GGE-Biplot Analysis of Nano-Titanium Dioxide and Nano-Silica Effects on Sunflower

Naser Sabaghnia, Mohsen Janmohammadi, Mehdi Mohebodini

Abstract**—**Present investigation is performed to evaluate the effects of foliar application of salicylic acid, glycine betaine, ascorbic acid, nano-silica, and nano-titanium dioxide on sunflower. Results showed that the first two principal components were sufficient to create a two-dimensional treatment by trait biplot, and such biplot accounted percentages of 49% and 19%, respectively of the interaction between traits and treatments. The vertex treatments of polygon were ascorbic acid, glycine betaine, nano-TiO_2, and control indicated that high performance in some important traits consists of number of days to seed maturity, number of seeds per head, number heads per single plant, hundred seed weight, seed length, seed yield performance, and oil content. Treatments suitable for obtaining the high seed yield were identified in the vector-view function of biplot and displayed nano-silica and nano titanium dioxide as the best treatments suitable for obtaining of high seed yield.

Keywords**—**Drought stress, nano-silicon dioxide, oil content, TiO_2 nanoparticles.

I. Introduction

SUNFLOWER (*Helianthus annuus* L.) is an oilseed crop which is grown throughout the semiarid regions in many areas of the world, and its oil represents a share of 7.3% of the annual global production [1]. It is belonging to the Asteraceae family which is important as oil crop in semiarid areas and characterized by a strong taproot, which enables it to thrive in dry climates and allows utilization of nutrients from below the root zone of cereals. The importance of oil crops such as sunflower has increased in recent years, especially with the interest in the production of biofuels because it is a crop which is well adapted to dry conditions [2]. Moreover, it is a well deep-rooted crop which can meet its water needs by exploring a big volume of soil in comparison to the most crops like cereal crops.

Utilization of exogenous compatible solutes and growth regulators in semi-arid regions can be an effective practice for improving crop performance which is generally applied to mitigate the adverse effect of environmental stress [3]. Compatible solutes are molecules that protect cells from desiccation by maintaining a high intracellular osmolality, and among different materials, glycine betaine (GB) has been further investigated and it was suggested that GB has very imperative role in crops protection under extreme environmental conditions [4]. Also, salicylic acid (SA) is which is a naturally occurring plant hormone, influences various physiological and biochemical functions in plants because it can play a role as a regulatory signal mediating plant response to abiotic stresses such as drought. Ascorbic acid (AA) has been used as a cofactor for enzymes involved in regulating photosynthesis, hormone biosynthesis, and regenerating other antioxidants.

Nano-titanium dioxide (TiO_2) particles are promising as efficient nutrient source for plants to improve biomass production by enhancing metabolic activities and conversion of light energy [5]. Foliar spray of nano silica (SiO_2) on plants improves the plant growth and performance by enhancing the accumulation of antioxidant enzymes and increases the efficiency of photosynthetic apparatus [6]. Therefore, the aim of this investigation was to determine the possible role of GB, SA, and AA growth regulators and nano SiO_2 and nano TiO_2 particles on morphological traits, yield components, seed yield, and oil content of sunflower.

II. Material and Methods

The experiment was performed based on randomised complete block design in four replicates with Azargol sunflower seeds at 28 March. Each experimental plot was consisting of eight rows, 4.5 m length, and 60×20 cm inter-plant and inter-row, respectively. Weeds were controlled by hand-hoeing. Treatments were control: water spray, nano SiO_2: foliar application of nano SiO_2 suspension (2 mM), GB: foliar spray of GB (100 mM), SA: foliar spray of SA (1 mM), AA: foliar application of AA (1 mM), and nano TiO_2: spray of nano TiO_2 suspension (2 mM). Nanomaterials were prepared from the Pishgaman Nano Company, Iran and the morphological characterization of nanoparticles has been determined by scanning electron micrograph (SEM) and transmission electron microscopy (TEM) (Fig. 1).

Chlorophyll content (CHL) was measured with a hand-held dual wavelength meter in fully expanded upper leaves at the flowering stage. Leaf length (LL) and leaf width (LW) were measured at the end of flowering stage. Also, traits days to 50% flowering (DF) and day to maturity (DM) were recorded. The morphological properties were plant height (PH), husk percentage (HP), number of seeds per head (NSH), head number per plant (HNP), percentage of empty achenes (PEA), 1000-seed weight (TSW), kernel weight (KW), grain length (GL), straw yield (STY), harvest index (HI), grain yield (GY). Oil percent (OIL) of seed was measured using a Near-infrared seed analyzers analyzer (Zeltex). Treatment by trait (TT)

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biplot analysis [7] was used to determine which treatment was best and for what trait which were generated using the standardized values of the traits means [8].

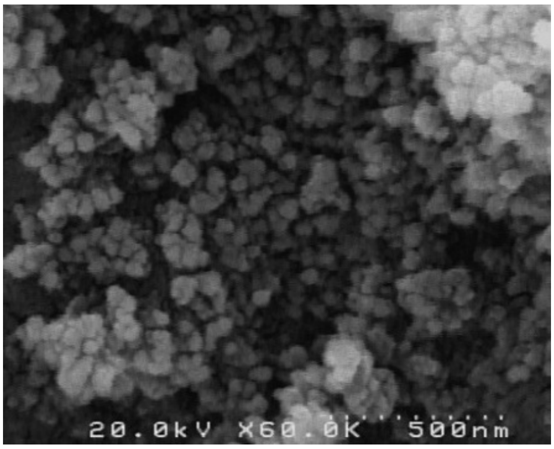

Fig. 1 SEM image of TiO_2 nanoparticles

III. Results and Discussion

Fig. 2 shows the "which-won-where" view of biplot, the outmost treatments (four in this case) formed a four-side polygon, and the biplot was divided into four sectors delimited by the lines perpendicular to each side of the polygon. The measured traits fell into all of the four sectors. For traits within a sector, the nominal "winner" is at the vertex, and so, control and AA were the wining treatments only for a single trait, percentage of empty achenes and plant height, respectively (Fig. 2). However, GB was the winning treatments in the sector containing the husk percentage, days to 50% flowering, LL, 1000-seed weight, and leaf width traits. Finally, nano TiO_2 was the winning treatments in the sector containing the other 10 traits including chlorophyll content, day to maturity, number of seeds per head, head number per plant, kernel weight, grain length, straw yield, harvest index, grain yield, and oil percent. The results shown in Fig. 1 suggested that there might be distinct groups of traits (four in this case) in compliance with the large magnitude of treatment by trait interaction and the high value of PC1 and PC2 contributions to the total sum of squares in TT biplot model analysis.

Summary of the interrelationships among the treatments for different traits provides Fig. 3. Based on the cosine of angles of traits vectors, there were positive correlation among CHL, STY, DM, and NSH as well as among GY, GL, KW, HNP, OIL, and HI (Fig. 3). Also, there was near zero correlation between LL with PH, between LL with HP, between PEA with PH, and between TSW with CHL, STY, DM, and NSH traits (Fig. 3). The presence of wide obtuse angles, i.e. strong negative correlations among the traits (between PEA with LL, between PH with DF and between HP with CHL, STY, DM and NSH) is an indication of strong cross-over type of TT interactions.

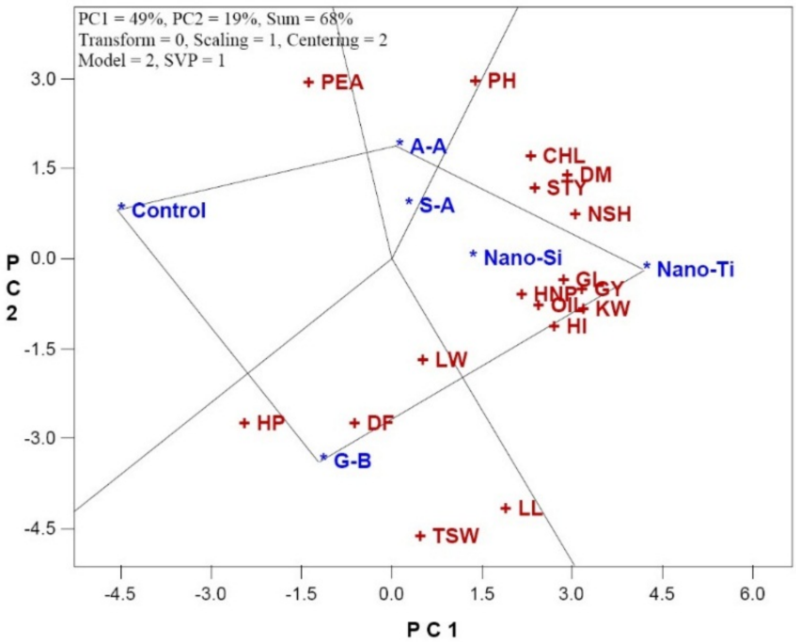

Fig. 2 Polygon-view of treatment by trait (TT) biplot showing which treatment had the highest values for which traits

As depicted in Fig. 4, the single-arrowed line called average–tester coordination abscissa points to higher performance across traits to identification of the ideal treatment which has high performance in most or all measured traits. GL, GY, KW, HNP, OIL, and HI had high performance across the treatments (Fig. 4). Also, CHL, DM, STY, and NSH following to PH, LL, and LW traits could be regarded similar to the mentioned traits.

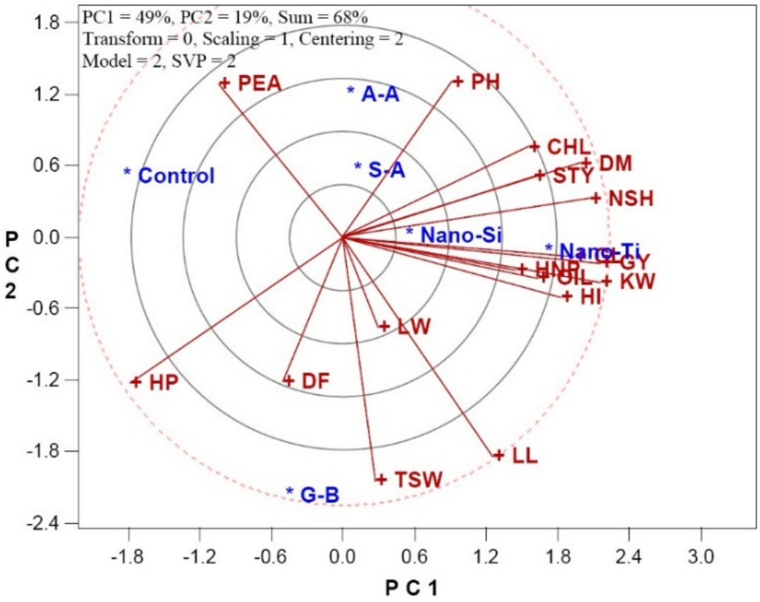

Fig. 3 Vector view of treatment by trait (TT) biplot showing the interrelationship among measured traits under different treatments

These study results indicate that nano TiO_2 and nano SiO_2 play a significant role on increasing of sunflower yield and other traits, so that higher amounts of traits obtained with spraying of nanoparticles in compared with spraying distilled water (Control), AS, AA, and GB. Nanoparticles have unique physicochemical properties and it seems that they have potential to mitigate the adverse effects of heat and drought stress on the growth and physiology of sunflower. Effectiveness of nanoparticles strongly depends on their concentration and varies from plants to plants, therefore effects of different concentrations and the interaction nanoparticles with cellular process need further evaluation and may provide a more comprehensive interpretation. Application of nano SiO_2 and nano TiO_2 particles improved seed germination of soybean by increasing nitrate reductase [9] and also by enhancing seeds ability to absorb and utilize water as well as nutrients [10].

IV. Conclusions

Foliar spray of nano TiO_2 and nano SiO_2 enhanced the yield and yield components of sunflower performance. Application of GB, SA, and AA had not any positive effect on sunflower.

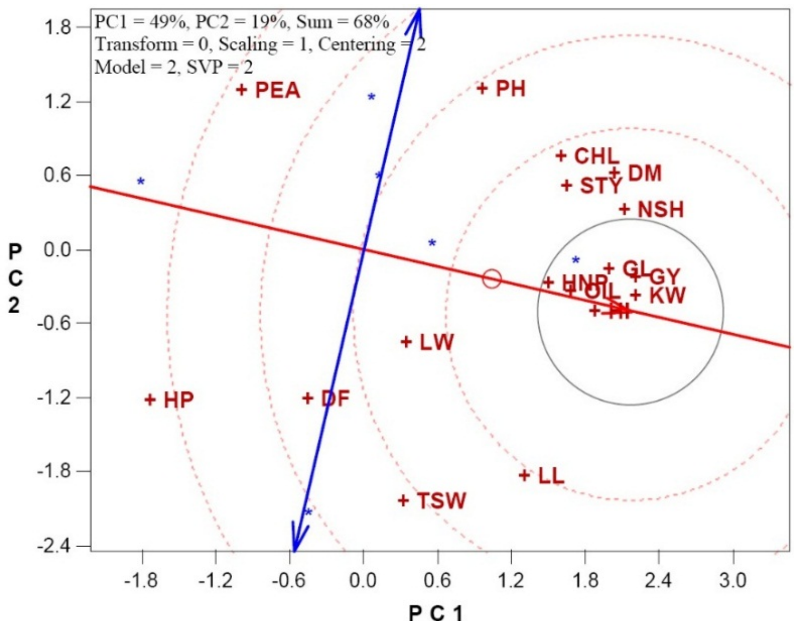

Fig. 4 Ideal tester view of treatment by trait (TT) biplot, showing the relationships of different traits with ideal tester

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