Australian Journal of Crop Science AJCS
AJCS 8(2):271-275 (2014) ISSN:1835-2707

Effect of foliar application of bio-stimulants on growth, yield, components, and storability of garlic (*Allium sativum* L.)

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Abstract

Increasing garlic yield and improving bulb quality are essential aims for growers to fulfill the requirements of the market and the consumers. Two field experiments were carried out during two successive seasons; 2010/2011 and 2011/2012 at a private farm to find out the influence of some bio-stimulants i.e., ascorbic acid, dry yeast, amino acids (Ruter and Total), seaweed extract (Alga 600) and Spirulina extract (*Arthospira fusiformis*) on plant growth, yield, yield components and storability of garlic plants "Balady" cultivar. One month after planting, foliar applications of bio-stimulants were applied, and repeated 3 times at 15 days intervals throughout the growing season. The design of the experiment was a complete randomized blocks (CRB) with three replicates. Results indicated that foliar application of Amino Total (1.2 ml l^{-1}) effectively increased plant height compared to all treatments and control. Number of leaves per plant was the least (9 and 9.5) in control plants in both seasons. Application of yeast (2 g l^{-1}) or amino total (1.2 ml l^{-1}) showed the heaviest bulb weight (67.7, 72.0 and 69.5, 66.6 g) in the first and second season, respectively. Weight loss of bulbs was the least with the application of ascorbic acid.

Keywords: *Allium sativum* L., amino acids, ascorbic acid, Spirulina extract, storability.

Introduction

Garlic (*Allium sativum* L.) is one of the main vegetable crops grown in Egypt for local consumption and exportation. Furthermore, it is cultivated for its flavor and medicinal properties, with the latter steadily arising worldwide (Collin, 2004). Therefore, increasing garlic yield and improving bulb quality are essential aims for growers. They both affected with any factor that influence plant growth and development (El-Morsy, 2004). The current global scenario firmly emphasizes the need to adopt eco-friendly agricultural practices for sustainable agriculture (Fawzy et al., 2012). Recent attention has been given to decreasing pollution sources in modern agriculture. One of the approaches to reduce soil pollution is the use of bio-stimulants, which have become commonly used as a safety nature of plant growth regulators, polyamines and vitamins. Such compounds can also improve plant resistance and tolerance to environmental stresses (Kowalczyk and Zielony, 2008). Recently, studies have proved that amino acids can directly or indirectly influence the physiological activities in plant growth and development. Also, amino acids are well known as bio-stimulants, which have positive effects on plant growth, yield and significantly mitigate the injuries caused by abiotic stresses (Kowalczyk and Zielony, 2008). Seaweed concentrate improved seedlings growth of okra under nutrient deficiency. It can overcome nutrient stress in crop plants and minimizing the use of expensive chemical fertilizers (Papenfus et al., 2013). It is known that yeast is considered as a natural source of cytokinins that stimulate cell division and enlargement as well as the synthesis of proteins, nucleic acids and chlorophyll (Fathy and Farid, 1996). Foliar application of yeast extract and ascorbic acid increased vegetative growth of eggplant (El-Tohamy et al., 2008). Also, Abou El-yazied and Mady (2012) found that yeast extract stimulated growth of broad bean and increased amino acid, auxins and cytokinins 75 days after sowing of broad bean. The application of ascorbic acid may have a stimulatory effect on plants, for example, its application caused significant increases in growth parameters and total yield of tomato during the cold season (Abdel-Halim, 1995). Similar results were found on other plants (El-Banna et al., 2006, Helal et al., 2005). The aim of this study was to investigate the effect of some bio-stimulants i.e; ascorbic acid, yeast, amino acids (Total and Ruter), seaweed extract (Alga 600) and Spirulina extract (*Arthospira fusiformis*) on growth, yield, bulb quality and storability of garlic.

Results

Growth characteristics

Results presented in the Table (1) showed a one season significant effect on plant height and number of cloves per bulb. Rather than that, all treatments significantly affected all growth characteristics in both seasons, except for bulbing ratio. The foliar spray with Amino Total gave the tallest plants with 90 cm and the differences among other treatments were insignificant. Number of leaves per plant was the least in control plants in both seasons.

Total yield and yield components

All bio-stimulants treatments clearly improved total yield per feddan, bulb weight and bulb diameter compared to the control (Table 1). Amino Total (1.2 ml l^{-1}) followed by yeast and Amino Ruter had the most pronounced effect on total yield (9.8, 9.0 and 8.3 ton per feddan, respectively) during the

Table 1. Effect of some bio-stimulants on growth, yield and yield components of garlic plants grown in 2010/11 and 2011/12 seasons.

Treatment	Plant height (cm)	Leaf number	Total yield (ton/fedd.)	Bulb weight (g)	Buld diameter (cm)	Bulbing ratio	Outer cloves No.	Total cloves No.
2010/ 2011								
Control	64.1 b	9.0 b	6.4 c	49.2 c	3.65 d	0.29 a	5.3 d	16.0 a
Yeast (2 g l^{-1})	72.2 b	10.5 ab	9.0 a	67.7 a	4.40 ab	0.25 a	8.6 ab	18.7 a
Ascorbic acid (0.2 g l^{-1})	65.7 b	10.2 ab	6.5 c	50.5 bc	4.05 c	0.27 a	6.3 cd	17.5 a
Alga 600 (1 g l^{-1})	70.2 b	9.2 b	7.3 bc	55.3 bc	4.25 bc	0.22 a	6.3 cd	18.1 a
Amino Ruter (1.2 ml l^{-1})	79.1 ab	11.2 a	8.3 ab	61.7 ab	4.2 bc	0.25 a	7.3 bc	17.3 a
Amino Total (1.2 ml l^{-1})	90.0 a	11.2 a	9.8 a	72.0 a	4.5 a	0.28 a	9.6 a	18.5 a
Spirulina (1 ml l^{-1})	77.2 ab	11.0 a	6.8 bc	52.5 bc	4.1 bc	0.25 a	9.0 ab	17.2 a
2011/2012								
Control	65.5 a	9.5 c	5.9 c	46.0 c	3.85 e	0.28 a	5.0 c	15.5 c
Yeast (2 g l^{-1})	67.3 a	11.0 ab	9.4 a	69.5 a	4.65 a	0.22 a	6.0 bc	18.8 a
Ascorbic acid (0.2 g l^{-1})	71.2 a	10.5 abc	6.6 bc	51.0 bc	4.05 d	0.28 a	8.5 ab	17.5 abc
Alga 600 (1 g l^{-1})	72.5 a	10.25 bc	8.3 abc	62.3 abc	4.0 de	0.25 a	6.0 bc	17.6 abc
Amino Ruter (1.2 ml l^{-1})	77.0 a	10.5 abc	7.7 abc	58.25 abc	4.25 c	0.25 a	7.0 bc	16.5 abc
Amino Total (1.2 ml l^{-1})	67.3 a	11.5 a	8.9 a	66.6 ab	4.45 d	0.26 a	10.0 a	18.25 ab
Spirulina (1 ml l^{-1})	67.7 a	10.75 ab	6.9 abc	52.75 abc	4.25 c	0.29 a	8.5 ab	16.3 bc

Values with common letter in the same column are not significantly different at 5% level as per DMRT.

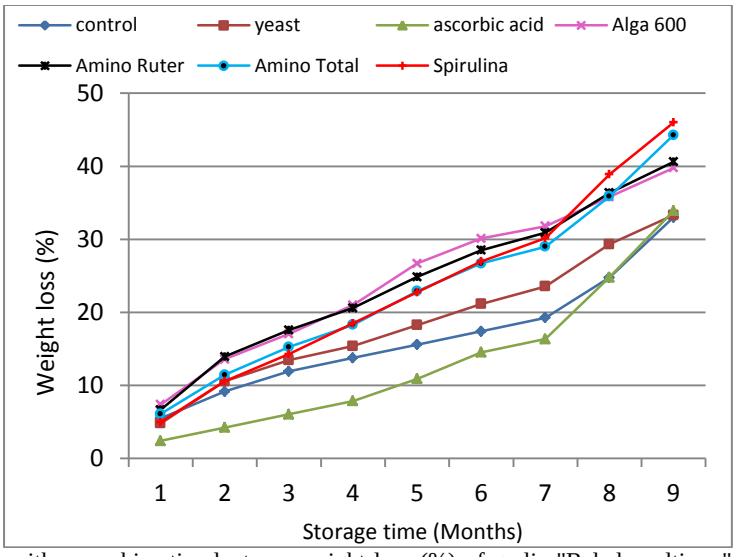

Fig 1. Effect of foliar spray with some bio-stimulants on weight loss (%) of garlic "Balady cultivar." during 9 months of storage under room temperature in 2011/2012 season.

first season, however, yeast followed by amino total were the most effective treatments on total yield (9.4 and 8.9 ton per feddan, respectively) during the second season. The lowest yield was obtained from the control in both seasons. Both yeast and Amino Total treatments were found to give the highest bulb weight and size in both seasons and they produced the highest number of cloves per bulb in the second season. All bio-stimulant treatments significantly increased surrounding number of cloves compared with the control.

Storability

The percentage of weight loss was steadily increased until 7 months of storage, then, it rapidly increased until the end of storage (Fig. 1). Ascorbic acid treatment had the most pronounced effect on bulb weight loss during storage, compared to the control and other treatments. All other treatments showed higher percentage of weight loss compared to the control during all storage times. Concerning shrinking percentage, it was noticed that plants sprayed with either ascorbic acid or yeast had better storability of bulbs than other treatments and the control (Fig. 2).

Discussion

The results of this study revealed that foliar spray with bio-stimulants increased vegetative growth parameters. This might be due to the fact that bio-stimulants contain amino acids and some other elements, which enhance the metabolism processes in plant tissues. Yeast is considered as a natural source of cytokinins that stimulate cell division and enlargement as well as the synthesis of proteins, nucleic acids and chlorophyll (Fathy and Farid, 1996). The effect of active dry yeast on plant growth may be attributed to its content of different nutrients, higher level of proteins and vitamins, especially vitamin B which may play an important role improving growth and controlling the incidence of fungal diseases, as mentioned by Bevilacqua et al., (2008). In this respect, foliar application of yeast and ascorbic acid resulted in higher growth and yield of eggplant (El-Tohamy et al. 2008). Our results are in some direction with that of Paul et al. (2001); Pourtan, et al. (2004); Abd El-Aal et al. (2010). Similar results on the stimulatory effects of ascorbic acid on other plants were also noticed (El-Banna et al., 2006; Helal et al., 2005). Abdel-Halim (1995) found that the application of

Table 2. Monthly average of maximum and minimum air temperature and relative humidity during storage time.

Months	Temperature (°C)		Relative humidity (RH%)	
	Maximum	Minimum	7:30 am	1:30 pm
April	28.2	11.0	96.0	40.7
May	29.6	14.4	72.6	39.5
June	33.5	19.3	79.2	43.5
July	32.0	20.0	82.0	48.2
August	34.0	21.2	85.0	50.8
September	33.4	19.2	82.2	48.5
October	30.7	17.0	72.0	45.0
November	26.8	11.0	82.0	54.2
December	22.0	8.3	85.0	55.7

Data recorded by Sakha Meteorological Station, Kafrelsheikh, Egypt.

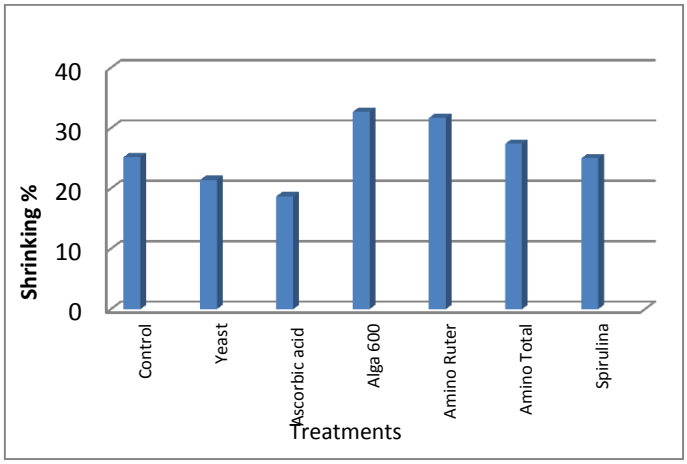

Fig 2. Effect of foliar spray with some bio-stimulants on shrinking (%) of garlic 'Balady cv.' after 9 months of storage under room temperature in 2011/2012 season.

ascorbic acid on tomato plants significantly improved stem length, dry weight of shoots per plant, number of branches, leaves, flowers and fruit, fruit set, fruit weight and number, and total yield. The regulatory effect of amino acids on growth could be explained by the notion that some amino acids can affect plant growth and development through their influence on gibberellins biosynthesis (Walter and Nawacki, 1978). Also, amino total as a source of amino acids may play an important role in plant metabolism and protein assimilation which are necessary for cell formation and consequently increase fresh and dry mater. This regulatory effect was reported on strawberry (Abo Sedera et al. 2010) and celery (Shehata et al. 2011). The high values of bulb diameter and weight were reflected on the total yield of garlic plants sprayed with amino acids and dry yeast, compared to the control. Previous findings indicated that amino acids can directly or indirectly influence the physiological activities and the development of the plants (El-Shabasi et al., 2005; Abd El-Aal et al., 2010). Amino acids enhance plant growth, yield and overall bulb quality (El-Shabasi et al., 2005; Fawzy et al., 2012; Abd El-Aal et al., 2010). Commercially available amino acid stimulants can improve fertilizer assimilation, increase uptake of nutrients and water, enhance the photosynthetic rate and dry matter partitioning, and hence increase crop yield (El- Shabasi et al., 2005; Shaheen et al., 2010; Papenfus et al., 2013). Garlic plants treated with ascorbic acid recorded the lowest percentage of bulb weight loss during storage. In this regard, Bardisi (2004) found that high quality of bulbs was obtained during 300 days of storage when plants were sprayed with ascorbic acid. Ahmed et al. (2010) stated that plants sprayed with humic acid had better storability than untreated ones. These results may be due to the effect of humic acid on growth parameters which may reflect on enhancing the quality and storability of garlic bulbs.

Materials and Methods

The present study was carried out during two successive seasons; 2010/2011 and 2011/2012 at a private farm in El-Mahalla El-Kubra district, El-Gharbia Governorate, Egypt, to study the effect of some bio-stimulants i.e., seaweed extract (Alga 600), dry yeast, ascorbic acid, amino acids and Spirulina extract (*Arthospira fusiformis*) on growth, yield and storability of garlic "Balady" cultivar. Garlic cloves were selected for uniformity in size and were sown on both sides of the rows with a distance of 10 cm between planted cloves. The experimental unit area was 7.2 m^2. It contained three rows of 4 m length and 60 cm width. Planting was carried out on 14th and 16th October in the first and second seasons, respectively. All agricultural practices were applied as commonly recommended for commercial garlic production in the district.

Treatments and experimental design

Floiar application of garlic plants was including seven different bio-stimulants treatments, as follow; 1) Dry yeast at rate of 2 g l^{-1}; 2) Ascorbic acid at rate of 0.2 g l^{-1}; 3) Seaweed extract (Alga 600) at rate of 1 g l^{-1}; 4) Amino Ruter at rate of 1.2 ml l^{-1}; 5) Amino Total at rate of 1.2 ml l^{-1}; 6) Spirulina extract (*Arthospira fusiformis*) at rate of 1ml l^{-1}; and 7) Tap water (control). Active dry yeast was dissolved in water and sugar was added at a ratio of 1:1 (w/w), and then kept overnight at room temperature for activation and reproduction of yeast.

Spraying treatments were started one month after the planting date and repeated 3 times 15 days intervals throughout the growing season. The design of the experiments was a complete randomized blocks (CRB) with three replicates.

Chemical analysis of bio-stimulants

The commercial seaweed extract product "Alga 600" comprised three seaweed species (*Ascophyllum nodosum*, *Laminaria spp* and *Sargassum sp)*. The seaweed extract also contains N (1%), K (18.5%), Ca (0.17%), Mg (0.42%), Fe (0.06%), S (2.2%), alganic acids (10-12%) and plant hormones (600 ppm). The commercial product "Amino Ruter" was used as a source of amino acids and its components were (w/v): free amino acids (8.4%), N (6.6%), P_2O_5 (6%), K_2O (4.2%), Fe (0.036%), Mn (0.06%), Mo (0.012%) and Zn (0.084%). The commercial product "Amino Total" was also used as another source of amino acids. In this product 17 different amino acids; glutammic acid (7.24-9.12%) and arginine (5.2-6.2%) are the most important in their bio effect (Shehata *et al*., 2011).

Data collection

Ten plants were selected randomly, from each treatment, at 150 days after planting to measure plant height (cm) and number of leaves per plant. At harvest, all plants of each treatment were harvested and total yield per feddan was calculated after curing for 7 days. Also, random samples were taken from each treatment to determine bulb fresh weight (g), number of cloves per bulb, neck diameter (cm), bulb diameter (cm) and bulbing ratio which was calculated as follows:
Bulbing ratio = neck diameter / bulb diameter

Storability

After curing in the second season, random samples of 5 kg of garlic bulbs were taken from each treatment and stored for 9 months at room conditions. Monthly average of air temperature and relative humidity during storage time are presented in Table (2). Weight loss percentage was calculated every month up to the end of the storage period and shrinking percentage was recorded only at the end of storage period. Shrinking percentage was calculated using the following equation; Shrinking (%) = (number of decayed bulbs / number of total bulbs) x 100

Statistical analysis

Statistical analysis was made using the Costat Computer Program according to procedures outlined by Snedecor and Cochran (1980) and Duncan's multiple range test was used for the comparisons among treatment means (Duncan, 1955).

Conclusion

Foliar application of amino total (1.2 ml l^{-1}) or yeast (2 g l^{-1}), as bio-stimulants can be recommended to enhance total yield and bulb quality of garlic, while foliar application of ascorbic acid was the best for bulbs storability.

Acknowledgments

The authors wish to thank Dr. Elsayed A. Belal, Botany Department, Faculty of Agriculture, Kafrelsheikh University for providing the Spirulina extract. We wish also to thank Dr. Shamel Alam-Eldein, Citrus Research and Education Center, University of Florida, Lake Alfred, Florida, USA for improving the readability of the manuscript.

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