ORIGINAL ARTICLES

Production Capability of Wheat Cultivars under Low Light Intensity (Date Palm Shade) Conditions and Some Bioregulators

H.F. Abouziena and M.S. Abd El Wahed

Botany Department, National Research Centre, Dokki, Cairo, Egypt, 12622

ABSTRACT

The tendency for exploitation the land under date palms whether for annual or perennial crops is increasing day by day to better utilization the microclimate and soils under date palm trees. Field experiments were conducted to evaluate the efficacy of 4 wheat cultivars namely Gemmiza 9, Sakha 93, Giza 168 and Sakha 94 under low light conditions and the effect of Stearic acid, Glutathione and Salicylic acid at 50 or 100ppm on wheat productivity. The results indicated that Gemmiza 9 cv. recorded the highest flag leaf area and weight, plant dry weight, total chlorophyll, tillers fertility %, spike weight and grain index and consequently gave more grain yield/ha than Sakha 93, Giza 168 and Sakha 94 cultivars by 43.2, 51.8 and 22.0%, respectively. Stearic acid (100ppm), Glutathione (50ppm) and Salicylic acid (100ppm) increased the grain yield/ha by 29.8, 25.1 and 22.4%, respectively, compared to control. Chemical constituents varied between wheat cultivars, and total phenolic content decreased in grains with the bioregulators. The results suggest that Gemmiza 9 cv. could be used beneficially to tolerate the low light intensity under the date palm shade and could be improved the grain yield through application of Glutathione or Salicylic acid at 50ppm concentration.

Key words: intercropping, chemical constituents, Glutathione, Stearic acid, Salicylic acid

Introduction

The tendency for exploitation the land under date palms whether for annual or perennial crops is increasing day by day to better utilization the microclimate and soils under date palm trees. Little research papers about the possibility of growing annual or perennial crops intercropping on the date palm were found in the literature, except some fact sheets. Date palm trees provide enough space for intercropping even if they are fully grown as they do not cover much area being a very tall tree (Akyurt et al. 2002). In the Northern and river Nile state date palm is intercropped with wheat, broad beans and fodder Intercropping alfalfa, tomato and Okra with date palm increases the income of one hectare up to US$ 3085, 2740 and 1621/yr, respectively (Elmakki 2006).

There is gap between the production and consumption of wheat in Egypt. To overcome this problem there are two strategies; either by horizontal expansion (increasing the wheat area) or by vertical expansion (increasing the productivity per unit area). In this study the two purposes were taken through exploitation the date palm area for growing wheat crop and increasing the plant productivity using the bioregulators. Date palm shade caused a reduction in the wheat productivity. Quero et al. (2006) reported that shade by the tree canopy has indirect effects, such as reducing leaf and air temperatures, vapour pressure deficit and oxidative stress, that would alleviate the drought impact on seedlings in the understory (Holmgren 2000).

Wheat cultivars differed in their capability to grow under abiotic stress, such as shading. Yield potential, defined as the yield of an adapted genotype grown under optimal management and in the absence of biotic and abiotic stresses, has been found to be a very useful concept since progress in yield potential usually leads to progress in wheat yield in farmers’ fields, particularly if stresses are mild (Curtis et al. 2002). Destro et al. (2000) reported that the reduction in grain yield depends on the genotype cultivated and the physiological stage of the plants under stress (Moustafa et al. 1996). Souza and Soares Sobrinho (1983) found that the BH-1146 cultivar had more stable yield under the most adverse environmental conditions due to its tolerance to drought, temperature variations and different sunlight conditions.

Zahir et al. (2007) reported that managing balance between vegetative and reproductive growth is a very important part of crop productivity. Plant growth regulators can help to manage this balance (Silvertooth 2000). The importance of biologically active substances in plants is well documented. Plant growth regulators are natural compounds that have shown farreaching effects on the growth, flowering, assimilate translocation in plants (Hayat et al. 2001; Naeem et al. 2004) and development of plants even at low concentration (Arshad and Frankenberger 1998).

Stearic acid is one of a group of long-chain fatty acids occurring in the cells of plants and animals. It occurs very extensively in nature, most often being incorporated into triglycerides. It is also known to promote the
growth of some soil organisms, such as bacteria. Higher plants contain two galactolipids, monogalactosyldiacylglycerol (MGD) and digalactosyldiacylglycerol (DGD), which constitute about 75 mol% of the thylakoid lipids in chloroplasts (Dörmann and Benning 2002).

MGD and DGD are synthesized from UDP-Gal and diacylglycerol by MGD and DGD synthases in the plastid (“prokaryotic lipid”), DGD is largely derived from endoplasmic reticulum (ER) lipid precursors “eukaryotic lipid” (Browse et al. 1986). Recent results suggest that an ATP-binding cassette-type transport complex is involved in the transfer of eukaryotic lipids from the ER to the chloroplast (Xu et al. 2003). Galactolipids do not only establish the lipid bilayer into which the photosynthetic complexes are embedded. Structural analysis of crystallized protein complexes revealed that galactolipids are also found within the structures of PSI and PSII, light-harvesting complex II (LHCCI), and cytochrome b_{6f} (Liu et al. 2004; Loll et al. 2005; Jones 2007). The strong growth of Arabidopsis retardation of the DGD-deficient lines dgd1 and dgd1dgd2 can be primarily attributed to a decreased capacity for chloroplast membrane assembly and proliferation and, to a smaller extent, to photosynthetic deficiency. During phosphate limitation, GGD increases in plastidial and extraplastidial membranes of the transgenic lines to an extent similar to that of DGD in the wild type, indicating that synthesis and transport of the bacterial lipid (GGD) and of the authentic plant lipid (DGD) are subject to the same mechanisms of regulation (Hölzl et al. 2009). Therefore, using Stearic acid on plant led to increased plant growth and yield as follow bean, marigold and squash (twice), carrots (30%) and Red beets (60%). The mechanism of stimulation in an enzyme system by Stearic acid, then, is proposed to be in the Calvin Cycle of photosynthetic reactions. Specifically, the rate-limiting step of carbon dioxide fixation, in which ribulose 1, 5 diphosphate is converted into 3 phosphoglyceric acid; a reaction catalyzed by reibulose 3, 5 biphosphate carboxylase, is proposed to be the affected system. It is thus proposed that that stimulating effect of Stearic acid observed is due to its hormone-like effects on plants (Hamilton 2012).

Glutathione (L-cystene, L-glutamine and L-glycine) could be improvising the economic plants through build blocks of protein synthesis, which could be enzyme, hormones and antioxidants important for metabolic activities (Gilbert et al., 1990). Low molecular weight antioxidants, such as ascorbate, glutathione, and tocopherol, are information-rich redox buffers that interact with numerous cellular components. In addition to crucial roles in defense and as enzyme cofactors, cellular antioxidants influence plant growth and development by modulating processes from mitosis and cell elongation to senescence and death (Potters et al. 2004; Tokunaga et al. 2005). Whereas, ascorbate and glutathione are major redox metabolites in plant callus with specific roles in cellular redox homeostasis and the regulation of cell cycle (Pellny et al. 2009).

Devi et al. (2011) reported that Salicylic acid cyclic acid (C_{7}H_{6}O_{3}) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan et al. 2003; Shakirova et al. 2003). Foliar application of Salicylic acid exerted a significant effect on plant growth metabolism when applied at physiological concentration and thus acted as one of the plant growth regulating substances (Kalarani et al. 2002). Salicylic acid enhanced wheat growth (Shakirova et al. 2003) and maize growth (Sheheta et al. 2001; Abdel-Wahed et al. 2006).

Therefore, the objective of this study was to investigate the production capability of wheat cultivars under low light intensity conditions and the effect of some bioregulators on the wheat productivity.

Materials and Methods

A study was carried out in 17-yr-old date palm intercropped with wheat at a private orchard at Salheia District, Sharkia Governorate, Egypt. The experiments were conducted in the winter seasons of 2009/2010 and 2010/2011 to evaluate the production capability of wheat cultivars grown under low light intensity conditions (under palms shading) and some bioregulators. The texture of the experimental soil was sandy soil with pH 7.8, organic matter 1.6%, E.C. 1.18 mmohs/cm, CaCO_{3} 1.56%, total N 0.043%, total P 0.022%, and total K 0.02%.

The treatments were 4 cultivars i.e Gemmeiza 9, Giza 168, Sakha 93 and Sakha 94, while the three bioregulators were Glutathione (L-gammaglutamyl-L-cysteynlyglycine), Stearic acid (CH_{3}(CH_{2})_{16}CO_{2}H) and Salicylic acid at 50 and 100ppm concentrations and the control treatment. The seeds of four wheat cultivars were obtained from Agricultural Research Centre, Giza, Egypt and sowing in the first week of November in both seasons. The distance between date palms was 7m in both directions.

The plot area was 10.5 m² (3.0 m width by 3.5m length), containing five ridges spaced 60 cm apart. Wheat seeds were sown in constant spaced hills (20 cm apart) on the both sides of ridge according to Abouziena et al. (2007). The experiment was established with a split-plot design having three replicates. The main plots included four wheat cultivars and subplots were assigned to seven bioregulators treatments. The normal cultural practices for growing wheat in sandy soil were applied as recommended, except for the bioregulators treatment. After one month from sowing, the wheat plants were sprayed with the bioregulators.
Light intensity:

The light intensity was measured at noon after 1, 2 and 3 months from sowing at 50cm from plant canopy level (the wheat canopy growing intercropping with date palm and in using luxmeter (LX-101). Three observations were recorded from each measuring under the date palm and under natural sunlight wheat farm and the average of these three readings was calculated.

Growth and yield criteria:

At heading stage, 5 holes from each plot was taken to determine plant height, Number of tillers/m², flag leaf area (cm²), flag leaf weight, fresh and dry weight of plant (g/m²) at heading stage.

At harvest, a plant sample of one square meter from each plot was taken to determine the plant height, spike-producing tillers percent (number of spike-bearing tillers/total tillers number (%), spike weight, spike length and grain index (1000 grains weight), and harvest index (percentage of grain yield to biological yield). Biological and grain yields per hectare were determined by harvesting the whole plot wheat plants area.

Chlorophyll Extraction and Measurement:

Chlorophyll concentration was determined from fully expanded flag leave at heading stage. A leaf sample of 0.1 g was ground and extracted with 5 mL of 80% (v/v) acetone in the dark (Arnon, 1949). The mixture was filtered and absorbancies (Jenway 6105 UV/VIS, Spectrophotometer) were determined at 645, 663 and 450 nm. Concentration of chlorophyll a (Chl a), chlorophyll b (Chl b) and carotenoids were estimated by the equations of Witham et al. (1971).

Biochemical constituent’s determination:

Photosynthetic pigments (chl. a, b and carotenoids) were determined in the flag leave according to Wettstein (1957). Wheat grains were dried in oven at 70°C and then finally ground for determination free amino acid (Plummrer 1978) and total phenols (Danial and George 1972). Total sugars were determined according to Dubois et al. (1956) and sucrose according to Handle (1968).

Statistical Analysis:

The obtained results were subjected to the statistical analysis by M-STAT-C statistical analysis program (MSTAT 1988). Since the trend was similar in both seasons, Bartlett’s test and the combined analysis of the two growing seasons were applied. Means were compared using least significant difference test at 5% probability level.

Results And Discussion

Among the main environmental factors, solar radiation is the most significant one that regulates the photosynthesis, and consequently, the plant survival, growth and adaptation. In any habitat the light intensity varies temporally (seasonally and diurnally) and spatially (Zervoudakis et al. 2012). Therefore, plants develop acclimation and plasticity to cope with the varying light regimes (Zhang et al. 2003). The majority of plant species have the ability to develop anatomical, morphological, physiological and biochemical alterations in response to different light intensities (Sousa Paiva et al. 2003; Zhang et al. 2003; Zervoudakis et al. 2012). According to Chapman and Carter (1976) the minimum limit for the process of photosynthesis in most plants is between 100 and 200 fc (One foot candle (fc) is about 10.764 Lux). But light intensity of as low as 10 lux (0.93 fc), which occurs at twilight, can affect phototropic response (Vergara 1978). The average light intensities measured in 29th January, 26th February and 1st April in both seasons were 36000, 45400 and 50000 Lux in natural sunlight and 4600, 6200 and 12000 Lux under palm date (1.0 m above the wheat canopy level), respectively.

Vegetative growth:

Effect of wheat cultivars:

Cultivars did not differ significantly in plant height and number of tillers/m²; however Giza 168 cv was taller than the other cultivars (Table 1) under low light intensity condition. While, flag leaf area, flag leaf weight, fresh and dry weight of plants were significantly varied. The highest values of these parameters were
recorded with Gemmeiza 9 cultivar, the lowest one was recorded with Sakha 93 and 94 cultivars and insignificantly differences were recorded between the Gemmeiza 9 and Giza 168 as well as between the two Sakha cultivars.

The highest flag leaf area and weight were showed with Gemmeiza 9 variety which more than Sakha 93, Giza 168 and Sakha 94 cultivars by 48.9, 34.2 and 47.70, 16.7 and 75.0, respectively (Table 1). This effect may be due to genetic effect of the used genotypes under the study condition, which reflected on it response to low light intensity conditions. McMaster et al. (1992) and Petroczi and Matus (2002) did not find differences in the phyllochron among 10 cultivars of winter wheat or between maturity classes. However, others have reported that growth criteria for wheat cultivars were differed according the agronomic practices (Siddique et al., 1989; Abouziena et al. 2008 and 2011; Khakwani et al. 2012).

Gemmeiza 9 cv. produced a significant more plant dry weight than Sakha 93, Giza 168 and Sakha 94 varieties by 16.0, 10.7 and 18.4%, respectively. Insignificant differences in the dry weight were noticed among Sakha 93, Giza 168 and Sakha 94 cultivars. Hangarter (1997) reported that plants have evolved highly sensitive and selective mechanisms that detect and respond to various aspects of their environment. As a plant develops, it integrates the environmental information perceived by all of its sensory systems and adapts its growth to the prevailing environmental conditions. Light is of critical importance because plants depend on it for energy and, thus, survival. The quantity, quality and direction of light are perceived by several different photosensory systems that together regulate nearly all stages of plant development, presumably in order to maintain photosynthetic efficiency.

Effect of bioregulators treatments:

Application of bioregulators (Stearic acid, glutathione and salicylic acid) significantly affected on vegetative characters of the used genotypes wheat plants. Stearic acid at 100ppm gave the tallest plants (Table 1), while Stearic acid at 50ppm caused a reduction in the wheat plant height by 6% compared to the unsprayed plants. Concerning the spike-producing tillers percent/m², the results showed that the three bioregulators at two concentrations caused a significant increase in the fertility tillers and Salicylic acid treatments were the superior treatments, whereas the application of Salicylic acid at 50 and 100ppm increased the tillers fertility/m² by 43.7% and 89.4%, respectively compared to untreated plants. These results might be due to that Salicylic acid had a regulatory effect on activating biochemical pathways associated with tolerance mechanisms in plants (Najafian et al. 2009). Increasing the Salicylic acid concentration from 50 to 100ppm resulted in increase the spike-producing tillers percent by 31.8% (Table 1). Increased the application rate of Stearic acid and Glutathione from 50 to 100ppm reduced the spike-producing tillers %, however the both treatments produced a significant increases of this criteria if compared to the control. Spraying the wheat plants by Salicylic acid at 100ppm gave the maximum fresh and dry weights of wheat plants which increased by 46.1 and 67.4%, respectively compared to unsprayed plants. The capacity of the plants to convert solar energy into chemical energy was reduced with shading (Mouris et al. 1976). Therefore, application of Salicylic acid ameliorated the wheat growth parameters (Table 1). Gharib and Hegazi (2010) reported that Salicylic acid stimulated various growth aspects of bean seedlings perhaps through interference with the enzymatic activities responsible for biosynthesis and/or catabolism of growth promoting and inhibiting substances. Thus, it might be concluded that, SA could eliminate the adverse effects of cold stress in common bean.

Application of Glutathion at 100ppm caused a significant reduction of the plants fresh weight by 24.2%, compared to the control. Using Stearic acid improving the fresh and dry weight of plants by 19.7 and 15.3%, respectively compared to unsprayed plants, however the Stearic acid at 50ppm had insignificant effect on the dry weight of the plants. Hormones play a critical role in regulating branching (McSteen and Leyser 2005; Ongaro and Leyser 2008). Salicylic acid is a tool to increase plant tolerance against the adverse effect of biotic and abiotic stresses (Bosch et al. 2007) either by foliar application or seed treatment. Since, it has a regulatory effect on activating biochemical pathways associated with tolerance mechanisms in plants (Najafian et al. 2009).

Application of Glutathione at 100ppm caused a significant reduction in the plants fresh weight by 24.2%, compared to the control. Using Stearic acid at 100ppm improving the fresh and dry weight of plants by 19.7 and 15.3%, respectively compared to unsprayed plants, however the Stearic acid at 50ppm had insignificant effect on the dry weight of the plants (Table 1). Application of Stearic acid led to increase plant growth and yield as follow bean, marigold and squash (twice), carrots (30%) and Red beets (60%) (Hamilton 2012). The mechanism of stimulation in an enzyme system by Stearic Acid, then, is proposed to be in the Calvin Cycle of photosynthetic reactions. Specifically, the rate-limiting step of carbon dioxide fixation, in which ribulose 1, 5 diphosphate is converted into 3 phosphoglyceric acid; a reaction catalyzed by ribulose 3, 5 biphosphate carboxylase, is proposed to be the affected system. It is thus proposed that observed stimulating effect of Stearic acid is due to its hormone-like effects on plants growth and photosynthesis (Hamilton 2012).
Effect of interaction between wheat cultivars and bioregulators treatments:

Wheat cultivars varied significantly in their responses to bioregulators application. Flag leaf area and weight of wheat cultivar (Gemiza 9) gave the highest values with Stearic acid (100ppm). Percent of spike-borne tillers/m² and fresh and dry weight of plant were enhanced by Salicylic acid (100ppm) application in all cultivars, if compared to untreated plants (Table 1). Similar finding was reported with El-Awadi and Abd El-Wwahed (2011) on onion. Salicylic acid ameliorates seedling growth, phytohormone and enzymes activity in bean (Phaseolus vulgaris L.) under abiotic stress (Khodary 2004; Gharib and Hegazi 2010). Khodary (2004) reported that Salicylic acid and related compounds have been reported to induce significant effects on various biological aspects in plants. These compounds influence in a variable manner; inhibiting certain processes and enhancing others (Raskin 1992).

Photosynthetic pigments:

Effect of wheat cultivars:

There was significant difference between Gemiza 9 and Sakha 93 in the chlorophyll a content as well as among Gemmiza 9, Sakha 93 and Giza 164 cultivars in chlorophyll b content (Table 2). Sakha 94 recorded the lowest chlorophyll a and b compared to the three cultivars studied. The results in Table 2 (showed that wheat cultivars varied in the carotene content in leaves, whereas Giza 168 cultivar accumulated more carotene, followed by Sakha 94 cv, while the lowest one was recorded with Sakha 94 cultivar. Gemmiza 9 accumulated the highest total Chlorophyll and surpassed the plants of Sakha 94 by 11.9%.

The extent of the changes, however, differed between cultivars. Gemmiza 9 appeared to be shade-tolerant cultivar as their total chlorophyll more than those of the other cultivars in the shade, suggesting that their light-harvesting systems may be normally adapted to shade conditions. Gemmiza 9 also adapted to shade by a greater proportional increase in leaf area and flag leaf weight than the other cultivars (Johnston and Onwueme 1998).

Effect of bioregulators treatments:

Spraying Stearic acid at 100 ppm gave the highest accumulation of chl a, while application of Stearic acid at 50 ppm exhibited the highest chlorophyll b and carotene pigments, and the two treatments surpassed the other bioregulators treatments in the total chlorophyll (Table 1). In most cases, bioregulators treatments, except Stearic acid, exhibited insignificant or lower concentration of photosynthetic pigments under low light intensity compared to the unspayed plants as shown in Table 2. Salicylic acid slightly increased the total chlorophyll compared to the control. Xu et al. (2003) suggest that an ATP-binding cassette-type transport complex is involved in the transfer of eukaryotic lipids from the ER to the chloroplast. Structural analysis of crystallized protein complexes revealed that galactolipids are also found within the structures of PSI and PSII, light-harvesting complex II (LHCII), and cytochrome b/f (Liu et al. 2004; Loll et al. 2005; Jones 2007). Application of Salicylic acid in soybean plants (Zhao et al. 1995) and maize (Sinha et al. 1993; Khodary 2004) increased pigments content in the leaves as well as the rate of photosynthesis.
Table 2: Effect of some bio-regulators on Photosynthetic pigments (mg/100g fresh wt) at 75 days after planting of four wheat cultivars grown under low light conditions (combined analysis of the two seasons)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Gem 9</th>
<th>Sahka 93</th>
<th>Giza 168</th>
<th>Sahka 94</th>
<th>Mean</th>
<th>Gem 9</th>
<th>Sahka 93</th>
<th>Giza 168</th>
<th>Sahka 94</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotene (mg g⁻¹)</td>
<td>3.990</td>
<td>2.438</td>
<td>3.990</td>
<td>3.414</td>
<td>3.458</td>
<td>2.580</td>
<td>1.582</td>
<td>2.355</td>
<td>2.082</td>
<td>2.150</td>
</tr>
<tr>
<td>Total Chlorophyll (a+b) (mg g⁻¹)</td>
<td>2.270</td>
<td>2.981</td>
<td>3.990</td>
<td>3.506</td>
<td>3.187</td>
<td>2.291</td>
<td>2.490</td>
<td>1.780</td>
<td>1.877</td>
<td>2.110</td>
</tr>
<tr>
<td>Stearic acid 50 ppm</td>
<td>1.327</td>
<td>1.312</td>
<td>1.644</td>
<td>1.586</td>
<td>1.467</td>
<td>1.593</td>
<td>1.427</td>
<td>1.617</td>
<td>1.498</td>
<td>1.534</td>
</tr>
<tr>
<td>Glutathione 50 ppm</td>
<td>1.242</td>
<td>1.682</td>
<td>1.389</td>
<td>1.503</td>
<td>1.454</td>
<td>1.461</td>
<td>1.391</td>
<td>1.336</td>
<td>1.300</td>
<td>1.372</td>
</tr>
<tr>
<td>Salicylic acid 50 ppm</td>
<td>1.438</td>
<td>1.568</td>
<td>2.103</td>
<td>1.920</td>
<td>1.757</td>
<td>1.521</td>
<td>1.663</td>
<td>1.600</td>
<td>1.535</td>
<td>1.580</td>
</tr>
<tr>
<td>Control</td>
<td>1.617</td>
<td>1.950</td>
<td>1.379</td>
<td>1.458</td>
<td>1.601</td>
<td>1.528</td>
<td>1.462</td>
<td>1.456</td>
<td>1.468</td>
<td>1.479</td>
</tr>
<tr>
<td>Mean</td>
<td>1.956</td>
<td>1.928</td>
<td>2.330</td>
<td>2.162</td>
<td></td>
<td>1.776</td>
<td>1.656</td>
<td>1.627</td>
<td>1.587</td>
<td></td>
</tr>
</tbody>
</table>

LSD at 5% for varieties 0.062 0.082
LSD at 5% for Bioreg. 0.030 0.036
LSD at 5% for Inter NS 0.071

Abbreviations: Conc: concentration, Gem: Gemmeiza, Bioreg.: bioregulators, Inter: interaction

Stearic acid at 50 and 100ppm recorded the highest total chlorophyll accumulations and increased its content by 52.7% and 49.9% over the unsprayed plants, respectively (Table 2). Spraying Glutathione at 50ppm increased the accumulation of chlorophyll (a & b) by 12.2 and 9% than unsprayed plants. Glutathione system plays critical roles in the coordination of cellular processes with photosynthetic activity (Foyer and Noctor 2009). Photosynthetic organisms have developed robust antioxidant and redox buffering systems composed of enzymatic and small molecule components (Latifi et al. 2009).

Effect of the interaction between wheat cultivars and bioregulators treatments:

The interaction between wheat cultivars and bioregulators treatments had a significant effect on chlorophyll a, chlorophyll b and total chlorophyll pigments content, but insignificant effect on carotene pigment (Table 2). Stearic acid at 50ppm on Gemmiza 9 plants exhibited the highest value of chlorophyll b and total chlorophyll, while the highest chlorophyll a content was recorded with the application of Stearic acid at 100ppm on Sakha 93 cv.

Yield and its attributes:

Effect of wheat cultivars:

Data in Table (3) showed that there are insignificant differences among wheat cultivars grown under palm date shading in the plant height and harvest index parameters at harvest; however Gemmeiza 9 and Giza 168 cultivars recorded the tallest plants and Gemmeiza 9 recorded the lowest value of harvest index. This result means that Gemmeiza 9 cultivar contribute relatively more resources to the vegetative plant parts compared to the other cultivars. Insignificant differences among wheat cultivars were noticed in the fertile tillers% character, however Gemmeiza 9 significantly increased the fertile tillers % (Spikes number/tillers number) than Sakha 93, Sahka 94 and Giza 168 by 12.5, 13.2 and 7.4%, respectively. Speak length and weight criteria take the same direction where Gemmeiza 9 recorded the highest values than the three cultivars studied. Insignificant differences were recorded in grain index among Gemmeiza 9 and the two Sakha cultivars, while Giza 168 recorded the lowest grain index compared to the three cultivars.

Gemmeiza 9 significantly surpassed the three cultivars in the grain and biological yields criteria (Table 3 and Figs 1 and 2). In the same direction, the highest grain yield per unit area was recorded with Gemmeiza 9, while the lowest was recorded with Giza 168.

Gemmeiza 9 significantly gave more grain yield than Sakha 93, Giza 168 and Sakha 94 cultivars by 43.2, 51.8 and 22.0%, respectively (Table 3). This result was expected, where Gemmeiza 9 recorded the highest...
values of plant height, spike weight and grain index. Higher grain yield and biomass of shade tolerant cultivar Gemmeiza 9 may be the result of higher potential of this cultivar in employing the environmental factors especially light to produce grain yield. According to Petroczy and Matuz (2002), the better productivity of the Gemmeiza 9 were due to the higher flag leaf area and weight (Table 1), total photosynthetic pigments (Table 2), spikes number/tillers number (%), spike weight and length and 100 grain weight (Table 3), but other characteristics were intermediate.

The differences in yield potentiality among cultivars in grain and biological yields might be due to the genetically differences among cultivars and different genotypes concerning dry matter partitioning where wheat cultivars might differ in carbon equivalent, yield energy per plant and per hectare (Abd El-Gawad (2000)). Genetically differences among cultivars and different genotypes concerning dry matter partitioning where wheat characteristics were intermediate.

Bioregulators varied of their effect on the yield and its attributes of wheat plant. Salicylic acid was more effective on plant height, spike-producing tillers %, grain index, spike weight and biological yield, while Stearic acid at 50ppm was more effective on spike length and biological yield (Table 3 and Fig. 1). The stimulatory effect of salicylic acid on the biological yield of wheat plants may be attributed to the effect of Salicylic acid on many biochemical and physiological processes that were reflected on improving vegetative growth and active translocation of the photosynthesis products from source to sink. Similar findings were recorded with Abd Elwahed et al. (2006) and El-Khallal et al. (2009) on maize and Dawood et al. (2012) on sunflower.

Glutathione at 50ppm recorded the greatest grain yield/ha, followed by Stearic acid (100ppm) and Salicylic acid (100ppm) with insignificant differences among the three superiorities treatments (Table 3) in this respect. The three superior treatments increased the grain yield/ha by 29.8, 25.1 and 22.4%, respectively, if compared to untreated plants. Reisinger et al. (2008) reported that glutathione plays a central role in protecting plants from environmental stresses, including oxidative stress, xenobiotics, and some heavy metals (May et al. 1998; Noctor and Foyer 1998; Foyer and Noctor 2003; Freeman et al. 2005). Indeed, glutathione acts as an antioxidant, quenching the reactive oxygen species (ROS) generated in response to stress before ROS cause damage to cells (Navari-Izzo et al. 1997).

### Table 3: Effect of some bio-regulators on yield and its related characters of four wheat cultivars grown under low light conditions (combined analysis of the two seasons).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Gem 9</th>
<th>Sakha 93</th>
<th>Sakha 168</th>
<th>Sakha 94</th>
<th>Mean</th>
<th>Gem 9</th>
<th>Sakha 93</th>
<th>Sakha 168</th>
<th>Sakha 94</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spike number/tiller (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spike weight (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for varieties</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for interaction</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for interaction</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>86.5</td>
<td>85.0</td>
<td>89.5</td>
<td>88.5</td>
<td>88.5</td>
<td>85.0</td>
<td>85.0</td>
<td>85.5</td>
<td>85.5</td>
<td>85.0</td>
</tr>
<tr>
<td>LSD at 5% for varieties</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for bioreg.</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for interaction</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Abbreviations:
- Conc: concentration
- Gem: Gemmeiza
- Bioreg.: bioregulators

Increasing the concentration of Glutathione and Salicylic acid from 50 to 100ppm had insignificant effect on the grain yield compared to control, while increasing the concentration of Stearic acid from 50 to 100ppm increased the grain yield/ha by 63.7%, while application of Stearic acid at 50ppm caused a reduction in the grain yield by 23.6% relative to the control treatment. Devi et al. (2011) reported that the increase in the soybean seed yield could be a reflection of the effect of bioregulators on growth and development, it might be due to marked increase in the number of branches per plant which gave a chance to the plant to carry more seeds and increase in the photosynthetic pigments content, which could lead to increase in photosynthesis, resulting in greater transfer of assimilates to the seeds and causing increase in their weight.
The increments in wheat grain yield due to Glutathione at 50 ppm, Stearic acid (100 ppm) and Salicylic acid (100 ppm) may be attributed to that Glutathione is as an antioxidant protecting the cell from damage caused by free radical hydrogen. Glutathione also help the other antioxidation in the cells stay in their active form. The externally supplied glutathione similarly increased the enzyme activities, particularly peroxides (Alla 1995). In addition, it could be through improve wheat growth physiology that reflect in build blocks of protein synthesis which could be enzymes, and hormones important for metabolic activates (Gilbert et al. 1990). Khan et al. (2003) and Shakirove et al. (2003) reported that Salicylic acid is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance.

Fig. 1: Grain yield as affected by the interaction between wheat cultivars and bioregulators treatments (Combined analysis of the two seasons). Abbreviations: StA: Stearic acid; Gl. Glutathione; SA Salicylic acid.

Fig. 2: Biological yields as affected by the interaction between wheat cultivars and bioregulators treatments (Combined analysis of the two seasons). Abbreviations: StA: Stearic acid; Gl. Glutathione; SA Salicylic acid. (StA: Stearic acid; Gl. Glutathione; SA Salicylic acid.

Effect of the interaction between wheat cultivars and bioregulators treatments:

Data presented in Table (3) indicated that the interaction among wheat cultivars and bioregulators treatments had insignificant effect on the plant height, spike weight and length, grain index, spikes number/tillers number (%) and harvest index, while biological and grain yields were significantly affected by
this interaction. The highest biological yield was recorded with Gemmeiza 9 sprayed with Stearic acid (100 ppm), while the lowest one was recorded with Giza 168 sprayed with Stearic acid at 50ppm.

Spraying the shade tolerant wheat cultivar (Gemmeiza 9 cv) with Glutathione or Salicylic acid (50ppm) produced the greatest grain yield, while the lowest grain yield was obtained from Giza 168 plants and Stearic acid (50ppm) treatments. The role of Glutathione in increasing Gemmeiza 9 cv productivity may be attributed to that Glutathione is as an antioxidant protecting the cell from damage caused by free radical hydrogen. Glutathione also help the other antioxidant in the cells stay in their active form. Localized activity of glutathione could also help elucidate the mechanism of stress resistance. This effect indicates that glutathione may be involved in protection against DNA damage (Lodhi 1998). The externally supplied glutathione similarly increased the enzyme activities, particularly peroxides (Alla 1995). In addition, it could be through improve wheat growth physiology that reflect in build blocks of protein synthesis which could be enzymes, and hormones important for metabolic activates (Gilbert et al. 1990). The extremely supplied glutathione increased the enzyme activity, particularly peroxidase. Alla (1995) reported the role of glutathione in the defence against oxidative stress, may be due to this compound is are involved in plant growth and cell cycle control (Potters et al. 2004).

Chemical constituents of wheat grains:

Effect of wheat cultivars:

Sakha 94 cultivar had more free amino acids and sucrose, while Gemmeiza 9 and Sakha 93 had a higher value of total phenolics and total sugars, respectively (Table 4). The better productivity of Gemmeiza 9 variety may be attributed to the higher total phenolic, where the total phenols is signal of the plant tolerant to biotic and abiotic stress. Jansen et al. (2001) conclude that phenol-oxidizing peroxidases concurrently contribute to UV protection as well as the control of leaf and plant architecture.

Effect of bioregulators treatments:

Untreated plants, in most cases, had more total phenolics, more or equal free amino acids intermediate sucrose and less total sugars in grains compared to the bioregulated- treated plants (Table 4). It's obvious that application of Stearic acid at 50 and 100 ppm caused a reduction in the free amino acids, total phenolics and sucrose concentrations in the grain, however it caused a significant increase in the total sugars by 6.5% when applied at 100 ppm. Glutathione and Salicylic acid treatments had more or equal sucrose and total sugars in the wheat grains compared to the control. Total sugars content was more with Glutathione application than the other used bioregulators. El-Awadi and Abd El- Wahed (2011) reported that application of Glutathione on onion plants significantly increased the fixed oil percentage, total protein, phenols, and free amino acids, flavonoids and indoles, in green onion compared with control treatment.

Effect of the interaction between wheat cultivars and bioregulators treatments:

The interaction between wheat cultivars and bioregulators treatments had significant effects on the chemical constituents of wheat grains as shown in (Table 4). Spraying glutathione at 50ppm on Gemmeiza 9 variety plants gave the highest value of sucrose, while the same bioregulator treatment recorded the lowest sucrose percent in the grains of Sakha 93 cv (Table 4).

It is obvious that the highest total sugars content was found in the grains of Sakha 93 cv plants sprayed with salicylic acid at 50ppm. It could be noticed that there is no specific direction of the interaction results in terms of the biochemical constituents.

These results might be due to vary genotypes genetically response to the bioregulators effect on translocation and accumulation metabolites to wheat grains. In addition, galactolipids are also found within the structures of PSI and PSII, light-harvesting complex II (LHCII), and cytochrome b6/f (Liu et al. 2004; Loll et al. 2005; Jones 2007) that reflected on increasing free amino acids, sucrose and total sugars.

Salicylic acid increased the wheat growth (Shakirova et al. 2003) and maize growth (Shehata et al. 2001; Abdel-Wahed et al. 2006). Gharib and Hegazi (2010) reported that Salicylic acid stimulated various growth aspects of plants perhaps through interference with the enzymatic activities responsible for biosynthesis and/or catabolism of growth promoting and inhibiting substances low molecular weight antioxidants, such as ascorbate, glutathione, and tocopherol, are information-rich redox buffers that interact with numerous cellular components. In addition to crucial roles in defence and as enzyme cofactors, cellular antioxidants influence plant growth and development by modulating processes from mitosis and cell elongation to senescence and death (Potters et al. 2004; Tokunaga et al. 2005).
Table 4: Effect of some bio-regulators on biochemical constituents in grains of four wheat cultivars grown under low light conditions (combined analysis of the two seasons).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Gem 9</th>
<th>Sakha 93</th>
<th>Giza 168</th>
<th>Sakha 94</th>
<th>Mean</th>
<th>Gem 9</th>
<th>Sakha 93</th>
<th>Giza 168</th>
<th>Sakha 94</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free amino acids mg g⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stearic acid 50</td>
<td>5.6</td>
<td>4.7</td>
<td>8.0</td>
<td>5.1</td>
<td>5.9</td>
<td>5.2</td>
<td>1.7</td>
<td>2.9</td>
<td>2.5</td>
<td>3.1</td>
</tr>
<tr>
<td>Stearic acid 100</td>
<td>5.3</td>
<td>5.8</td>
<td>6.0</td>
<td>6.1</td>
<td>5.8</td>
<td>3.1</td>
<td>2.3</td>
<td>3.8</td>
<td>2.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Glutathione 50</td>
<td>4.6</td>
<td>5.4</td>
<td>5.0</td>
<td>5.3</td>
<td>5.1</td>
<td>2.8</td>
<td>2.6</td>
<td>2.6</td>
<td>3.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Glutathione 100</td>
<td>6.3</td>
<td>5.5</td>
<td>5.7</td>
<td>9.5</td>
<td>6.8</td>
<td>4.8</td>
<td>4.4</td>
<td>2.1</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Salicylic acid 50</td>
<td>5.7</td>
<td>6.8</td>
<td>7.4</td>
<td>8.2</td>
<td>7.0</td>
<td>1.5</td>
<td>1.7</td>
<td>1.4</td>
<td>3.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Salicylic acid 100</td>
<td>5.5</td>
<td>7.2</td>
<td>7.3</td>
<td>7.1</td>
<td>6.8</td>
<td>2.2</td>
<td>2.2</td>
<td>3.5</td>
<td>1.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Control</td>
<td>-</td>
<td>6.4</td>
<td>7.2</td>
<td>7.5</td>
<td>7.0</td>
<td>7.0</td>
<td>6.6</td>
<td>3.8</td>
<td>3.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Mean</td>
<td>5.6</td>
<td>6.1</td>
<td>6.7</td>
<td>6.9</td>
<td>3.8</td>
<td>2.7</td>
<td>2.9</td>
<td>2.9</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>LSD at 5% for varieties</td>
<td>0.5</td>
<td>0.2</td>
<td>0.7</td>
<td>0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for Bioreg.</td>
<td>0.5</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for Inter</td>
<td>0.9</td>
<td>0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total phenols mg g⁻¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stearic acid 50</td>
<td>3.0</td>
<td>3.2</td>
<td>3.0</td>
<td>3.0</td>
<td>3.1</td>
<td>70.8</td>
<td>74.3</td>
<td>72.4</td>
<td>82.4</td>
<td>75.0</td>
</tr>
<tr>
<td>Stearic acid 100</td>
<td>2.7</td>
<td>2.9</td>
<td>2.7</td>
<td>3.4</td>
<td>2.9</td>
<td>81.2</td>
<td>77.0</td>
<td>72.8</td>
<td>76.9</td>
<td>77.0</td>
</tr>
<tr>
<td>Glutathione 50</td>
<td>4.9</td>
<td>2.5</td>
<td>3.3</td>
<td>3.5</td>
<td>3.6</td>
<td>72.0</td>
<td>83.8</td>
<td>73.6</td>
<td>82.1</td>
<td>77.9</td>
</tr>
<tr>
<td>Glutathione 100</td>
<td>2.5</td>
<td>4.1</td>
<td>4.1</td>
<td>4.8</td>
<td>3.9</td>
<td>82.1</td>
<td>77.2</td>
<td>77.0</td>
<td>75.4</td>
<td>76.4</td>
</tr>
<tr>
<td>Salicylic acid 50</td>
<td>3.4</td>
<td>4.6</td>
<td>4.3</td>
<td>5.0</td>
<td>4.3</td>
<td>64.4</td>
<td>88.9</td>
<td>66.5</td>
<td>81.6</td>
<td>75.4</td>
</tr>
<tr>
<td>Salicylic acid 100</td>
<td>4.9</td>
<td>4.4</td>
<td>4.0</td>
<td>3.8</td>
<td>4.1</td>
<td>70.2</td>
<td>77.4</td>
<td>72.6</td>
<td>90.0</td>
<td>72.5</td>
</tr>
<tr>
<td>Control</td>
<td>-</td>
<td>2.8</td>
<td>3.9</td>
<td>3.6</td>
<td>3.5</td>
<td>3.4</td>
<td>83.6</td>
<td>65.4</td>
<td>69.7</td>
<td>70.4</td>
</tr>
<tr>
<td>Mean</td>
<td>3.4</td>
<td>3.6</td>
<td>3.6</td>
<td>3.9</td>
<td>74.9</td>
<td>77.7</td>
<td>71.2</td>
<td>77.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for varieties</td>
<td>0.2</td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD at 5% for Bioreg.</td>
<td>0.1</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interaction</td>
<td>0.3</td>
<td>4.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: Conc: concentration, Gem: Gemmeiza, Bioreg.: bioregulators, Inter: interaction

Conclusion:

The results suggest that Gemmiza 9 cv. could be used beneficially to tolerate the low light intensity (date palm shade) and could be improved its grain yield through application of Glutathione or Salicylic acid at 50ppm after one month from wheat sowing.

References


MSTAT-C., 1988. MSTAT-C, a microcomputer program for the design, arrangement, and analysis of agronomic research. Michigan State University East Lansing.


