomonas fluorescens* bacteria (Pse), mycorrhizal fungi *Glomus spp* (Gl.), *Saccharomyces cerevisiae* yeast (Sa.), Ps+Gl, Gl+Sa, Ps+Sa, Ps+Sa+Gl, in addition to the control treatment.

Mycorrhizal fungi *Glomus spp.* grown on wheat roots and bacteria *Pseudomonas* grown in King B liquid medium in an incubator at 28°C for 48 hours. The count was done at the end of the incubation period and the number of colonies was 1×10^8 cfu ml⁻¹. A yeast culture medium was prepared consisting of 10 g L⁻¹ commercial baker's yeast, 20 g L⁻¹

peptone and 200 g L⁻¹ D-glucose and incubated at 30°C for 24 hours to obtain number of live cells of more than 10^9 cfu ml⁻¹. The bioagents were added to the experimental soil at a depth of 5 cm below the planting lines and at a rate of 1 g per line for *Glomus* and 1 ml each for *Pseudomonas* and *Saccharomyces*. In separate experimental units, each according to its treatment. The treatments were separated from each other by a distance of 1 m to prevent interference between them. Table 1 shows some of the physical and chemical properties of the soil. The seeds were planted on 20/11/2019 (Mahmood and Al-Hassan, 2023.) in rows with a distance of 20 cm between each row to give a seed rate of 120 kg ha⁻¹. Nitrogen, phosphorus and potassium fertilizers were added at 50% of the recommended rate (Hamed *et al.*, 2022). Due to the use of beneficial soil biota, nitrogen fertilizer (60 kg N ha⁻¹) was added at the ZGS21 and ZGS41 stages (Al-Zubade, 2022) and phosphorus and potassium fertilizer at a rate of 50 kg ha⁻¹ for each of P and K. The traits were measured: Plant height (cm) and leaf area (cm²) by equation Leaf area = leaf length×leaf width at mid-point×0.95, Number of leaves on the main stem, leaf weight (g) leaves were weighed after separation from the stem and drying crop growth the crop growth rate (CGR) (g m⁻² day⁻¹).

$$CGR = \frac{(1/GA) * (W2 - W1)}{(T2 - T1)}$$

Number of tillers (tillers m⁻²) and total dry weight (kg ha⁻¹).

The data were statistically analyzed according to the analysis of variance (ANOVA), using the GenStat statistical computer program and a significance level of 0.05. The means were compared using the least significant difference test (LSD) (Table 1). Some chemical and physical characteristics of field soil.

RESULTS AND DISCUSSION

Plant height (cm)

The result shows that all treatments significantly outperformed the control treatment (Table 2). The Sa treatment exhibited a

Table 1: Some chemical and physical characteristics of field soil.

	Traits	Unit	Value
Soil pH			7.4
	Electrical conductivity (EC)	da m ⁻¹ 3.5	
	Organic matter (O.M)	g kg ⁻¹	0.63
	Calcium carbonate (CaCO ₃)	%	34.01
	Calcium	me l ⁻¹	11.12
	Chloride (Cl)		14.96
	Available nitrogen		2.2
	Available phosphorus		4.91
	Available potassium	me l ⁻¹	82.33
Soil separates	Clay content		20.85
	Silt content	%	30.00
	Sand content		49.15
	Soil texture		Loamy

6.85% increase compared to the control treatment, which was the lowest among the superior treatments. Subsequently, the percentage increased in the other individual and double combined treatments, culminating in its peak at the Ps+Sa treatment, which recorded an increase of 11.41%. It should be emphasized that there were no significant differences observed among these treatments. Notably, the triple treatment (Ps+Sa+GI) demonstrated the highest plant height, significantly exceeding all other treatments, with an increase percentage of 25.42% relative to the control treatment. This increase in plant height with the use of biological factors, as well as the combination of the three biological factors, indicates the importance of these factors. We find that Ps and Sa secrete growth-promoting substances such as auxins, gibberellins and cytokinins in the Rhizosphere region, known for stimulating growth by increasing plant cell division and elongation, especially in the plant stem. As for GI fungi, they degrade complex compounds in the soil, increase nutrient availability, stimulate the production of growth-promoting plant hormones and enhance the efficiency of photosynthesis. This may reflect in the stimulation of plant meristematic tissue by increasing cell division. When the three factors are combined in a single treatment (Ps+Sa+GI), it outperforms all other treatments because it combines all the features in one treatment.

Leaf area (cm²)

Data presented in Table 2 indicate that the control treatments, Ps and GI, exhibited the lowest average leaf area. Notably, all other treatment groups surpassed these in terms of leaf area. It appears that the Sa treatment is the only one among the individual treatments that achieved a significant improvement, joining the double and triple treatments. This may be due to the yeast's production of cytokinins, auxins and gibberellins, which are necessary for cell division, expansion, photosynthesis and transport stimulation in plant tissues. The yeast also produces various enzymes such as sucrase, lactase, maltase, hexose phosphatase, reductase, carboxylase, melibiase and vitamins such as B2, B4, B5, B6, B12, niacin and biotin. These compounds vary between harmoniously stimulating growth and breaking down complex compounds in the

growth medium to make them easily absorbable by the plant and provide it with enzymes that facilitate various metabolic processes, resulting in increased leaf area. Regarding GI fungi, it increases the availability of essential minerals such as P, Mn, Cu, Zn, Mg and Ca by secreting certain acids, making it easier for the plant to absorb these elements and utilize them in various metabolic processes. This includes improving the efficiency of photosynthesis and enhancing transport processes between different parts of the plant. As for Ps bacteria, which fix important nitrogen and increase the availability of phosphorus and other mineral nutrients for the plant, they are important growth factors that may positively impact the increase in leaf area. Although the individual GI and Ps treatments did not achieve significant superiority over the control treatment, their combination with each other or with the yeast treatment in double or triple treatments resulted in a significant improvement in leaf area.

Number of main stem leaves

According to the results presented in Table 2, no statistically significant differences were observed among treatments in the number of main stem leaves. Notably, this was the only trait where all treatment groups remained statistically not significant from the control. This could be due to the number of tillers, in which all treatments surpassed the control treatment, meaning that dry matter distribution is spread over more units, thus depleting the plant's energy needed to produce a greater number of leaves on the main stem according to the compensation principle. This claim is supported by the significant increase in CGR, tiller number and total dry weight in all treatments compared to the control treatment.

Leaves weight (gm)

The result indicate a significant increase in the leaf weight of wheat plants in the Sa treatment (from the individual treatments), Ps+Sa treatment (from the double treatments) and Ps+Sa+GI treatment (from the triple treatments) compared to the rest of the treatments (Table 2). Leaves are considered the most important tissues in photosynthesis and their dry weight reflects the efficiency of this process, as well as the efficiency of plant transportation and healthy growth (Ali and Abraheem, 2023). The increase in leaf weight in the

Table 2: The effect of biological factors and their combinations on some vegetative growth traits of wheat.

Treatments	Plant height cm	Flag leaf area cm ²	Leaves number on main stem	Leaves weight g m ⁻²	Number of tillers m ⁻²	CGR (g g ⁻¹ d ⁻¹)	Total dry massg m ⁻²
GI	84.82	46.43	4.41	532.7	510.8	7.16	1075.
Ps	85.51	44.83	4.16	560.0	508.7	7.09	1064.
Sa	83.91	48.12	4.31	625.9	521.90	7.57	1136
Ps+GI	86.38	49.43	4.16	552.0	510.9	7.09	1065.
GI+Sa	87.11	47.99	4.16	544.7	519.8	7.46	1120.
Ps+Sa	87.87	53.09	4.79	626.4	528.8	7.76	1165.
Ps+Sa+GI	98.50	49.19	4.41	645.4	569.7	8.13	1220.
Control	78.53	41.10	4.02	521.1	488.5	6.32	949.
LSD	5.56	5.94	N.S	62.50	13.89	0.57	86.4

Sa treatment indicates the role of microorganisms in growth regulation, such as cytokinins, gibberellins and auxins, known for stimulating growth, increasing leaf area, preserving chlorophyll content, enhancing transportation efficiency between plant tissues and providing easily absorbable nutrients. These factors act as stimulants for increasing vegetative growth, which is reflected in the increase in leaf weight. It is worth noting that this treatment was also superior in leaf area. The Ps+Sa and Ps+Sa+GI treatments contain yeast, which has previously been discussed for its effect on leaf dry weight, in addition to Ps bacteria known for increasing the availability of plant nutrients and GI fungi, which improve vegetative and root growth indices by enhancing nutrient availability, stimulating plant hormone production and increasing photosynthetic efficiency.

Tiller number

The results reveal that all treatments significantly enhanced tillering compared to the control, leading to greater tiller density (tillers per m²). Tiller abundance in cereals increases with the availability of growth factors such as nutrients, water, space, light, planting date and variety, in addition to the encouraging hormonal balance for tillering. With the stability of factors like water availability, plant density, light exposure, planting date and variety, the nutrients provided by biological factors in the Rhizosphere and plant hormones such as cytokinins, known for promoting bud release from dormancy, will manifest their effect in increasing tiller number. Ps+Sa+GI outperformed all treatments, suggesting synergistic effects of combined biofactors.

Crop growth rate (CGR)

Results of Table 2 showed a significant superiority of all treatments over the control treatment in plant height, leaf number and total dry weight. The Ps+Sa+GI and Ps+Sa treatments significantly outperformed all other treatments in all measured traits. This increase in growth traits can be interpreted through the increase in CGR, indicating a daily increase in dry matter deposition in the plant. This is due to the stimulation exerted by biological factors in increasing vegetative growth, which varies between providing important mineral elements in growth (such as NPK and growth-promoting regulators) cytokinins, auxins and gibberellins and some acids, enzymes, vitamins and others, which push towards increasing plant growth. The combination of biological factors in the Ps+ Sa +GI treatment and two factors in the Ps+Sa treatment has given it an advantage by combining growth promoters in one treatment, surpassing these two treatments over all other treatments. This result is consistent with (Mahmood and Zeboon, 2019), who found that spraying wheat plants with gibberellin GA3 increased CGR and since these organisms produce GA3 and other hormones that lead to increased CGR.

The total dry mass (g m⁻²)

The results revealed a significant superiority of all treatments over the control treatment in total dry mass total dry mass. Previously, all treatments surpassed the control treatment

in terms of the number of tillers, CGR, plant height and increases in these traits led to the accumulation of dry matter in the plant body, surpassing the control treatment. Conversely, a decrease in these traits leads to a reduction in the total dry mass, which is the result of photosynthetic processes, respiration, photosynthetic respiration, nutrient absorption and transportation (Abraheem, 2017).

The treatments provided an increase in nutrient availability such as N, P, Zn, K, Cu, K, S, Mn, Ca, Fe, essential for plants, as well as growth-promoting plant hormones such as cytokinins, gibberellins and auxins, in addition to essential plant mineral elements provided by yeast. Moreover, *Pseudomonas spp* bacteria, which solubilize phosphorus, fix nitrogen, oxidize sulfur, increase root permeability, reduce the effect of growth inhibitors (such as ethylene) and increase growth-promoting plant hormones (cytokinins, auxins, gibberellins), these features of biological fertilizers have made them important support factors for plant growth, resulting in a greater total dry mass than the control treatment, reaching the peak increase in the Ps+ Sa +GI treatment, which contained features of all three treatments together.

CONCLUSION

Mineral fertilizers may be an unsustainable resource, in addition to their environmental pollution and high production costs. On the other hand, many microorganisms are able to provide the plant with important nutrients for its good and healthy growth and they are cheap and sustainable. The Ps+Sa+GI treatment showed a significant increase in plant height and number. Tillage and statistical superiority in most other growth indicators. These results indicate that combining multiple biological agents within a single treatment resulted in a synergistic interaction that enhanced vegetative growth in wheat plants.

Conflict of interest

The authors declare that there is no conflict of interest.

REFERENCES

- Abed, Y.M., Abdul-Ratha, H.A. and Hadown, H.A. (2016). Effect of biofertilizer produced from local isolates of *Pseudomonas putida* and *Pseudomonas fluorescens* on some soil characteristics and yield of wheat (*Triticum aestivum* L). B-concentrations of some nutrients in soil. The Iraqi Journal of Agricultural Sciences. 47(6): 1413-1422.
- Abraheem, B.A. (2017). Effect of gelatin anti-transpiration in some growth and yield characteristics of wheat under water stress. The Iraqi Journal of Agricultural Sciences. 6(48): 1634-1643.
- Ali, Z.A. and Abraheem, B.A. (2023). The role of selected treatments in the parameters of leaf growth and yield of stevia plants under deficit irrigation system. IOP Conference Series: Earth and Environmental Science. 1225(1): 012083.
- Aljuboori, F.K., Ibrahim, B.Y. and Mohamed, A.H. (2022). Biological control of the complex disease of Rhizoctonia solani and root-knot nematode *Meloidogyne javanica* on chickpea by *Glomus spp.* and *Pseudomonas sp.* The Iraqi Journal of Agricultural Sciences. 53(3): 669-676.

- Al-Zubade, A., Jacobson, K., Phillips, T., Williams, M. and VanSanford, D. (2022). Impact of nitrogen rate in conventional and organic production systems on yield and bread baking quality of soft red winter wheat. *Agronomy Journal*. 11(9): 1-15.
- Bargaz, A., Wissal, E., Said, K., Bouchra, B., Kira, A.B. and Zineb, R. (2023). Benefits of phosphate solubilizing bacteria on belowground crop performance for improved crop acquisition of phosphorus. *Microbiological Research*. volume 252. <https://doi.org/10.1016/j.micres.2021.126842>. 1-21.
- Bitterlich, M. and P. Franken, J. (2018) Graefe arbuscular mycorrhiza improves substrate hydraulic conductivity in the plant available moisture range under root growth exclusion front. *Plant Sci*. 9: 301. doi: 10.3389/fpls.2018.00301.
- Dey, S., Choudhury, D., Mukherjee, C. and Dutta, S. (2024). Applications of plant growth promoting bacteria (pgpb) and vesicular arbuscular mycorrhizal (vam) fungi on aloe *Barbadensis* mill., a medicinally important succulent herb. *Agricultural Science Digest*. 44(2): 201-211. doi: 10.18805/ag. D-5811.
- El-Latif, A. and Mohamed, H.M. (2011). Molecular genetic identification of yeast strains isolated from Egyptian soils for solubilization of inorganic phosphates and growth promotion of corn plants. *Journal of Microbiology and Biotechnology*. 21: 55-61.
- Etesami, H. and Adl, S.M. (2020). Plant growth-promoting rhizobacteria (PGPR) and their action mechanisms in availability of nutrients to plants. *Phyto-Microbiome in Stress Regulation*, pp. 147-203.
- Gouda, S., Kerry, R.G., Das, G., Paramithiotis, S., Shin, H.S. and Patra, J.K. (2018). Revitalization of plant growth promoting rhizobacteria for sustainable development in agriculture. *Microbial Research*. 206: 131-140.
- Hamed, S.M., El Gaml, N.M. and Eissa, S.T. (2022). Integrated biofertilization using yeast with cyanobacteria on growth and productivity of wheat. *Beni-Suef University Journal of Basic and Applied Sciences*. 11: 112.
- Ifthikhar, A., Nazish, A., Rida, F., Sadaf, A., Ali, Z., Mariyam, M., Muhammad, I., Mehmood, T., Muhammad, A., Muhammad, A. and Anabia, S. (2023) beneficial role of phosphate solubilizing bacteria (psb) in enhancing soil fertility through a variety of actions on plants growth and ecological perspective: An updated review. *Journal of Xi'an Shiyou University, Natural Science Edition*. VOL.19 ISS. 09. 520-547.
- Kamil, S.H., AlJasani, R.F. and ALShammari, H.I. (2023). Isolation, identification and efficiency of *Pseudomonas fluorescens* bacteria to termite *Microcerotermis diversus*. *The Iraqi Journal of Agricultural Sciences*. 54(6): 1583-1593.
- Luo X., Liu Y., Li S. and He X. (2023). Interplant carbon and nitrogen transfers mediated by common arbuscular mycorrhizal networks: Beneficial pathways for system functionality. *Front. Plant Sci*. 14: 1169310. doi: 10.3389/fpls.2023.1169310.
- Mahmood, J.W. and Al-Hassan, M.F. (2023). Effect of hierarchy of the production of tillers in wheat (*Triticum aestivum* L.) cultivar (KM5180) under the influence of planting dates. *Research on Crops*. 24(2): 236-240.
- Mahmood, R.S.H. and Zeboon, N.H. (2019). Effect of foliar spraying with gibberellic and humic acid on wheat growth. *International Journal of Agriculture and Statistical Sciences*. 15(2): 621-625.
- Mahmoud, S.H., A.M.M. El-Tanahy and Z.F. Fawzy, (2020). The effects of exogenous application of some bio stimulant substances on growth, physical parameters and endogenous components of onion plants. *Inter. J. of Agric. and Earth Sci*. 6(2): 1-13
- Mohamed, H.M., El-Homasy, R.F., Abd-Elatef, A.E.H., Salh, F.M. and Hussein, M.Y. (2017). Identification of yeast strains isolated from agricultural soils for releasing potassium-bearing minerals. *Geomicrobiology Journal*. 34(3): 261-266. <https://doi.org/10.1080/01490451.2016.1186762>.
- Resmi, A.R., Lovely, B., Jayapal, A., Suja, G. and Chitra, N. (2024). Effect of inoculation of plant growth promoting rhizobacteria (PGPR) mix I formulations on plant growth, yield, disease incidence and disease severity of rhizoctonia leaf blight of amaranthus (*Amaranthus tricolor* L.). *Indian Journal of Agricultural Research*. 58(2): 361-365. doi: 10.18805/IJARE.A-5684.
- Sangothari, A., Radhamani, S., Janaki, P., Ravichandran, V., Gnanachitra, M. and Thavaprakash, N. (2024). Effect of arbuscular mycorrhizal fungi and different combination of foliar application of nutrients on nutrient uptake and yield of Aerobic rice. *Agricultural Science Digest*. 44(2): 265-269. doi: 10.18805/ag.D-5814.
- Wahab, Abdul, Muhammad, M., Munir, A., Abdi, G., Zaman, W., Ayaz, A., Khizar, C. and Reddy, S.P.P. (2023). Role of arbuscular mycorrhizal fungi in regulating growth, enhancing productivity and potentially influencing ecosystems under abiotic and biotic stresses. *Plants*. 12(17): 3102. <https://doi.org/10.3390/plants12173102>.
- Zhang Y., Feng H., Druzhinina I.S., Xie X., Wang E., Martin F., Yuan Z. (2023). Phosphorus/nitrogen sensing and signaling in diverse root-fungus symbioses. *Trends Microbiol*. doi: 10.1016/j.tim.2023.08.005.
- Zhao, C., Zhang, X., Hua, H. Chenggui Han and Xuehong Wu. (2019). Sensitivity of *Rhizoctonia* spp. to flutolanil and characterization of the point mutation in succinate dehydrogenase conferring fungicide resistance. *Eur. J. Plant. Pathol*. 155: 13-23. <https://doi.org/10.1007/s10658-019-01739-6>.
- Ziane, H., Meddad-Hamza, A., Beddiar, A. and Gianinazzi, S. (2017). Effects of arbuscular mycorrhizal fungi and fertilization levels on industrial tomato growth and production. *International Journal of Agriculture and Biology*. ISSN Print: 1560-8530; ISSN Online: 1814-9596. doi: 10.17957/IJAB/15.0287.