Exogenous application of plant growth promoting substances enhances the growth, yield and quality of maize (Zea mays L.)

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Abstract

Plant growth promoting substances (PGPS) improve plant performance through modulation of its growth and yield. To study the possible role of PGPS maize was subjected to various PGPS Viz; kinetin (30 ppm), humic acid (2%), Moringa leaves extract (MLE) (2%), ascorbic acid (2%), Salicylic acid (2%), ‘neem’ seed powder (NSP) extract (2%) and water spray (control) at 6 leaf and 8 leaf stage. We found that foliar application of kinetin, humic acid, MLE and ascorbic acid remarkably (p<0.05) improved growth, yield and quality attributes of maize while salicylic acid and NSP extract application was not so much promotive in action compared to control (water spray). MLE enhanced crop growth rate and number of leaves per plant while maximum leaf area, 1000-grain weight, grain and biological yield as well as grain protein and starch contents were recorded where ascorbic acid was applied. However, plant height and total phenolic content were highest in plants treated with humic acid. So, all tested PGPS were variable in their effect, however, they improved the plant performance and may be applied to improve growth and yield of maize.

Keyword: growth; humic acid; Moringa leaves extracts; yield; Zea mays.

Abbreviations: PGPS– plant growth promoting substances; MLE– Moringa leaves extract; NSP– neem seed powder.

Introduction

Maize is the third most important cereal after wheat and rice and used as staple food in many countries (Frova et al., 1999). To meet the current and future food requirements of increasing population and their rising dietary needs it is necessary to boost up crop yields (Gao et al., 2010). However, improvement in maize yield is dependent on its genetic characteristics, morpho-physiological behavior and its interaction with the environment. (Xu et al., 2004). There are various approaches to be used to enhance the crop productivity, one of them is exogenous application of plant growth promoting substances (PGPS). Biochemical analysis showed that foliar spray of different growth substances enhanced total protein, sugar and phenolic contents, and triggered chlorophyll biosynthesis (Farahat et al., 2007). It further improves source-sink relationship that results in more flowers, fruits, seeds and final crop produce (Solaimalai et al., 2001). Anjum et al. (2013) also examined the improved growth and yield of various cereals and oil seeds when various organic osmolytes were applied exogenously. Among the plant growth promoters Moringa leaves are rich source of plant growth regulators (ascorbates), nutrients (potassium and calcium), pigments (carotenoid and phenols) which promote the plant growth when applied mostly as exogenous growth enhancers (Foidl et al. 2001). Cytokinins are known to have a crucial role in enhancing division of cells, synthesis of chlorophyll and apical dominance alteration in plants (Taiz and Zeiger, 2006). Humic substances also consist of plant hormone like constituents that stimulate the growth of several plants (Pizzeghello et al., 2002). Foliar spray of humic substances in nutrient solutions enhanced chlorophyll contents (Chen and Aviad 1990). However, effects of humic substances on plant growth depend on the source and concentration, as well as on the molecular fraction weight of humus. Lower molecular size fraction easily reaches the plasma lemma of plant cells, determining a positive effect on plant growth, as well as a later effect at the level of plasma membrane, that is, the nutrient uptake, especially nitrate. The effects on intermediary metabolism are less understood, but it seems that humic substances may influence both respiration and photosynthesis (Nardi et al., 2002). Foliar application each of humic and amino acids enhanced grain and straw yield of wheat when applied exogenously (El-Naggar and El-Ghamry, 2007). Foliar application of ascorbic acid promoted the growth and quality parameters of lemon grass (Tarraf et al., 1999) while Talaat (2003) examined that foliar spray of ascorbic acid significantly increased the macronutrients contents i.e. N, P and K. Salicylic acid played positive role in increasing the growth and yield of many cereals including wheat and maize at lower concentration (Khan et al., 2003). Salicylic acid increased the number of flowers, pods per plant and grain yield of soybean (Gutierrez-Coronado et al., 1998). Moharekar et al. (2003) stated that salicylic acid increased the synthesis of many pigments like carotenoid, xanthophylls and de-epoxidation rate but it also decreases the amount of chlorophyll pigments in wheat and mung and chlorophyll a/b ratio in wheat plantlets. Scientists are working to sustain agriculture by introducing biological means of nutrition like growth regulators, organic manures and biofertilizers for crops and minimizing the dependence on chemical fertilizers (Robert, 1976, Reganold et al., 1990; Parr and Hornik, 1992).
Table 1. Response of maize regarding growth and yield to foliar applied PGPS.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Plant height (cm)</th>
<th>1000-grain weight (g)</th>
<th>Biological yield (t/ha)</th>
<th>Grain yield (t/ha)</th>
<th>Harvest Index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>183.90 d</td>
<td>208.10 f</td>
<td>18.68 f</td>
<td>5.42 e</td>
<td>29.06 b</td>
</tr>
<tr>
<td>Kinetin (30 ppm)</td>
<td>205.40 b</td>
<td>228.53 c</td>
<td>21.19 d</td>
<td>6.51 c</td>
<td>30.71 ab</td>
</tr>
<tr>
<td>Humic Acid (2%)</td>
<td>216.30 a</td>
<td>242.70 b</td>
<td>22.66 b</td>
<td>7.22 b</td>
<td>31.88 a</td>
</tr>
<tr>
<td>MLE (2%)</td>
<td>192.20 c</td>
<td>221.00 d</td>
<td>21.87 c</td>
<td>6.75 c</td>
<td>30.85 ab</td>
</tr>
<tr>
<td>Salicylic Acid (2%)</td>
<td>202.00 b</td>
<td>216.00 e</td>
<td>20.15 e</td>
<td>5.96 d</td>
<td>29.59 b</td>
</tr>
<tr>
<td>Ascorbic Acid (2%)</td>
<td>206.80 b</td>
<td>251.83 a</td>
<td>23.62 a</td>
<td>7.68 a</td>
<td>32.50 a</td>
</tr>
<tr>
<td>NSP extract (2%)</td>
<td>172.50 c</td>
<td>203.10 g</td>
<td>17.08 g</td>
<td>4.18 f</td>
<td>24.44 c</td>
</tr>
<tr>
<td>LSD (p≤0.05)</td>
<td>5.50</td>
<td>4.51</td>
<td>0.46</td>
<td>0.39</td>
<td>2.09</td>
</tr>
</tbody>
</table>

Values sharing a letter in common within a column do not differ significantly at p≤0.05. Values are the means of three replicates (n=3).

Fig 1. Effect of PGPS on (a) crop growth rate (CGR), (b) leaf area (LA) and (c) number of leaves per plant of maize. Vertical bars above means are S.E. of three replicates (n=3).

Fig 2. Effect of PGPS on (a) Chl a, (b) Chl b and (c) total chlorophyll contents of maize. Vertical bars above means are S.E. of three replicates (n=3).
So, foliar application of nutrients or other organic osmolytes in liquid form can be used to augment crop yields. This study was therefore conducted to assess possible role of PGPS in improving maize performance and its productivity under field conditions.

Results and Discussion

Growth and development

Exogenous application of PGPS substantially improved maize growth and developmental traits. Crop growth rate and number of leaves per plant was found maximum where MLE was applied. However, 2% ascorbic acid resulted in maximum leaf area while plant height was recorded highest where 2% humic acid was applied (Fig. 1). Further, a significant reduction in plant height (Table 1) and number of leaves per plant were recorded where NSP extract was applied compared to control. Exogenous application of PGPS help plant in turgor maintenance, and promotes antioxidative enzymatic activity and carbohydrate metabolism (Farooq et al., 2008). Increased growth related attributes due to application of MLE, ascorbic acid and other PGPS on various plant species has also been reported by (Fuglie, 2000; Hamada and Al-Hakimi, 2001). Furthermore, Bakhsh et al. (2011) also revealed a regulatory effect of plant growth hormones on growth, yield and yield components of rice.

Yield and yield related attributes

Yield and related attributes of maize significantly improved with the application of PGPS. 2% foliar application of ascorbic resulted in highest 1000-grain weight, grain yield and harvest index whereas maximum biological yield was harvested from those plots where humic acid (2%) was sprayed at 6 and 8 leaf stage (Table 1). It is interesting to note that NSP extract application reduced all yield parameters under study compared with control. Hence, NSP extract showed inhibitory effect rather promotive on maize. Exogenous application of osmolytes promotes some known physiological mechanisms that results in better growth and improved crop yield. Application of fulvic acid, brassinolides and humic acid not only promoted growth but also triggered other physiological and biochemical attributes in maize and soybean (Anjum et al., 2011a, b). Hence, these osmolytes regulates photosynthesis, gas exchange attributes and enzymatic activities to alleviate oxidative damage (Anjum et al., 2011c). Further, moringa application (as a priming agent) improved seedling growth, development and improved seed vigor. (Basra et al., 2011). Moreover, application of growth hormones improves the performance of field crops by establishing a strong source sink relationship (Solaimalai et al., 2001).

Chl a, Chl b, and phenolic contents

All PGPS substantially improved leaf chlorophyll content. Foliar application of 30 ppm kinetin showed highest values for chlorophyll contents (2.22 mg g⁻¹), followed by 2% humic acid (2.22 mg g⁻¹), 2% ascorbic acid (2.12 mg g⁻¹), 2% salicylic acid (2.100 mg g⁻¹) and 2% MLE (2.09 mg g⁻¹), respectively. Lowest chl a content (0.950 mg g⁻¹) was recorded in plants treated with water spray. Conversely, impact of foliar applied PGPS on the chl b were non-significant (Fig. 2 a&b).

Application of ascorbic acid and other antioxidants as foliar sprays enhanced the photosynthetic pigments in tomato (Fathy et al., 2003). This stimulatory response of ascorbic acid, salicylic acid and other antioxidants might be due to the phenomenon of antioxidant scavenging to provide protection to chloroplast and chlorophyll against degradation caused by reactive oxygen species. Salicylic acid enhanced the chlorophyll and anthocyanins contents in Spirodela plants (Rhoads and McIntosh, 1991) and increased or decreased the chlorophyll contents depending on the variety genetic makeup in cowpea (Chandra and Bhatt, 1998). Improvement in chlorophyll content by humic acid was reported by (Ferrara et al., 2007). Kinetin application as foliar sprays increased the chlorophyll content in mulberry (Das et al., 2002). As for total phenolic contents are concerned, maximum (0.059 mg GAE/L) were recorded in plants treated with 2% humic acid but statistically similar with 2% ascorbic acid (0.049 mg GAE/L), 2% NSP extract (0.046 mg GAE/L) and 2% salicylic acid (0.045 mg GAE/L). Minimum phenolic contents (0.022 mg GAE/L) were recorded in control. Whereas, phenolic contents of 30 ppm kinetin and MLE were statistically same (Fig 2 c). Overall, results revealed that foliar applied PGPS improved total phenolic contents in maize. Earlier studies indicated the improvement in various pigments, antioxidants and enzymes activities by the application of plant growth substances (Amin et al., 2008; Athar et al., 2009).

Quality parameters

PGPS including ascorbic acid, humic acid, MLE, kinetin and salicylic acid had significant effects on maize quality parameters. Maximum amount of protein and starch contents were accumulated in grains which received the foliar sprays of 2% ascorbic acid (10.19%, 69.65%), respectively. Further, 9.64%, 67.41% protein and starch contents, respectively, was noted where 2% humic acid was applied while lowest proteins and starch were reserved by grains of 2% NSP extract foliar sprays (7.45%, 60.70%) treated plants, correspondingly (Fig. 3). Our results are in line with the findings of Kalinova and Moudry (2006) in millet and El-Bassioni et al. (2010). Moreover, exogenous application of ascorbic acid increased the protein as well as starch contents in potato (Sajid and Aftab, 2009) and chick pea (Beltagi, 2008).

Materials and Methods

Experimental site and plant material

The proposed study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (31.25°N latitude, 73.09°E longitude, altitude 184 m) under semi-arid and subtropical climate on sandy clay loam soil during spring 2012. The experiment was laid out in randomized complete block design with three replications. Maize hybrid ‘FSH–810’ was sown on well prepared seed bed on 20th February, 2012 using seed rate of 25 kg ha⁻¹. Crop was sown on 75 cm apart ridges by maintaining plant to plant distance of 15 cm. Gap filling was done after 15 days of sowing. Hoeing was done twice i.e. 25 and 45 days after sowing of crop. Pesticides were sprayed accordingly to the recommendations for the maize. In addition to rainfall received during the whole growing period, a total of six irrigations were applied each of 7.5 cm depth.
First irrigation was applied 25 days after sowing, while subsequent irrigations were applied with 15 days interval. The growth promoting substances i.e., humic acid (2%), kinetin (30 ppm), ascorbic acid (2%), salicylic acid (2%), MLE (2%), NSP extract (2%) and water spray was applied twice as foliar sprays at 6 and 8 leaf stage. Data regarding growth, yield and quality parameters were recorded after 15 days of foliar application of treatments.

Observations

10 plants from each replicate were randomly selected to determine plant height, number of leaves per plant, leaf area, 1000-grain weight, while grain and biological yield was recorded by harvesting the whole produce from each replicate. Further, crop growth rate (g m⁻² d⁻¹) was calculated according to the formula described by Hunt (1978).

Chlorophyll and total phenolic contents

The chlorophyll $a$ and $b$ was determined by the method described by Arnon (1949) and calculated by using following formulae governed by Nagata and Yamashita, (1992):

Chlorophyll $a$ (mg 100/mL) = 0.999 $A_{663} - 0.0989 \ A_{645}$

Chlorophyll $b$ (mg 100/mL) = -0.328 $A_{663} + 1.77 \ A_{645}$

Moreover, total phenolic contents were determined as directed by (Waterhouse, 2002).

Protein and starch contents

2.0 g of oven dried grinded plant material was mixed with 25 ml of concentrated $H_2SO_4$ and 5 g digestion mixture ($K_2SO_4;CuSO_4;FeSO_4$ in the ratio of 20:2:1) and digested the material on the gas heater in Kjeldahl digestion flask until the light green color was appeared, cooled it and made the volume up to 250 ml. Put 10 ml of that diluted solution in micro Kjeldahl apparatus and added 25 ml of 40% NaOH solution. Put a receiving flask containing 10 ml of 2% boric acid solution and indicator (methyl red) in such a way that the delivery tube after coming through condenser dipped into it. Opened the steam generator plug and let the content of distillation tube be boiled until whole ammonia was liberated. After that it was titrated it against standard N/10 $H_2SO_4$ solution. The protein contents were determined by the following formula:

% Protein = $\%$ of nitrogen $\times$ 6.25 (conversion factor for maize)

Starch content was determined according to the Megazyme total starch assay procedure (Megazyme, 2009).

Statistical analysis

All the data obtained were subjected to statistical analysis by using Statistix 8.0 computer software and least significant difference (LSD) test was used for comparison of treatment means (Steel et al., 1997). Figures were generated by using SigmaPlot 9.0.

Conclusion

In crux, maize responded positively to all PGPS (applied exogenously) except ‘neem’ seed powder extract, with respect to corn growth, yield and quality. Among the osmolytes used, ascorbic acid was found the most effective one regarding crop performance under field conditions.

References


