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THE EFFECT OF DIFFERENT NANO-, BIO- AND CONVENTIONAL MINERAL FERTILIZERS APPLICATION ON SOME MORPHOLOGICAL CHARACTERISTICS OF MAIZE

SUMMARY

Effective management of nutrient application is important part of the crop production puzzle and it seems that nano-fertilizers may have high potential for achieving sustainable crop production. A field experiment was carried out to investigate the effect of adding different nano-size and biological fertilizers on maize growth under various irrigation regimes. The experiment conducted under optimal irrigation level (up to ~50% field capacity) which is applied from the beginning of the reproductive period. Fertilizer's treatments included control (Nf; no-fertilizer application), N biofertilizer (Bio-N), P biofertilizer (Bio-P), nano-chelated B (Nano-B), nano-chelated Zn (Nano-Zn), complete nano-fertilizer (Nano-C) and conventional mineral NPK fertilizer. Bio-P was the best treatment in terms of grain yield, ear length, biological yield, number of the kernels per row, length of ear leaf and straw yield traits, while Nano-Zn was the best treatment for increase of protein content and Nf was the best treatment for increase of oil content. Bio-N was the best treatment in terms of leaf area, ear diameter and hundred grain weight, while Nano-B was the best treatment for plant height, harvest index, stem diameter, number of the row per ear and number of the kernels per ears traits. Nano-C and NPK are not outstanding for any of the traits. Nano-Zn had good effect on high yield and high protein content while nano-B was good for better performance of plant height, stem diameter, number of the row per ear, harvest index and number of the kernels per ears traits. Such an outcome could be used in the future to advise good recommendation strategies for recommendations for maize and other crops in other areas of the world.

Keywords: Grain yield, Micronutrient, Nano-chelated fertilizers, Yield components

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INTRODUCTION

Mediterranean semi-arid areas are characterized by low erratic rainfall and water shortage is the most severe restriction for crop production. Although cereal production is increased through applying the modern agricultural technologies, the arid and semi-arid areas have not greatly benefited from this increase. Also, it appears that plant production in drier agro-ecological zones, such as Mediterranean-type climate areas of Middle East is usually constrained by water limitation as well as nutrient limitation (Ryan *et al*., 2012). Available soil moisture has a significant influence on nutrient use efficiency, and it determines crop yield. In arid and semi-arid areas, the loss of organic matter and low fertility are of great concern which causes low biomass production and high rates of organic matter decomposition. Also, the main challenge in the future decades will be the task of meeting food needs with less water, especially in arid and semi-arid regions and a watering strategy that whereby water supply is reduced below maximum levels is allowed with minimal effects on yield performance (Geerts and Raes 2009).

Nutrient deficiencies have been reported for a long period of time as a result of decline in soil organic carbon status in semi-arid regions (Sahrawat and Wani 2013). During the last decades, application of the fertilizers has been increased in arid and semi-arid areas. Nutrient management is a fundamental concern from the economic perspective and there are a range of options available for this purpose (Golzarfar *et al.,* 2012). The utilization of bio-fertilizers has become important in agriculture for their potential role in improving soil fertility and crop production (Bhardwaj *et al.,* 2014). Bio-fertilizers containing strains of symbiotic and non-symbiotic microorganisms which are beneficial bacterial or fungal inoculants that improve uptake of nutrients by crop roots.

Nitrogen (N) and phosphorus (P) are the two essential nutrients for maize growth and development; therefore, their bio-fertilizers could strongly improve the plant performance (Janmohammadi *et al.,* 2012). It has been recognized that conventional mineral fertilizer may cause some problems such as polluting water basins, destroying micro-organisms and friendly insects; however, it seems that bio-fertilizers application can overcome these problems (Chen, 2006). Most farmers of arid and semi-arid regions apply only N and P fertilizers that supply macronutrients, while micronutrients shortage is prominent (Ryan *et al.,* 2012). Although much lower levels of micronutrients are needed for obtaining satisfy yield and quality, they play vital role in plants development (Marschner, 2012). Up to now, the main source of supplying the micronutrients are mineral bulk fertilizers, while recently the tendency to use new fertilizers in nano-size (Nano-fertilizers) is increased (De Rosa *et al.,* 2010).

Nano-fertilizers are innovative agricultural input which is aimed to release nutrients into the soil gradually, avoiding environmental damages (Sekhon, 2014). In nano-fertilizers, nutrients can be encapsulated by nanomaterials, coated with a thin protective film, or delivered as emulsions or nano-particles (De Rosa *et al.,* 2010). Nano-fertilizers could be able to release nutritional elements in a controlled manner as a reaction to different environmental fluctuations, so that it can enhance plant growth effectively more than conventional fertilizers (Naderi and Danesh-Shahraki 2013). Nano-fertilizers provide the nano-scale or nano-structured nutrients in a controlled release and lead to an increased efficiency of the nutrients, improve nutrient use efficiency and decrease costs of environmental protection (Sekhon, 2014).

Despite the plenty of information available on application of some nanoparticles on crops, there was not sufficient information about efficiency of nano-fertilizers under water scarcity condition. Therefore, the present investigation was carried out to evaluate the impact of some bio-fertilizers and nano-fertilizers under deficit irrigation on yield and yield components of maize in Mediterranean-type environment.

MATERIAL AND METHODS

Field experiments were carried out at the Moghan (46° 46‘E and 39°36‘N), Iran, during the growing season of 2014. It has warm and humid summers and temperate winters with dry winds and short freezing period and average annual rainfall was about 335 mm. The soil type was a clay loam, pH 7.22 and EC =2.35 dS.m^{-1}, organic matter 0.85%, potassium 306.4 mgkg^{-1}, phosphorous 15.8 mgkg^{-1}. The mean temperature and total rainfall during the growth season was 21°C and 124 mm, respectively. The trial was conducted in a randomized complete block designs with three replicates. The water deficit irrigation was 50% soil water content in field capacity level during initiation of reproductive growth until maturity stage. At mentioned area, the clay loamy soil has sufficient depth (more than 1 meter) and field capacity was at 33% and wilting point at 16% by volume for the surface to 100-cm soil layer.

Seeds of single cross 704 hybrid were hand sown on 27 April in 5 cm depth of soil. Each experimental plot area was 25 m^2 (5×5m) with 0.65 m spacing between rows and 0.2 m spacing between plants. Soil was tilled by moldboard ploughs during the August 2013 and seedbed preparation was carried out by disc plough, disks, leveler and furrower during April 2014. Fertility treatments consisted control (no-fertilizer), nitrogen bio-fertilizer (contains *Azotobacter vinelandii* strain O4), phosphorous bio-fertilizer (contains phosphate-solubilizing bacteria; *Pantoea agglomerans* strain P5 and *Pseudomonas putida* strain P13), nano-chelated boron, nano-chelated zinc, complete nano-fertilizer and conventional mineral NPK (nitrogen, phosphorus and potassium). Bio-fertilizer was applied as seed inoculation just before planting. Conventional mineral NPK consisted of 180 kg N ha^{-1} in the form of urea, 100 kg P ha^{-1} in the form of super phosphate, and 50 kg K ha^{-1} in the form of potassium sulphate. Half of the N and all of P and K were applied before sowing (incorporated by disk). The remaining N was applied as a top dressing one month after sowing.

Nano-chelate fertilizers were obtained from the Fanavar Sepehr Parmis Company, Iran and due to the calcareous nature of the region soil micronutrients nano-fertilizers were applied as foliar spry at three times (2000 ppm) including 9-

leaf stage, stem elongation and heading. Nano-fertilizers contained nanoparticles of zinc oxide, boric acid or combination of absorbable forms of key micronutrients elements (Fe, Cu, Zn, B, Mn). Two hand weeding were carried out at 20 and 40 days after sowing date, respectively. Relative water content (RWC) was measured in leaves adjusted to ear at the beginning of grain development stage (BBCH-scale=71) according to Barrs and Weatherley (1962). Chlorophyll content was measured on ten leaves of a plant at each plot, using a SPAD-meter at the beginning of seed development stage. The central two rows from each plot were harvested at maturity and biological yield, straw yield, seed yield and harvest index were measured. Different agronomic traits including plant height, length of ear leaf, hundred kernel weight, kernel number, number of the kernel per row, number of the row per ear, cob diameter, ear diameter, ear length, stem diameter, leaf area per plant, biological yield. Content of protein and oil in grain (or kernel) were measured using a Near-infrared seed analyzer (Zeltex).

Treatment by Trait (TT) analysis was used to data analysis and plots were generated by the GGE biplot software (Yan, 2001; http://www.ggebiplot.com). This statistical method has been described in detail by Yan and Tinker (2005) and Yan *et al.* (2007).

RESULTS

The TT biplot of mean performance of coconut treatments explained 59% (41 and 18% for the first and second principal components, respectively) of the total variation of the standardized data (Fig. 1).

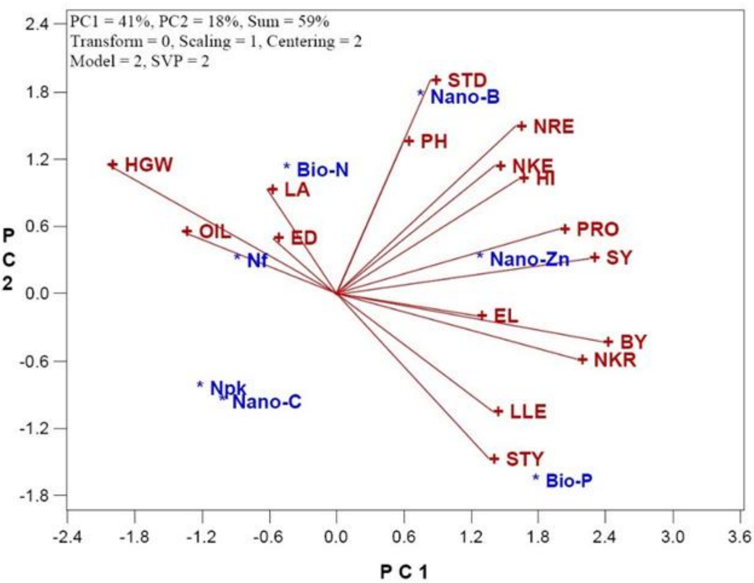

Fig. 1. Vector view of treatment by trait (TT) biplot indicating the interrelationship among traits under different fertilizer treatments (Nano and Bulk). For traits abbreviations, refer to the text.

The traits were considered as the tester and the treatments as entries. This relatively moderate percentage variation reflects the accuracy of interrelationships among the measured traits across different treatments. In the TT biplot, a vector is drawn from the biplot origin to each marker of the traits to facilitate visualization of the relationships between and among the traits. Provided that the biplot described an enough amount of the total variation, the association coefficient between any two traits is approximated by the cosine of the angle between their vectors (Yan and Rajcan 2002). On this premise, two traits are positively correlated if the angle between their vectors is an acute angle (< 90°) while they are negatively correlated if their vectors are an obtuse angle (> 90°). LLE and STY, PRO and SY, STD and PH, OIL and HGW were positively associated (an acute angle) as shown in Fig. 1. These relationships suggest that it is possible to combine higher seed yield with higher protein content in a single genotype. Also, these traits were positively correlated with each other (acute angles); NRE and NKE with HI; EL and BY with NKR (Fig. 1). STD and PH traits were not correlated with OIL and HGW due to near right angles and similar association was observed for LLE and STY traits with NRE, NKE and HI (Fig. 1). LLE and STY had negative correlation with OIL and HGW traits (Fig. 1).

Fig. 2 is biplot showing the polygon view of the treatment × trait analysis on the morphological traits based on first two principal component axes. The treatment(s) at each vertex (vertex treatment) of the polygon in the biplot were the best in terms of the trait(s) found within the sector demarcated by any two lines that meet at the origin of the polygon.

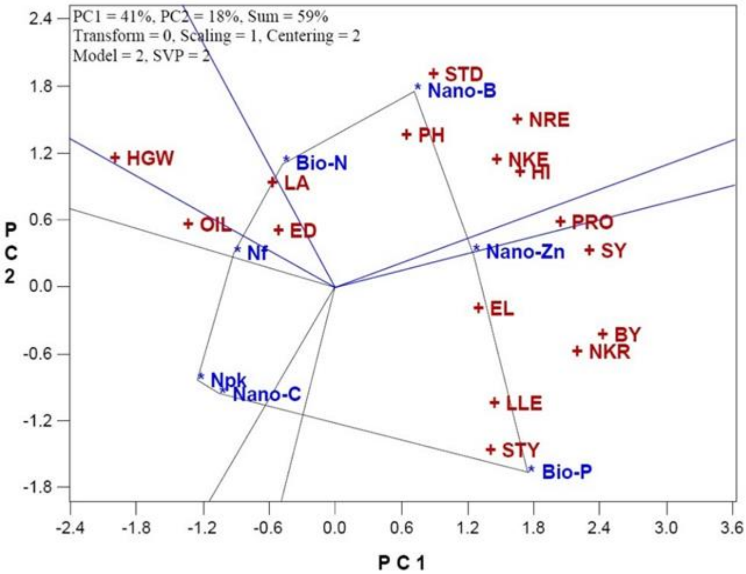

Fig. 2. Polygon view of treatment by trait (TT) biplot showing which fertilizer treatment (Nano and Bulk) expressed to the highest values for which traits. For traits abbreviations, refer to the text.

From Fig. 2, Bio-P was the best treatment in terms of seed yield, EL, BY, NKR, LLE and STY indicating that it can be used as the best fertilizer in the corn production. Even though Bio-P was identified for good performance in these traits, it was not the best for other remained traits, indicating that these traits might not be a good trait-indicator for seed yield. Nano-Zn was the best treatment for high protein content while Nf was the best treatment for high oil content. From Fig. 2, Bio-N was the best treatment in terms of LA, ED and HGW indicating that it can be used as the best fertilizer for achieving good performance of these traits while Nano-B was the best treatment for PH, HI, STD, NRE and NKE traits. Nano-C and Npk were also vertex treatments but no trait was found in their respective sector, an indication that they are not outstanding for any of the traits (Fig. 2). In other word, none of measured traits could not perform in high magnitudes regarding Nano-C and Npk treatments.

In the context of treatment-by-trait analysis, an ideal treatment (Nano-B) has been defined as the treatment that combines several good traits in its performance. An ideal treatment should possess the highest mean performance across traits (i.e., longest projection onto the average tester coordinate (ATC abscissa) axis and shortest entry-vector, thus, it should be close to the ideal treatment represented by the innermost concentric circle with an arrow pointing to it (Yan and Rajcan 2002). Such ideal treatment can, therefore, be used as a reference check in subsequent trials where the set of traits will be measured. In the biplot displayed in Fig. 3, the single-arrow line that passes through the biplot origin is referred to as the ATC abscissa, and on this line is ranked the treatments in terms of their performance.

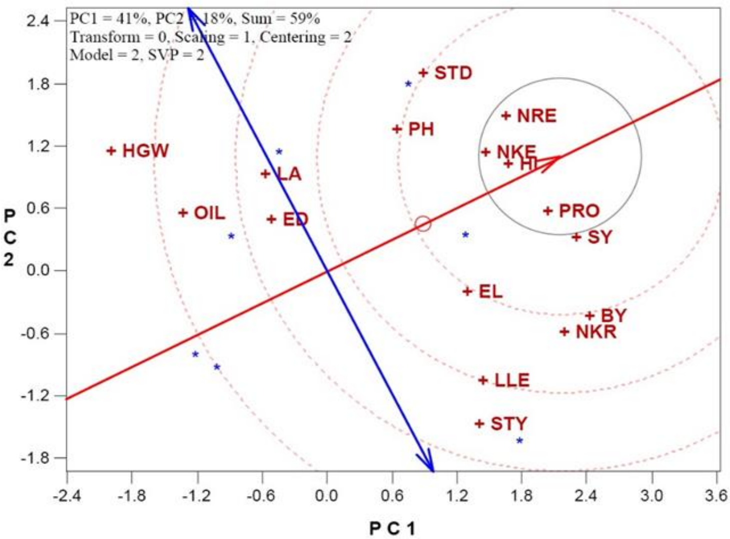

Fig. 3. Ideal tesr view of treatment by trait (TT) biplot, showing the relationships of different fertilizer treatments (Nano and Bulk) with ideal entry. For traits abbreviations, refer to the text.

The double-arrow line (ATC) divides the ATC abscissa into two at the middle (YAN *et al.* 2007). The portion of the ATC towards the right displays the above average treatments and towards the left shows those treatments below average. Based on this biplot, the treatments that performed above average were Nano-B, Nano-Zn, Bio-N and Bio-P treatments; while Nano-C, Npk and Nf treatments performed below average in terms of measured traits (Fig. 3). Nano-B is closest to the position of an ideal treatment and it is ranked the highest in term of morphological performance because it is desirable in terms of most of the traits. This treatment could serve as a good fertilizer for corn production.

A vector is drawn from the biplot origin to each marker of the treatment to enhance visualization of the relationships between and among the treatments (Fig. 4). The vector length of a treatment measures its effect (positive or negative) with others (Yan and Tinker 2005). The cosine of the angle between the vectors of any two treatments approximates the correlation coefficient (degree of association) between the treatments. From Fig. 4, Npk and Nano-C positively correlated, and it shows they all gave similar performance in the measured traits. Npk and Nano-C with Nano-Zn, and Bio-P with Bio-N were negatively correlated and indicated different performance. Nano-B did not show any association with Bio-P as well as Npk and Nano-C treatments (Fig. 4).

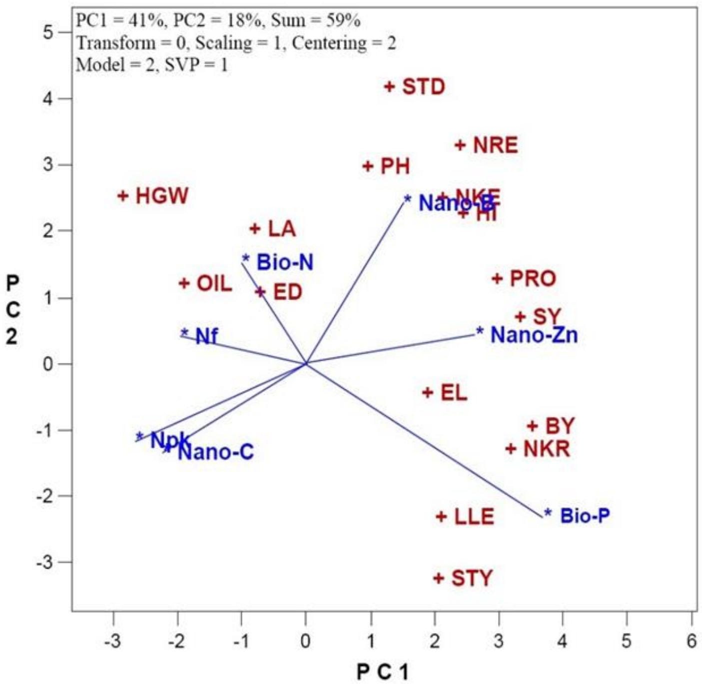

Fig. 4. Ideal entry view of treatment by trait (TT) biplot, showing the relationships of different fertilizer treatments (Nano and Bulk) with ideal entry. For traits abbreviations, refer to the text.

Ranking of various fertilizer treatments for seed yield (SY) performance indicated that Nano-Zn was the best treatment regarding high seed yield following to Nano-B and Bio-P fertilizer treatments, but the other treatments could not produce good yield performance in decreasing order Bio-N > Nf > Nano-Zn > Npk (Fig. 5). Zinc is the essential element in function of some enzymes and its application may efficient the ability of maintaining high yield. Using nano-size zinc had positive effects on obtaining high yield performance.

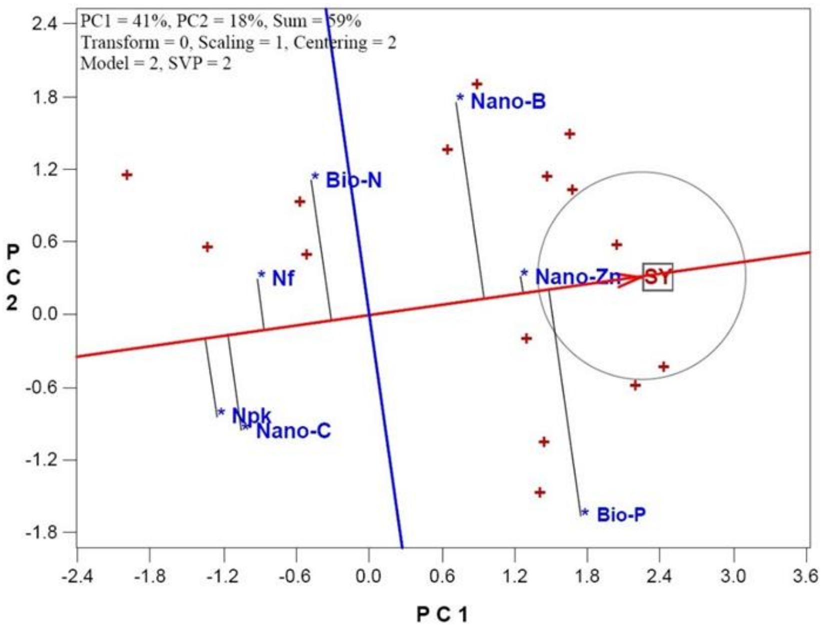

Fig. 5. Vector view of treatment by trait (TT) biplot, showing the relationships of different fertilizer treatments (Nano and Bulk) with target trait (SY, seed yield). For traits abbreviations, refer to the text.

DISCUSSION

Nano-fertilizers or bio-fertilizers play an important role when they are compared to conventional mineral fertilizers. Nanotechnology in many fields is in its primary stage, seeing new innovations it tells that it has a great scope and for any technology to that object there will be interested. We found that nano-Zn had good effect on increase of yield and protein content in comparison to the other fertilizer treatments. Zinc has general deficit in the world and its amount intake through daily food is very low, thus by application of zinc fertilizer there are least chances of indirect supply to human (Rameshaiah *et al.*, 2015). The nano-size zinc can be used to get a diffused and soluble zinc, and equal ratios between surface area and size of nano-particles should be carefully designed (Malik *et al.*, 2014). Also, for better performance of plant height, stem diameter, number of the row per ear, harvest index and number of the kernels per ears traits, nano-B could be used but nano-C could not affect the measured traits.

Nano-fertilizers are capable to hold bountiful of nutrient ions due to their high surface area and release it slowly and steadily that commensurate with crop demand. Subramanian *et al.* (2008) reported that nano-fertilizers can be used to control the release of nutrients from the fertilizer granules. They improve the nutrient use efficiency while preventing the nutrient ions from either getting fixed or lost in the environment and have high use efficiency and can be delivered in a timely manner to a rhizospheric target. It is still unclear whether type of nanotechnology for use in agriculture will has any long-term impacts on human or the environment; thus, further investigation into the impact that the nano-nanotechnology may has been studied (Rai *et al.,* 2012). It is difficult to predict the impact of nanotechnology on fertilizers' application in the future, for researchers, this insight may allow them to contribute nano-fertilizers in field.

For obtaining high kernel yield, these traits: ear length, number of the row per ear, number of the kernels per ears, biological yield, harvest index and protein content would be effective and useful. Several authors have attempted to determine relation between the characters on which the selection for high yield can be made. Annapurna *et al.* (1998) found that seed yield was correlated with plant height, ear diameter, number of seed per row and number of rows per ear. Knowledge about the traits' association is a great importance for success in selections to be conducted in breeding programs. The effects of different traits on seed yield were studied in 90 genotypes by Geetha and Jayaraman (2000) and they reported that number of seeds per row exerted a direct effect on yield.

Grain yield is the complex trait in maize and any change in any component leads to the yield loss whereas it is very sensitive to any crops. In this study we emphasized to determine the correlation coefficient of the traits via vector-view of biplot in order to understand and identify the correlated traits that play an important role in selection and breeding for improvement proposes. Therefore, these traits must be analyzed to know their relationship and their contribution on grain yield and we found ear length, number of the row per ear, number of the kernels per ears, biological yield, harvest index and protein content were the most effective traits on yield. It is clear that the biplot method is an excellent tool for visual data analysis because compared with conventional methods, the biplot approach has some advantages (Yan *et al.,* 2007). The first advantage of the biplot is its graphical presentation of the data, which enhances ability to understand the patterns. The second is that it is more interpretative and facilitates pair-wise treatment or trait comparisons. The third advantage of biplot method is that it facilitates identification of possible positive or negative interactions of treatment versus traits.

CONCLUSIONS

Based on the results which we get in this research conclusions are: (i) maize grain yield was positively associated with ear length, number of the row per ear, number of the kernels per ears, biological yield, harvest index and protein content traits, (ii) nano-B was the best fertilizer treatment while nano-Zn produced high yield and high protein content and (iii) no-fertilizer (Nf), conventional NPK and nano-B were not good fertilizers for most of the measured maize traits.

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