

T.R.
VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF FIELD CROPS

**EFFECT OF ACTIVE DRY YEAST AND NANO IRON FERTILIZER ON SOME
YIELD AND QUALITY CHARACTERISTICS OF MAIZE (*Zea mays* L.) PLANTS
GROWN IN ALKALINE SOIL**

Ph.D. THESIS

PREPARED BY: Mohammad ALOBAIDY
SUPERVISOR: Prof. Dr. Şeyda ZORER ÇELEBİ

VAN-2022

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ACCEPTANCE and APPROVAL PAGE

This thesis entitled “Effect of Active Dry Yeast and Nano Iron Fertilizer on Some Yield and Quality Characteristics of Maize (*Zea mays* L.) Plants Grown in Alkaline Soil” presented by Mohammad ALOBAIDY under supervision of Prof. Dr. Şeyda ZORER ÇELEBİ in the Department of Field Crops has been accepted as a Ph.D. thesis according to Legislations of Graduate Higher Education on 05/09/2022 with unanimity of votes members of jury.

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Signature

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Director of Institute

THESIS STATEMENT

All information presented in the thesis obtained in the frame of ethical behavior and academic rules. In addition, all kinds of information that does not belong to me have been cited appropriately in the thesis prepared by the thesis writing rules.

Mohammad ALOBAIDY

A handwritten signature in dark blue ink, appearing to read 'M. Alobaidy', is positioned below the printed name. The signature is fluid and cursive, with a large loop at the end.

ABSTRACT

EFFECT OF ACTIVE DRY YEAST AND NANO IRON FERTILIZER ON SOME YIELD AND QUALITY CHARACTERISTICS OF MAIZE (*Zea mays* L.) PLANTS GROWN IN ALKALINE SOIL

ALOBAILY, Mohammad
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Corn is an important plant used as silage in animal feeding in the world and in Türkiye as well. The field experiments were conducted at high pH levels at the Campus of Van Yuzuncu Yil University, in the research and experiment station in the two successive summer years (2019 and 2020) to investigate the effects of foliar application of (0.4, 0.6, and 0.8 g.L⁻¹) nano iron oxide Fe₃O₄ and (5, 7.5, and 10 g.L⁻¹) active dry yeast and their combination on maize (*Zea mays* Cv. Tuano) grown for silage purposes. The experimental design was RCBD. The spraying was applied two times, firstly after planting 54 days (DAP), and secondly 15 days later. Results reveal that there is a significant improvement in the plant growth characteristics by using all concentrations of either nano Fe₃O₄ or dry yeast or their mixture. Plant high at 74, 84, and 117 DAP, the weight of (leaves, stem, cobs, and shoot per plant), the number of cobs per plant, fresh and dry herbage weight per decare (da), and plant cob ratio percentage at 117 DAP have increased, while no significant difference in the number of leaves/plant and stem diameter compared to control. On the contrary, the plant (stem, leaf) ratio percentage decreased when using nano iron and/or dry yeast and control recorded the best values. The inorganic chemical concentrations significantly enhanced in the corn plant during the dough period (117 DAP) i.e., P, K, Ca, Mg, Fe, Cu, Se, and Zn, and also chlorophyll content at 74 and 84 DAP compared to the control. Whilst, molybdenum concentration negative effect due to the use of dry yeast and or nano Fe₃O₄. However, the M3: 10 g.L⁻¹ of yeast and N2: 0.6 g.L⁻¹ nano Fe₃O₄ gave the higher values of the studied parameters compared to control, but the interaction treatments especially N1M3 recorded the best and highest values in comparison to control and/or singular treatment by yeast and nano iron under alkali soil in the Van city for producing corn silage.

Keywords: Active dry yeast, Alkaline soil, Corn silage, Nano iron.

ÖZET

ALKALİN TOPRAKTA AKTİF KURU MAYA VE NANO DEMİR GÜBRE UYGULAMALARININ MISIRIN (*Zea mays* L.) BAZI VERİM VE KALİTE ÖZELLİKLERİ ÜZERİNE ETKİLERİ

ALOBADY, Mohammad

Doktora Tezi, Tarla Bitkileri Anabilim Dalı

Tez Danışmanı: Prof. Dr. Şeyda ZORER ÇELEBİ

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Mısır dünyada ve Türkiye'de hayvan beslemede silaj materyali olarak kullanılan önemli bir bitkidir. Van Yüzüncü Yıl Üniversitesi, Ziraat Fakültesi, Araştırma ve Deneme Alanı'nda, nano demir ve aktif kuru mayanın yapraktan uygulanmasının etkilerini araştırmak için, 2019 ve 2020 yıllarında yüksek pH seviyelerine sahip alanda iki saha denemesi yürütülmüştür. Araştırmada nano demir oksit Fe_3O_4 (0.4, 0.6 ve 0.8 g.L⁻¹) ve aktif kuru maya (5, 7.5 ve 10 g.L⁻¹)'nın farklı dozları ve bu dozların birlikte kullanımının silaj amaçlı yetiştirilen mısır (*Zea mays* Cv. Tuano) bitkisi üzerine etkileri araştırılmıştır. Deneme tesadüf blokları deneme deseninde üç tekerrürlü olarak düzenlenmiştir. İlk uygulama ekimden 54 gün sonra (DAP), ikinci uygulama birinci uygulamadan 15 gün sonra tekrarlanmıştır. Sonuçlar nano demir, maya ve her ikisinin birlikte uygulamalarının tüm konsantrasyonlarının, yetiştirilen mısırın büyüme ve gelişmesi üzerine önemli etkilerinin olduğunu ortaya koymuştur. Bitki boyu, DAP 74, 84 ve 117. günlerde, bitkide yaprak, sap ve koçan ağırlığı, bitkide koçan sayısı, yaş ve kuru ot verimleri hamur olum döneminde (117. DAP) kontrole göre tüm uygulamalarda artmıştır. Bitkideki yaprak sayısı ve sap kalınlığı üzerine uygulamaların etkisi önemsiz bulunmuş. Mısır bitkisinin hamur olum döneminde (117. DAP) P, K, Ca, Mg, Fe, Cu, Se ve Zn konsantrasyonları uygulamalar ile artmış, bunun yanı sıra 74 ve 84. DAP ölçümlerinde uygulamalar ile klorofil içeriği de kontrole göre önemli ölçüde artmıştır. Sonuç olarak, Van'da alkali topraklarda silaj amaçlı mısır üretiminde, mayanın 10 g.L⁻¹ uygulamasının ve nano demirin 0.6 g.L⁻¹ doz uygulamalarının çalışılan parametreleri olumlu etkilediği, bununla birlikte maya ve nano demirin birlikte kullanımının sonuçları tekli kullanıma göre pozitif etkilediği, özellikle N1M3 uygulamasının, kontrol ve tekli uygulamalarla karşılaştırıldığında en yüksek değerleri verdiği belirlenmiştir.

Anahtar kelimeler: Aktif kuru maya, Alkali toprak, Mısır silajı, Nano demir.



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2022

Mohammad ALOBAIDY



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SYMBOLS AND ABBREVIATIONS

Some symbols and abbreviations used in this study are presented below, along with descriptions.

List of abbreviations as follows:

Abbreviations	Description
ANOVA	Analysis of Variance
CEC	Cation Exchange Capacity
Cv.	Cultivar
DAP	Day After Planting
EDTA	Ethylene Di-amine Tetraacetic Acid
i.e.,	id est Latin for that is English
ICP	Inductively Coupled Plasma
nm	Nanometers
NPs	Nanoparticles
OES	Optical Emission Spectrometer
pH	Potential of Hydrogen
RCBD	Randomized Complete Block Design
SPAD	The Soil Plant Analysis Development
VYYU	Van Yuzuncu Yıl University

List of Symbols as follows:

Symbols	Description
Al	Aluminum
B	Boron
C°	Degree Celsius

Symbols	Description
Ca	Calcium
Cl	Chlorine
cm	Centimeter
CO ₂	Carbon Dioxide
Cu	Copper
da	Decar/Da=1000m ²
Fe	Iron
g	Gram
ha	Hectare
K	Potassium
L	Liter
me	Milliequivalents
Mg	Magnesium
mg	Milligrams
mL	Milliliter
mm	Millimeter
Mn	Manganese
N	Nitrogen
N	Nitrogen
Na	Sodium
ng	Nanograms
P	Phosphor
P ₂ O ₅	Phosphorus Pentoxide
Se	Selenium
μL	Microliter
Zn	Zinc

1. INTRODUCTION

The original home of maize/corn *Zea mays* is Mexico and Central America (tropical America), from which it moved to Southern Europe and then to Africa and Asia. Corn is a C4 plant that belongs to the cereal family (Poaceae). It is a cross-pollinated plant characterized by separating the male and female organs on the same plant. Maize is a low-ripened annual summer crop, rapid growth with high productivity, easily harvested and loved by animals, such as environmental tolerant, and it is one of most the widely spread grain crops globally and ranks third after wheat and rice in terms of importance at the global level (Younis and Al-Hasan, 2013). Maize ranks second in the world in terms of production area among cereals and ranks first in terms of production amount due to its high productivity (Anonymous, 2019a). Türkiye is one of the countries where maize is grown well. Corn production in Türkiye can be made in every region, and many projects are carried out, especially at regional sowing time, depth, and frequency, and the results are used by the farmers of the region (Cengiz, 2016). In Türkiye, corn ranks third among cereals in terms of cultivation area and production (Anonymous, 2019b). The corn plant is grown as the main or secondary crop. The economic importance of yellow corn is with multiple uses and can be explained in the following areas: Food uses (human food): Yellow corn kernels are used in human food and gluten-free bread is made, as well as starch, grain germ oil, and dextrin. Industrial uses: maize is used in many industries, such as clothing dyes, printing ink, paper, rubber, glucose, biofuels, and others. Feed uses, the main purpose of cultivating yellow corn is animal feed, as the grains are used in the form of concentrated feed, green fodder, silage, or hay made from them. Greed or fresh fodder is the backbone of dairy farming as it plays a vital role in turning dairy farms into profitable businesses. Silage is green fodder that is kept isolated from the air. Preservation is carried out through the fermentation processes of plants with high humidity, as respiration and anaerobic fermentation produce alcohol and organic acids, which increase the acidity of the feed to the point of stopping the spoilage factors that usually occur in aerobic conditions. Silage is as full of nourishment as non-dry or fresh fodders because it keeps the nutrient in its original form and thus it is as better for feeding animals like green fodder itself (Kumar et al., 2019). Corn is used as silage and grain and provides an

increase in milk yield and quality in animals, is used as 27% of human food and 73% of animal feed in the world. While corn is used for animal nutrition for 46% and raw material for human food and industry for 54% in underdeveloped countries, it is used for 90% for animal nutrition, and 10% for human food and industry in developed countries (Öz et al., 2017). Green plants are used to prepare silage provided to animals as green fodder during winter when green fodder is unavailable. Corn silage retains high nutritional value, dry matter 69.50%, crude protein 4.25%, crude fiber 25.20%, ash 2.63%, and soluble carbohydrates 62.8%. Corn is used as silage and grain and provides an increase in yield and quality of milk in animals. Silage of corn is mainly used as a high-energy fodder for feeding the dairy cow during lactation (Paye et al., 2022). The cultivation area of corn produced for silage in Türkiye is about 4.7 million decares (das). Silage corn production is approximately 23.2 million tons, and the silage yield is 4915 kg/da on average, although it varies by region (Acar et al., 2020). Corn is an important crop used both as a concentrate and as a source of forage. Corn silage has become a staple feed ingredient in dairy cattle rations in the last two decades (Khan et al., 2015; Korkmaz et al., 2019). Forage production is one of the most substantial needs of livestock husbandry. Feed requirements for 500 kg cattle weight, to meet nutritional needs, are 25-30 kg per day of good quality dry material and for green grass or silage maize 10 kg each day with good quality as well (Alçiçek et al., 2010). In this context, in parallel with the increasing number of livestock in Türkiye, the requirements for feed are increasing. Feed inputs in animal production constitute about 70% of the entire production cost (Cevher and Altunkaynak, 2020). To meet the nutritional demand of the increasing world population, it is aimed to obtain maximum efficiency from the minimum area. In this context, the demand for fertilizers, plant nutrition, and protection products is increasing. Due to the effects of excessive use of chemical fertilizers on the sustainability of agricultural lands, the tendency to use organic fertilizers has increased. Inorganic chemical fertilizers, which provide the nutrients necessary for plant growth and development, increase the yield, but unconscious and excessive use of these chemicals causes negative consequences for human and environmental health (Altunlu et al., 2019), they are lost due to evaporation, drift, hydrolysis, leaching, runoff, and the microbial or photolytic destruction of nutrients, which prevent them from reaching the target location (Manjunatha, et al., 2019). On the one hand, the traditional fertilizers increase crop yield, but on the other hand, the

efficiency of the macronutrient utilization of these fertilizers appeared to be too low-grade because 50-70% of their nutrients have vanished into the surrounding environment such as soil, water, air, and do not benefit plants (Marchiol, 2019). Consequently, the fertilizers used to increase crop production, pollute the environment, and as a result, the economic efficiency reduces (Ha et al., 2019).

For achieving food security and sustainability in agriculture, good soil conditions (fertility and healthy) are essential. But it faces challenges due to management weak and climate change. Soil deterioration increases and becomes marginal to production. Contemporary anxieties about the global motives for the retrogression of the soil contain salinity, wind and water erosion, high or low soil pH, and pollution (Anonymous, 2015). The situation became compounding and even made more difficult by the requirement for excess production of food to feed a growing world population. Consequently, developing and implementing sustainable agricultural practices has become a topic of interest worldwide. Exercise works need to preserve the capacity of the soils for food production while providing other key ecosystem services i.e., nutrients regulation and storage and level of the soils' carbon.

Agriculture is progressing in enhancement and modification, and currently, the attention is not only concentrated on yield but on safeguarding the health of the environment as well. Thus, now the challenge for soil calcification (and other farm practices) is to reach out to management sustainability in an entire system approach (Gibbons et al., 2014).

For more than two decades, because the government supports, the cultivation areas of forage crops in Türkiye have increased to 206%. However, roughage shortage remains a major issue for livestock holding in the country. For this purpose, modern strategies should be evolved to expand areas of forage cultivation with attention to the global greenhouse, shortage of precipitation, and climate change. To meet the roughage need, it is important to increase the planting forage areas as the main and second crop production. Abandoned fields due to various issues should be reused to grow appropriate forage crops (Tan and Yolcu, 2021). Corn is an important plant used in human and animal nutrition and cultivated in large areas. It is an important hot climate fodder plant that produces more dry matter per unit area than other varieties. It is considered a green and silage plant.

Soil pH is only necessary for soil chemistry and fertility. However, in the natural environment, the acidity of the soil has a tremendous impact on the biogeochemical actions of soil. Therefore, the acidity of the soil is described as the “major soil variable” that influences countless soil biological, chemical, and physical features and processes that impact the growth of the plant and its biomass production (Neina, 2019). Due to high amounts of exchangeable sodium in alkaline soil, it is considered not fertile for plant growth, and in consequence, causes weak physical, chemical, and biological properties of soil (Gökoğlu and Çayci, 2021).

Nanotechnology, due to its unique chemical and electronic properties, has enormous possibilities as it has great applications in the fields of agriculture and the environment (Qureshi et al. 2018; Chhipa, 2019). Nano fertilizers are substances produced by nanotechnology and consist of nanoparticles. Using this technology aims the amelioration of nutrients and their use efficiency. Nano refers to a scale that scales down to a nanometer (nm). The size of nanoparticles (NPs) ranges from 1 nm to 100 nm, whether they are in a gaseous, liquid, or solid-state (Ghosh and Pal, 2007; Buzea et al., 2007).

Nano fertilizers are important in agriculture to increase crop yield and nutrient use efficiency, and to reduce the use of excessive doses of chemical fertilizers. The most important features of this type of fertilizer are that they are manufactured to include one or more of the nutrients (macro and micro), they are used in small amounts a frequency, and they are environmentally friendly. However, when applied in high doses, they reduce plant growth and crop yield like traditional chemical fertilizers (Dağhan, 2017). Recently, Nanomaterials have been used as plant growth stimulators to promote the production of crops in saline-alkali through the soil-root application (Li et al., 2021a). As well as Fe_3O_4 NPs could reinforce plant performance by improving photosynthetic effectiveness, enhancing its adaptability to the environment, and increasing the distribution ratio of substance made by photosynthesis to the roots part. Remarkably that nano Fe_3O_4 caused positive effects on the plant polysaccharides concentrations. The key techniques for enhancing photosynthetic performance and adaptation to photo-inhibitory settings were boosting mesophyll cells' photochemical activity and improving light energy usage efficiency. Furthermore, Fe_3O_4 NPs can affect various sides of plant growth, and the impacts are dose-dependent. Here, iron is a trace element that is recognized to be essential

for photosynthetic activity and plant development. The physiological basis for the accumulation of dry matter and high crop production is photosynthesis (Herrmann et al., 2019).

In comparison to traditional chemical fertilizers, nano fertilizers are recommended primarily because of their effectiveness and environmental friendliness (Janmohammadi, et al. 2016). Recently, widely reported of using nanomaterials for the betterment of resistance of plants to many abiotic stresses (Sajyan et al., 2020). Therefore, the NPs drove to best circumstances for growing plants and prevent them from stress conditions and positively affect the production of secondary metabolites (Moradi et al., 2018). Because nano iron can improve plant mineral nutrition and reduce the usage of conventional fertilizers, applying it can be a useful step toward achieving sustainable agriculture (Rui et al., 2016; Kopittke et al., 2019).

Active dry yeast *Saccharomyces cerevisiae* is a natural biofertilizer that affects plants due to it contains vitamins, amino acids, major and minor nutrients, and growth-promoting substances such as cytokinins (Medani and Ragab, 2015). Dry yeast is considered a natural source of cytokinins and bio-stimulant that stimulates cell enlargement and division, chlorophyll formation, and synthesis of nucleic acid and protein (Wanas, 2002; El- Desouky et al., 1998; and Wanas, 2006). Yeast extract may have an impact due to how it affects biological processes, enzyme activity, photosynthetic pigments, and metabolism, all of which promote vegetative development (El-Sherbeny et al., 2007; Wanas, 2002). It may increase antioxidants, and enhance metabolism and water-holding capacity (Abbas, 2013). It also releases CO₂ which leads to improving photosynthesis (Kurtzman and Fell, 2006). Dry yeast is used in the bio and organic fertilization system as an alternative source of growth substances (Ezz El-Din and Hendawy, 2010). Also, biofertilizers such as yeast and others play an important role in enhancing plant nutrient status and increasing its growth and yield parameters i.e., quality and quantity (Salim et al., 2018; Alsaady et al., 2020). At present, there is great interest in the potentiality of using yeast as a natural and safe item to catalyze plant growth, as it is estimated a promising factor to enhance the growth of various plant crops (Abed Nasser et al., 2019). In recent decades, a viable substitute for traditional chemical fertilizers, yeast solutions are secure for use around people, pets, and the environment (Omran, 2000).

The objective of this study aims to evaluate the *Zea mays* Cv. Tuano plants grown under high soil pH level improve the growth and productivity of maize plants by using the foliar application of bio-stimulants as active dry yeast and nanomaterial as Fe₃O₄ nano iron oxide for silage purposes.



2. LITERATURE REVIEW

Maize/corn is one of the popular oldest and most powerful cereals crops, which is popularly used for food, fodder, and also for medical purposes in the world (Huma, et al. 2019). Maize considers the main source of carbohydrates for livestock. Moreover, it is the main source of energy and food source for humans and animals in addition to its content of natural phytochemical compounds such as pigments, substantial fats, and starch (Rouf Shah et al., 2016; Kaul et al., 2019). Moreover, over the past few decades, the silage of corn has become the main fodder ingredient in dairy cows' rations (Khan et al. 2015). Maize or Corn is grown under a wide range of agronomic and environmental circumstances (Khan et al. 2015; Rouf Shah et al., 2016). According to López-González et al. (2022), the distribution of carbon between vegetative and reproductive tissues affects the production of cereal grains. Many abiotic and biotic stresses such as high soil pH decrease the quantity and quality of corn production. Moreover, when this silage is fed to animals, it gives them a variety of nutrients in varied amounts. Silages are regarded as a significant source of carbohydrates and minerals for animals (Bilal et al., 2020). The cultivation area of corn produced for silage in Türkiye is approximately 4.7 million das (decares). Total silage corn production is 23.2 million tons, and the silage yield is 4915 kg.da⁻¹ on average, although it may vary by region (Acar et al. 2020). 73% of corn production in the world and 90% in developed countries are used for animal feeding. In Türkiye, 70% of corn production, which ranks third after wheat and barley, is used for animal nutrition (Öz et al., 2017). Using environmentally materials to overcome the stresses on plants and raise production is increasing day by day, as our study aimed.

2.1. Effect of Alkaline Soil on Plant

Among abiotic factors related to soil quality and soil pH is a major factor limiting plants growth because it greatly affects the availability and absorption of various essential nutrients such as the availability of copper (Cu), iron (Fe) calcium (Ca), manganese (Mn)

and Zinc (Zn) (Foy, 1984; Robson, 1989; Bolan et al., 2003), and aluminum (Al) increases due to increased ability to be dissolved, desorption, or lowering (George et al., 2012; Parker and Norvell, 1999). In addition, soil pH influences many processes that will affect the solubility, mobility, and bioavailability of elements through organically bound mineralization, minerals uptake, and sedimentation reactions (Holland et al., 2018; Neina, 2019). While negative effects on plants can be distinguished in the high pH of the soil (Tinus, 1980; Fageria and Zimmermann, 1998). At a high level of pH (more than 7), the quality of the plant's being able to utilize phosphorus (P), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), and boron (B) is tiny. According to the salinity and alkalinity criteria used in the improved soil map studies in Türkiye, the problem of salinity and alkalinity exists in an area of 1.518.722 ha in Türkiye. Where 0.5% is alkaline, 8% is slightly salty alkali and 17.5% is salty alkali. The barren lands are equivalent to 5.48% of the total cultivated agricultural lands (Sönmez and Beyazgül, 2008). Several plant species commonly do not grow well in soils with a quite low pH. Pulses plants, including the bean *Vicia faba* L., use root nodules to fix nitrogen (Bolan et al., 2003)

Zinc deficiency is more potential to happen in alkaline soil, where zinc solubility is lower in alkaline soil than in moderately pH conditions, is often caused not by the low total concentration of zinc in soil but by low bioavailability of Zn, and the solubility of the zinc is further reduced as the carbonate concentration in soil is increases (Alloway, 2009; Duffner et al., 2012; Gupta et al., 2016). Moreover, Alloway (2009) pointed out that, the main soil aspects impacting Zinc availability to plants are low total Zn concentration, high pH, and high contents of the soil solution of Na, Ca, Mg, bicarbonate, and phosphate. Maize is the most susceptible cereal crop to Zn deficiency. On another aspect, biological measurable factors, such as plenty and diversity of soil biota, have long been recognized as potentially beneficial indicators of the quality of the soil (Doran and Zeiss, 2000; Ritz et al., 2009). In general, under alkaline soil conditions, the availability of most macronutrients is increased. In contrast, the availability of micronutrients and some macronutrients such as phosphorus is decreased. This decrease produces a negative effect on the vegetative and reproductive of the plants (Jiang et al., 2017).

Kerley and Huyghe (2001) conducted a trial to investigate the impact of varied pH on two lupin genotypes in liquid culture or pot and chamber soil systems. They noticed that the calcium content of the shoot increased when plants were cultivated in the calcareous soil in comparison to the non-calcareous one but it was kept unaltered between the liquid culture treatments. The root systems showed growth abnormalities, where the dry weights of the main and lateral roots of the two species were lesser in the calcareous soil than in the non-calcareous one. However, this did not lead to higher P concentrations of the shoot in the calcareous compared to plants grown in acidic soil.

Li et al. (2009) studied the impacts of salt (NaCl: Na₂SO₄) and high pH (NaHCO₃: Na₂CO₃) abiotic stresses on the wheat shoot concentrations of inorganic and organic chemical components. The high pH caused by alkaline stress improved the accumulation of sodium ions and affected the inorganic intake. To ensure the balance of ionic and osmotic, organic acids, soluble sugars, and proline were accumulated in wheat plants as the physiological responses and adaptive mechanisms to alkali stress.

Valdez-Aguilar and Reed (2010) stated that the elevated HCO⁻³ concentrations give rise to the alkalinity of irrigation water and are linked with inhibition of the growth of bean plants and reduction of the micronutrient contents, i.e. iron and zinc, thereby becoming unavailable for plant uptake. As well as a possible K⁺ content reduction in plant shoots grown under high pH levels perhaps happen and probably Na could supersede K in the shoot under these circumstances. In their experiment, high pH inhibited the growth of bean plants and the younger leaves' chlorophyll content.

Goenaga et al. (2013) found that when cowpea was grown at alkalinity conditions (pH >7.5), the acute cause of leaf chlorosis was mostly iron, zinc, and often manganese (Mn) deficiencies. It is most properly that iron deficiency or alkalinity chlorosis resulting from the high concentrations of calcium and magnesium carbonates in the soil was possibly a factor in the reduced yield of cowpea plants. Although the seeds germinated, the plants unwell grew afterward and lastly died or become weak without reaching the reproductive stage.

Gao et al. (2014) applied two neutral salts (NaCl and Na₂SO₄) and alkaline salts (NaHCO₃ and Na₂CO₃) were both mixed in a ratio of 2:1, and the impacts of abiotic stresses (saline and alkaline) on morphological and physiological changes in the seedlings of oat

plants were investigated. The result exhibited that the biomass and plant contents of water and chlorophyll reduced, while the permeability of the plant cell membrane increased significantly under alkaline conditions. Alkaline stress increased the pH value in the liquid of the root tissue. Under alkaline stress, the Na^+ , Na^+/K^+ , SO_4^{2-} contents increased more, and K^+ , NO_3^- , H_2PO_4^- decreased more, while the content of Cl^- had little change. High pH stress leads to more deleterious impacts on morphological and physiological changes in oat seedlings especially degrading of the pH constancy in the solution of root tissue. Under alkaline stress, proline and organic acid increases were higher, but under saline stress, no change was recorded in the organic acid concentration.

Gentili et al. (2018) studied the effects of soil pH on the germination, vegetative, and reproductive characteristics of *Ambrosia artemisiifolia* (common ragweed) through a controlled conditions experiment. Their results showed that plants grown at high pH levels had shorter leaves with a slower rate of development than those plants grown at pH5 and pH6 soil. Moreover, plants grown at a high pH did not give flowers and pollen. The authors also found that, at lower pH levels (5 and 6), plant shoots were bigger and had both larger and numerous inflorescences with earlier pollen production. This study suggests that the growth and development of *A. artemisiifolia* responded greatly to soil pH and indicates that it might have a function in decreasing the allocation and severity of the studied plant.

Ding et al. (2019) cultivated six genotypes of *Lupinus* in the hydroponics system under three pH levels; 5, 6.5, and 8. They found that chlorosis was observed in the small plant leaves at high pH for *L. angustifolius* and *L. cosentinii*, and P deficiency at high pH for all genotypes. The absorption of the iron (Fe) and zinc (Zn) in all genotypes decreased under high pH level. Moreover, the lateral root growth of plants was decreased. Each sensitive plant species' uptake of P, K, Ca, and manganese (Mn) followed the same upward trend. As well as P, Fe, Zn, Mn, and Ca translocation to leaves in the most vulnerable species was decreased. The authors concluded that under high pH conditions, Different *L. angustifolius* genotypes' lateral root growth was reduced, while *L. cosentinii*'s slower photosynthetic rate led to chlorosis in the leaves and weakened P uptake. Additionally, it greatly reduced the Fe and Zn intake in all studied species and that of Mn, K, and Ca in all sensitive species, and also

the movement of P, Fe, Zn, Mn, and Ca of most sensitive genotypes from roots to plant leaves.

Sirisuntornlak et al. (2020) carried out a pot experiment to investigate the interactive impact of seed priming with Si (0, 1, and 2 mM) and different soil pH levels (5.3, 6.3, 7.4, and 8.1) on the growth, yield, and uptake of nutrient of maize. They found that the more appropriate condition for plant growth, yield, and nutrient uptake of soil pH was from slightly acidic (6.3) to neutral (7.4). Across Si doses, at pH 7.4 than at pH 8.1, corn plants produced higher kernel number/cob about 21%, and more grain yield by about 8%. Moreover, shoot P decreased in plants grown at pH 8.1 by about 60%, soil K about 12% lesser, and shoot Si lower by about 21% than that grown at pH 7.4. Plant height significantly decreased with increasing soil pH from 5.3 to 8.1 where the lowest value was detected with a pH of 8.1 (17.9 cm). Leaf area was significantly affected by soil pH across measuring periods, where leaf area was significantly increased with decreasing pH from 8.1 to 5.3, and the topmost drooping (about 26%) was recorded under the highest pH level (8.1) compared with the lowest pH 5.3. No significant difference was recorded in the leaf area at pH 5.3, 6.3, and 7.4 with a respective increase of about 16%, 24%, and 15% than the leaf area at pH 8.1 at 60 days. Moreover, about 9%, 7%, and 9% were larger in size at soil pH of 6.3 than cob length at pH of 5.3, 7.4, and 8.1, respectively. For the number of kernel/cob parameters, pH 8.1 had the lowest value and the difference was significant in comparison to other pH levels. On another hand, a slight difference was detected in the grain yield character among all pH values. Chemically, a respective reduction of the concentration of this plant nutrient is about 67% and 93% than those estimated at pH 5.3 in both shoots and grain, where the lowest value was under pH 8.1. As well as, K concentration in the shoot was the highest at pH 6.3 and about 16% higher than K concentration at pH 8.1, also it was statistically at par with pH 5.3 and 7.4. Additionally, the highest grain K concentration was found under pH 6.3, which was about 63%, 26%, and 68% more than values at pH levels of 5.3, 7.4, and 8.1, respectively. Also, under pH 6.3, the shoot Ca concentration was the biggest with about 25%, 51%, and 26% higher than concentrations recorded at the pH levels of 5.3, 7.4, and 8.1, respectively. The same trend for grain calcium content, it was the highest under the pH of 6.3, which was about 55% and 113% higher than those detected at pH values of 5.3 and 8.1, respectively,

while the value under 6.3 was statistically at par with the grain calcium concentration at pH 7.4.

Mousa et al. (2022) studied the cowpea plant response to soil acidity was estimated by scaling the plant height among many pH levels. Broad bean seedling height varied dramatically between experimental groups, indicating a considerable impact of soil pH on the development of bean plants. Authors proved that soil pH altered the plant properties and indirect impacts of the soil pH on plant inner structure. The maximum plant height was detected in the plants grown under 5.3 soil pH with 10.58 cm, followed by pH 7.2 which minimized the height of plants to 9.35 cm, the difference was significantly exhibited among all pH levels.

2.2. Effect of Nano Iron on Plants

Iron is the fourth most abundant earth element, but it is not readily available to crops as its solubility in the soil is controlled by soil pH (Alidoust and Isoda, 2013). It is a major determinant of the biological functions of different enzymes in the cells that are essential for plant metabolism, respiration, and photosynthesis (Siddiqi and Husen, 2017). Additionally, iron plays a crucial role in boosting the productivity of plants, biomass, and plant growth by providing essential nutrients (Konate et al., 2017). Iron deficiency shows multiple troubles, like chlorosis in plants that show the symptoms of weak growth, a low leaves number, and reduced concentrations of chlorophyll. When iron oxide nanorods (NRs) are absorbed by the plants they are distributed, accumulated, and used as fertilizer, which has attracted researchers' interest. So, it is significant to develop a less harmful to the environment and unique approach to improve the iron intake in plant crops. The nanoparticles (NPs) have a massive possibility to enhance the crop's yield if applied in optimal concentrations (Khalid et al., 2022). At present focus is to know how the nanoparticles affect the biochemical, physiological, and molecular mechanisms of plants (Soliman et al., 2015). Owing to changed physical and chemical properties at the nanoscale level, nanomaterials have properties such as catalytic ROS (reactive oxygen species) scavenging ability and self-fluorescence that their bulk or commercial counterparts lack (Wu and Li, 2022). In this regard, nano fertilizers

containing zinc, magnesium, and iron play a crucial role in providing plants with the principles of micro/macronutrients (Khalid et al., 2022). Moreover, Heidari et al. (2018) studied the impact of nano Fe-chelated plant growth-promoting rhizobacteria (PGPR) on maize growth, grain yield, and physiological responses. They found that the maize plant growth and yield improved due to the foliar application of nano Fe. Bakhtiari et al. (2015) stated that the plants growing mainly in high pH and calcareous soils, Fe deficiency is a widespread nutritional problem. This problem might be resolved if the foliar application of Fe compounds with the technology of nano would be applied.

Bozorgi (2012) investigated the effects of foliar application with nano iron chelate fertilizer (0 g.L⁻¹ (control), 1, 2 g.L⁻¹) on fruit yield and several attributes of eggplant (*Solanum melongena* L.). The findings of the data analysis demonstrated that the application of nano iron chelate fertilizer had a substantial impact on all of the analyzed parameters (fruit yield, number of fruits produced per plant, number of branches per plant, length and width of the fruit) at the maturity stage. Additionally, foliar application of 2 g.L⁻¹ with 37.11 tons.ha⁻¹ was noted as the maximum amount of the eggplant fruit yield among nano iron chelate fertilizer doses.

Mamyandi et al. (2012) experimented to evaluate the effect of (0, 1, 2, and 3 mg.L⁻¹) Nano-iron on growth and some biochemical characteristics of sugar beet (*Beta vulgaris*) plants at different growth stages (20, 40, 60, 80, and 100 % of ground cover). The authors mentioned that the time (growth stage) of spraying the nano-iron significantly affects the root diameter, leaf length, and leaf width. Moreover, the length of the sugar beet peduncle was strongly influenced by the interaction effect between nano-iron content and stage of Fe spraying. Nano-iron spraying at 60% of ground cover obtained the highest value of the root diameter (14.3 cm) and leaf width (8.5 cm). On the other hand, at 20% of ground cover, the plants treated by 0.003 and 0.001 g.L⁻¹ titter produced the longest (16.17cm) and shortest (7.83cm) peduncle, respectively.

Armin et al. (2014) tested three application times (tillering, stem elongation, and tillering+stem elongation) and four concentrations of Nano-Fe application as spraying (0, 2, 4, and 6 as corresponding with 0, 2, 4, and 6 kg Fe/ha water-soluble Fe (Nano-Fe Chelates) on wheat (*Triticum aestivum*). The results showed that the timing of application had a

substantial impact on the tiller's number, seeds per spike, grain production, biological yield, and thousand grains weight. Spraying Fe during tillering+stem elongation and in the tillering had, respectively, 9.17% and 5.19% higher grain productivity than the foliar treatment of Fe at stem elongation. Wheat yield and its components increased with increasing of Nano-Fe concentration. The authors stated that the maximum grain yield was produced in the plants which sprayed with the 4 concentration. An increase of 12%, 22.09%, and 19.07% grain yield was produced, respectively, when plants foliar treated with Fe at 2%, 4%, and 6% compared to control plants.

Bakhtiari et al. (2015) experimented with two treatments: time of spraying iron two levels (13 days interval) and concentration of Fe Nano-oxide solution in five levels (0, 0.01%, 0.02%, 0.03%, and 0.04%) on wheat. The authors found that the time of spraying and Fe-concentration significantly affected all measured characteristics. The highest values of 1000 grain weight (36.10 g), spike weight (614.88 g), grain yield (3639.5 kg.ha⁻¹), biologic yield (8830 kg.ha⁻¹), and content of protein (16.01%) were detected in the first spraying time. Among the Fe concentrations, the 0.04% Fe concentration achieved the highest values of grain yield (3776.5), spike weight (666.96 g), biologic yield (8895.0 kg/ha), 1000 grain weight (37.96 g), and protein content (16.44%), in comparison to control (which determined the lowest values).

In their 2015 study, Ghafari and Razmjoo examined the effects of spraying durum wheat plants with nano-iron oxide (2 and 4 g.L⁻¹), iron chelate (EDTA 4 and 8 g.L⁻¹), iron sulfate (4 and 8 g.L⁻¹), and a control. Activities of all leaf enzymes and chlorophyll of leaf, protein of grain, concentrations of iron and carbohydrate, carbohydrate of grain, protein, and productivity of grain increased in a response to the iron foliar application. Application of 2 g.L⁻¹ of Nano iron oxide produced the highest concentration of chlorophyll, yield of grain, grain iron (38%) and contents of protein (58%), protein, carbohydrate yields, and iron, then followed by 8 g.L⁻¹ iron sulfate. Moreover, chlorophyll, grain iron, grain yield, harvest index, 1,000 gain-weight, protein contents, and carbohydrate yields all went up. However, these qualities are diminished when nano-iron oxide is used at higher doses. The authors advised foliar application of 2 g.L⁻¹ nano-iron oxide for durum wheat production since it was more effective than other Fe sources and rates.

Rezapour-Osalou et al. (2015) performed in an experimental field to study foliar application nano Fe_3O_4 performed at corn plants. Post-harvest corn seeds were soaked in water, germinated, and dried to determine iron content and phytase activity. The results revealed that the quality of corn seeds was enhanced because of using nano iron oxide fertilizers. Improving maize seed quality might be linked with decreasing phytate content and increasing Iron concentrations.

Roosbahani and Mohammadkhani (2015) conducted a factorial farm experiment, in Damavand to investigate the effect of vermicompost and Nano iron fertilizer on maximizing the yield of grain corn (*Zea mays* L.) plants. The first factor of vermicompost in two levels including control and applying vermicompost (5 ton.ha^{-1}) and the second factor of nano fertilizer of iron levels including control, applying of fertilizer as seed covered, foliar application. The result showed that except for the number of rows per silk, all traits were significantly affected by applying Vermicompost and iron nano fertilizer. Means comparison showed that traits such as the height of the stem, the number of rows per silk, the number of seeds per row, seed 1000 weight, grain yield, biological yield, and harvest index significantly increased by applying vermicompost and iron nano-fertilizer. Interaction effects of vermicompost and iron nano fertilizer were significant for stem height, and yield. In conclusion, using the vermicompost with iron nano fertilizer as seed covered and foliar application caused to reach the best result for investigated traits.

Shahrekizad et al. (2015) conducted experiments to study the effect of spray or soil amendment on the EDTA-grafted iron oxide nanoparticles Nano- Fe_3O_4 -EDTA and Fe-EDTA fertilizers on agronomic traits of sunflower (*Helianthus annuus*) plants. The results showed a largely prevailing impact of Nano- Fe_3O_4 -EDTA fertilizer on various of the studied factors such as dry biomass of the aerial organ (stem and leaves), number of leaves, and plant heights. Additionally, higher plant chlorophyll concentrations resulted after treatment with all fertilizers compared with the control. The use of nano-Fe-EDTA fertilizer significantly improves the content of Fe in plants, which is a promising strategy for preventing iron deficiency. It was also observed that the effects of the fertilizer on soil amendment are more pronounced than those of the foliar application. However, only some areas, such as aerial organ biomasses, can benefit from the foliar treatment.

To grow *Moringa peregrina* plants, Soliman et al. (2015) used four different salinity levels (0, 3000, 6000, and 9000 mg.kg⁻¹), as well as foliar sprays of Hoagland solution containing various concentrations of ZnO and Fe₃O₄ Nanoparticles (NP) (30, 60, and 90 mg.L⁻¹); the standard Hoagland solution served as a control. When compared to a control plant that had been treated with Hoagland containing ZnO and Fe₃O₄ NP in either normal or saline conditions, moringa plants demonstrated improved growth characteristics. Also, spraying plants with Hoagland-containing ZnO and Fe₃O₄ NP resulted in a statistically significant increment in total chlorophyll, carotenoids, crude protein concentrations, proline, carbohydrates, antioxidant non-enzymes and enzymes, and some minerals (N, P, K⁺, Ca²⁺, Mg²⁺, Fe, Zn), while a reduction in Na⁺ and Cl⁻ when compared to control, treated by normal Hoagland plants.

Jalali et al. (2016) studied maize plants (*Zea mays* L. cv. Merit) grown in calcareous soils with and without Fe₃O₄ nanoparticles (NPs) at 100 µg Fe/g and ethylenediamine-N,N-bis(2-hydroxyphenylacetic acid) iron-sodium complex (Fe-EDDHA), in different growth stages. Treatment with iron enhanced maize photosynthesis and the ability to scavenge hydrogen peroxide and superoxide anions and decreased membrane lipid peroxidation rates. Moreover, vegetative growth accelerated and caused the earlier entrance to the reproductive stage because using of iron treatment. The difference between the enhancement effect of Fe-EDDHA and Fe₃O₄ NPs was particularly pronounced at the reproductive stage. With the use of Fe₃O₄ NPs, the rise in calcium, Fe²⁺, total Fe, and ferritin levels was more noticeable (164%, 200%, 300%, and 200% of the control, respectively). The increased ferritin and its critical role in preserving Fe homeostasis and the balance of the plant redox system were partly responsible for the better growth of maize treated with Fe₃O₄ NPs.

Janmohammadi et al. (2016) studied the effect of treating barley plants with chelated nano-scale ferric oxide (Fe₃O₄) suspensions during the tillering stage, booting, and milky stages. The days to anthesis and maturity were found to have greatly increased. Furthermore, a considerable improvement was observed in the size of the grain, length of the spike, grains number per spike, the concentration of chlorophyll, harvest index, and grain productivity by application of nano-fertilizer. The results showed that using nanotechnology into fertilizer products might boost the effectiveness of fertilizer use and greatly increase barley yield.

However, the concentration and time of application of nanoparticles play a crucial role in plant response as well as the size, shape, and surface functionalization of the particles.

Joshan et al. (2016) studied the effects of foliar application with various doses of iron nanoparticles (0, 0.01%, 0.03%, and 0.05%) on the physiological and biochemical characteristics of forage maize (*Zea mays* L.) at different growth stages. The results showed that iron nanoparticles at different foliar application doses had significant effects on physiological factors such as ear and seed dry weight, but had more significant effects on leaf total soluble solids content, pigments (carotenoids, chlorophyll) and other biochemical properties. a and b), soluble leaf protein and peroxidase. Furthermore, the highest values for seed dry weight (710 g), chlorophyll a (2.85), chlorophyll b (0.51), carotenoids (0.88) and peroxidase (4.82) were due to the use of the highest dose of iron nanoparticles (0.05%). The use of 0/03% iron nanoparticles had the greatest effect on ear dry weight at 1120 g. In this regard, 0.01% of iron nanoparticles were produced when the leaf's total soluble solids (34.4) and soluble leaf proteins (4.24) were at their maximum levels.

Rui et al. (2016) investigated the effects of Fe₃O₄ NPs and chelated fertilizers (EDTA-Fe; EDTA-Fe) on the growth and development of peanut plants (*Arachis hypogaea*) in pot experiments. The results showed that the root length, plant height, biomass and SPAD value of peanut plants increased after the plants were treated with Fe₂O₃ NPs. Enhancing peanut growth by using Fe₂O₃ NPs may be linked with the role of nano iron in regulating the concentration of phytohormone and the activity of the antioxidant enzymes. The control group recorded the lowest level of Fe contents in peanut plants in comparison to Fe₂O₃ NPs and EDTA-Fe treatments. Taken together, these results suggest that Fe₂O₃ NPs can replace conventional Fe fertilizers in peanut crop cultivation.

Saedpanah et al. (2016) foliar sprayed forage maize (*Zea mays* L.) by nano-fertilizers Fe, Zn, K, NPK at the rates of 2 g.L⁻¹ and control (without fertilizers). Results showed that application of nano iron chelate increased leaf chlorophyll by 29%, 20%, 20%, and 16% compared with control, NPK, potassium, and zinc respectively. The lowest leaf chlorophyll belonged to the control treatment (44.38). Moreover, the highest and lowest plant height belonged to nano iron chelate (2.90 m) and control (2.35) treatments, respectively. The highest leaf dry weight was obtained in nano iron chelate treatments.

Seed soaking and foliar application with micro-nutrient iron (both nano and chemical) can be generally recommended as value-added management practices to improve plant growth and harvesting of soybeans are among the outcomes of the study by Sharifi et al (2016). Results indicated that both iron fertilizer types enhanced the concentration of leaf chlorophyll compared to other treatments and control. The nano-iron spraying treatment produced the highest levels soluble carbohydrates and soluble phosphorus concentration compared to other treatments. The phosphorus concentration, biomass, and concentration of the crude protein and soluble carbohydrate were increased as a result of the application of nano fertilizers, in comparison to chemical forms of fertilizers,

Askary et al. (2017) study's was aimed at exploring the effect of different dose levels of Fe_3O_4 nanoparticles (Fe_3O_4 NPs) on the physiological characteristics of peppermint (*Mentha piperita*) under salinity stress. The treatments of Fe_3O_4 NPs at the three different levels also increased the level of chlorophyll A and B. The levels of minerals (calcium, phosphorus, potassium, zinc, and iron). The results suggest that for stress resistance of the peppermint plant, a suitable dose of iron nanoparticles could be used.

Elanchezhian et al. (2017), the results of a study that compared maize plants fertilized with the suboptimal dose of Fe in the macro form (salts) to the optimal recommended dose of Fe in the nano form (54 M) revealed an improvement in morphological features, such as biomass (shoot and root), plant height, and the optimal concentrations of antioxidant enzyme activities are decreased.. However, plant leaf area and its content of proline positively influenced when half of the recommended dosage of Fe (27 μM) was used. This refer that it might reduce the supplementary dose of Fe for plants in the nano-form to enhance the nutrient use efficiency in the main grain crop like maize.

Fathi et al. (2017) evaluated the effects of two forms of normal and nanoparticles of 2 g.L⁻¹ iron oxide (Fe_2O_3) and zinc oxide (ZnO) on two wheat (Kavir and Tajan) genotypes at three levels (0, 75, and 150 mM) of salinity as NaCl in a pot experiment. Both Fe_2O_3 and ZnO forms significantly promoted the concentration of iron (Fe) and zinc (Zn), morphological traits such as shoot dry weight, plant height, and leaf area in comparison with non-spray treatment. The highest plant height and concentration of Fe leaf were detected when using the Fe_2O_3 nanoparticles.

Jalali et al. (2017) treated maize plants with or without 100 mg.kg⁻¹ Fe-NPs and 100 mg.kg⁻¹ Fe-Ch, and their seeds were planted to examine the second generation. In the second generation, the treatment with or without 100 mg.kg⁻¹ of iron chelate (Fe-Ch) or iron nanoparticles (Fe-NPs) was repeated, and the outcomes of both generations were compared. When plants were treated with Fe-NPs in comparison to the control and treatment with Fe-Ch, maize photosynthesis and hydrogen peroxide (H₂O₂) scavenging capacity improved and the rate of membrane lipid peroxidation decreased in the first generation. Moreover, the impact of Fe-NPs treatments on the improvement of contents of calcium, Fe²⁺, total iron and ferritin was clearer. The second generation of Fe-NPs-treated plants showed reduced biomass, chlorophyll, protein, and calcium contents, as well as a decreased capacity to scavenge H₂O₂, compared to the control and the first generation plants, although having a higher total iron content.

Konate et al. (2018) used nano- and bulk-iron oxide (Fe₃O₄) treatment on hydroponic cucumber plants (*Cucumis sativus*) (50, 500, and 2,000 mg.L⁻¹) over a 21-day period at a higher nano- Fe₃O₄ dose of 2000 mg.L⁻¹, biomass and the antioxidant enzymes superoxide dismutase (SOD) and peroxidase (POD) both significantly improved. However, at the low concentration (50 mg.L⁻¹) compared to the control, reduction of biomass and enzyme activities resulted due to nano- Fe₃O₄ use. On contrary, the treatment of bulk-Fe₃O₄ at a high concentration caused phytotoxicity in terms of biomass and enzyme activity.

Jayarambabu et al. (2018) looked into how biogenic iron oxide nanoparticles (Fe₃O₄ NPs) affected maize productivity and quality parameters. When compared to the control, the results demonstrated that pretreatment sowing of maize with Fe₃O₄ NPs at a dose of 0.3 mg increased yield and germination by 10% and 20%, respectively. Similarly, after the Fe₃O₄ NPs pretreatment planting, there was an increase of 20% in cob weight, 10% in average tassel length, and 15% in average plant height compared to control. Therefore, the present study showed that the 0.3 mg Fe₃O₄ NPs dose resulted in an enhancement of productivity and seed quality characters of maize under field conditions.

Sheykhabaglou et al. (2018) conducted an experiment to determine the impact of spraying five concentrations of ferrous nano-oxide (nano-Fe₂O₃) particles (0.5, 0.75, 1 g.L⁻¹) on the nutritional compounds of soybean (*Glycine max* L.) seed was repeated three times at

the 4 and 8 leaf stage as well as the beginning of the pod. Using a solution containing ferrous nano-oxide particles had a significant impact on soybean seed's nutritional compounds in comparison to the control. In comparison to the control, which produced the lowest content, using 0.75 g.L⁻¹ of ferrous nano-oxide produced the highest levels of fat and protein (25.4 and 33.8, respectively). Similar to the growth in lipid and protein levels, the profile of fatty acids (palmitic, oleic, linoleic, and linolenic acids), the amount of chlorophyll, and several mineral elements (Fe, Mg, Ca, and P) increased when ferrous nanooxide concentration rose from 0 to 0.75 g.L⁻¹. From 0.75 to 1 g, the concentration, however, decreased all parameters. The application of 0.75 to 1 gram was concluded by the authors. The L⁻¹ ferrous nano-oxide had the greatest impact on the soybean seed's nutrient composition.

De Souza et al. (2019) examined the effects of two different concentrations of Fe₃O₄ nanoparticles (NPs) on the chemical composition of the soil rhizosphere and the accumulation of nutrients in common bean plants. Due to the use of both nanoparticle doses, the total content of P, K, Ca, Mn, and Fe in the roots, stems, and leaves increased significantly, indicating a significant increase in the accumulation of nutrients in plants. The increased capacity of Fe₃O₄-NP-treated plants' roots, stems, and leaves to absorb nutrients suggests a beneficial effect on plant health and development. Similarly, compared with the control plants, the plant's roots were treated with Fe₃O₄ NPs intake and accumulated the greatest quantities of Mn and Fe nutrients.

Hoang et al. (2019), before sowing, zero-valent metal nanoparticles (Cu, Fe, and Co) were applied to maize seeds. The treated plants experienced significant improvements in their germination rate and early growth. Additionally, the metabolism of superoxide and the improved activities of the leaves' APX and SOD enzymes increased plant drought resistance.

Hussain et al. (2019) applied five doses of Fe NPs (0, 5, 10, 15, and 20 mg.kg⁻¹) via soil and foliar application to wheat (*Triticum aestivum*) plants in a pot experiment in soil that had previously been contaminated with Cd. After growing for 125 days, the plants were harvested. The photosynthetic pigments, morphological parameters, and wheat dry biomass of the shoots, roots, spike husks, and grains of the exogenously treated plants were enhanced by Fe NPs. Although the activities of superoxide dismutase and peroxidase increased, EL

decreased from wheat leaves compared to control. The Fe concentrations of wheat tissues and grains rose with Fe NPs application in a dose-additive manner.

Mahmoud et al. (2019) looked at how Zn and Fe oxides in green synthesized nanoparticles (GNPs) affected the growth characteristics, photosynthetic capacity, and nutritional quality of red radish (cv.Champion) participated in two field tests. Some treatments were: chicken manure combined with ZnO + FeO (GNPs) applied to the leaves at a rate of 60 and 50 mg.kg⁻¹, respectively. This study revealed that ZnO + FeO nanoparticles application caused a significant increment in the morphological and productivity of radish plants. The plants treated with ZnO + FeO (GNPs) gave the maximum root quality (diameter and weight), pigments of a plant leaf, and vegetative growth in nanoparticle application alone or combination with chicken manure.

Rizwan et al. (2019) primed the wheat (*Triticum aestivum*) seed with either nanoparticles zinc oxide (ZnO) (ZnO NPs 0, 25, 50, 75, and 100 mg.L⁻¹) or iron (Fe) nanoparticles (Fe NPs 0, 5, 10, 15, and 20 mg.L⁻¹). Morphological traits i.e. dry weights of (shoots, roots, spikes, and grains), plant height, and spike length were improved with NPs, particularly with the higher doses. The results depicted that photosynthesis of wheat which was treated by NPs positively affected as compared to the control. Both the ZnO and Fe NP concentrations in grains, roots, and shoots were increased when ZnO NPs were applied. In general, the NPs are essential to the rise in wheat biomass and nutrients.

Al-Amri et al. (2020) used nanomaterials made of iron (III) oxide (Fe₂O₃) on hydroponically grown wheat plants. Wheat treated with Fe₂O₃ NMs showed an improvement in root length, biomass, plant height, and chlorophyll content. In NMs treated plant tissues, the content of iron was found to be significantly increased, which probably participated in the growth improvement.

Al-Shaheen et al. (2020) experimented with the Glass House in the 2016-2017 year to evaluate spraying five levels of nano-iron (0, 25, 50, 75, and 100 mg) and the yeast extract at three levels (0, 100, and 150 g.L⁻¹) on maize productivity. The outcomes revealed that the nanoparticle treatments recorded the highest ratio of seed protein, chlorophyll content, and seed oil percentage. Similarly, spraying the plants with dry yeast extract gave a significant increment in the studied characters. The compounds of 60 grams and 100 milligrams of

nanoiron. When compared to other treatments, L^{-1} dry yeast extracts are distinguished by having the highest chlorophyll content, the highest oil content in seeds (in percent), and the highest protein rate in seeds (in percent).

Hasan et al. (2020) investigate the response of iron oxide nanorods (NRs) on summer maize (*Zea mays*). Authors found that iron NRs have shown a significantly enhanced content of total chlorophyll and nitrate by 80% and 6%, the number of leaves per plant (26%), and leaf area (13%) with biologically synthesized NRs. Additionally, the treatment with NRs caused plant anti-oxidative activity to increase due to their ability to create a complex with metal ions.

Kasivelu et al. (2020) studied the effects of nano iron ($\gamma\text{-Fe}_2\text{O}_3$) and zinc (ZnO) on morphological, crop yield, and absorption mechanism of rice (*Oryza sativa*) and maize (*Zea mays* L) plants. Results found that at the 500 mg.kg^{-1} of nanoscale $\gamma\text{-Fe}_2\text{O}_3$ treated in rice and maize, the biggest percentage of seed germination (100 %) and index of seedling vigor (27500 & 36500) were noticed for rice and corn, respectively. The results of field investigations showed that yield components i.e. yield (kg.ha^{-1}), 1000 grain weight, total grain weight (g/m^2), and seed (length, thickness, and width) were greatly enhanced by the spraying of (500 and 750 mg.kg^{-1}) nano $\gamma\text{-Fe}_2\text{O}_3$ and ZnO, respectively in rice and maize plants.

Sajyan and co.2020) looked at how Nano-chelate Super Plus ZFM (A) and Lithovit®-standard (B) affected the salt-stressed chili pepper individually and collectively. Each substance was administered in two distinct doses (A1, 2.5 g.L^{-1} , A2, 5 g.L^{-1} ; B1, 3 g.B2 and L^{-1} , 5 gramsL^{-1}), irrigated with three NaCl solutions on pepper. Zinc, manganese, and iron content in shoots and fruits significantly increased at a low dose of Nano-chelate Super Plus ZFM in (A1). While the elevated concentration of Lithovit®-standard enhanced the magnesium and calcium concentrations in plant parts, At the A1B2 dose, the number of plant parts and their fresh and dry weights increased the most. In addition, it significantly increased the plant yield, number of fruits, fruit fresh and dry weight, and fruit dimension in comparison to the control at all NaCl concentrations. All treatments reduced the amount of sodium and cellular electrolyte leakage in comparison to the control, while increasing the amount of carotenoids. Chlorophyll a, b, and total chlorophyll (TChl) concentrations increased more

under a low dose of Nano-chelate Super Plus ZFM than under a high dose (A2). A1B2 also promoted the development of photosynthetic pigments. When plants were treated with A1B2 and A1B1 in comparison to a control at all salinity levels, the content of most nitrogen and potassium increased in shoots and fruits, respectively.

Yan et al. (2020) investigated the compounds between Fe_3O_4 NPs and maize (*Zea mays*) plants grown in soil treated with (0, 50, and 500 mg/kg) Fe_3O_4 NPs for four weeks. As a result, reduced malondialdehyde (MDA) levels resulted in a considerable increase in root length in maize plants, demonstrating the beneficial impacts on membrane integrity and root development. It is revealed that Fe_3O_4 NPs led to a significant accumulation of the Fe in roots. Additionally, the dose of 500 mg/kg of Fe_3O_4 NPs markedly increased the activity of the dehydrogenase enzyme by 84.9%. Furthermore, the metabolic pathways connected to antioxidants and defense that Fe_3O_4 NPs inactivate play a protective role for microorganisms and plant roots, according to the authors.

Farshchi et al. (2021) studied the impact of foliar application of the Fe-nanoliposome (Fe-L) in two doses (2.5 and 5-fold diluted) on vegetative growth, the ferrous/total Fe content, and attributes of essential oil of sweet basil (*Ocimum basilicum* L.) plants grown in pots with calcareous loamy soil (pH ~ 7.6) in a greenhouse. As well, in the comparison, FeSO_4 -EDTA and a vehicle (citrate buffer) were both used. Egg-derived phosphatidylcholine (EPC)/Fe-liposomes enhanced total leaf area, increased the fresh and dry weight, and improved the content of ferrous, chlorophyll, and essential oil of the plants in comparison to the FeSO_4 fertilizer. Overall, Fe-liposomes are superior to FeSO_4 -EDTA in terms of Fe delivery and plant recovery.

Li et al. (2021a) conducted a field experiment to explore the effects of foliar spraying of (20–50 mg.L^{-1}) Fe_3O_4 nanoparticles (NPs) on *Pseudostellaria heterophylla*. Results showed that a significantly improved growth, and the dry matter distribution of root and root tuber yield per unit area were detected in the Fe_3O_4 NPs (20-50 mg.L^{-1}) treated plants. Fe_3O_4 NPs caused increasing chlorophyll content and in consequence, enhanced net photosynthetic rate (P_n). As well as by improving nonstomatal restriction, Fe_3O_4 NPs boosted P_n 's daily mean and peak values and reduced the "midday depression" phenomena. Chlorophyll fluorescence metrics show that Fe_3O_4 NPs enhanced the photochemical usage of surplus

excitation energy, which boosted PSII's photochemical activity and qualified photoinhibition. Moreover, Fe₃O₄ NPs improved the *P. heterophylla* high temperatures and strong light tolerance by improving the adaptability of photosynthesis to those abiotic stresses. Additionally, the polysaccharide content of the root tuber in the Fe₃O₄ NPs sprayed plants.

Li et al. (2021b) compared hydroponic the physiological effects of three different types of Fe-based NP: zero-valent iron (ZVI), Fe₃O₄, and Fe₂O₃ NPs on rice for 2 weeks after root exposure. Researchers compared the Fe-normal (Fe (+)) and Fe-deficient (Fe (-)) conditions. The results demonstrated that rice growth under typical conditions was enhanced by a low dose (50 mg.L⁻¹) of ZVI and Fe₃O₄NPs. None of the Fe-based NPs had a beneficial effect on the rice plants under Fe-normal conditions; above 500 mg, plant development was impeded. L⁻¹ was demonstrated by decreased root volume and leaf biomass, but increased oxidative stress in the plants. Under normal Fe conditions, a low dose (50 mg.L⁻¹) of ZVI NPs and Fe₃O₄ NPs promoted the concentration of chlorophyll by 30.7% and 26.9%, respectively.

Manzoor et al. (2021) applied iron oxide nanoparticles FeO-NPs for co-alleviation of salt stress in wheat plants. As a result of lessening the negative effects of salinity and reprogramming the morphophysiological state of wheat plants, the application of 100 mg.kg⁻¹ of the bioengineered FeO-NPs under salinity soil conditions promoted the growth of the wheat plant, which increased in length by 36.7% in comparison to the control group. In addition, with the presence of FeO-NPs in soil, the wheat grain contents of the nutrient concentrations of N, P, and K⁺ significantly increased, while the Na⁺ and Cl⁻ were reduced.

Prerna et al. (2021) have used iron NPs as a priming agent on rice and maize crops for enhancing seed germination percentage, physiological, and yield characters. Seeds primed with Fe-NPs at 25 mg.L⁻¹ markedly improved the rate of germination of seed and seedling parameters compared to traditional priming. Rice and maize seeds with nano-primed coatings produce more ROS during germination than seeds with traditional hydro-priming. Under field conditions, foliar application of low dose (10 mg.L⁻¹) iron NPs significantly promoted the rice and maize crops' chlorophyll content and components of yield.

Solimanazadeh and Fekri (2021) assessed the impacts of green Fe NPs on Fe availability in calcareous soils on sorghum (*Sorghum bicolor* L. Moench) plants. The authors

pointed out that the Fe NPs application resulted in an increase in growth, Fe absorption, and sorghum plants' photosynthetic pigment contents.

Khalid et al. (2022) compared the impacts of synthesized nanoparticles (NPs) with the control plants and their traditional fertilizers i.e. $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ (Zn-bulk), $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ (Fe-bulk), and $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (Mg-bulk) on the (*Caesalpinia bonducella*) plants. In comparison to control plants, the results showed that applying NPs and traditional fertilizers boosted the plants' morphological parameters by 28–50% and 50–93%, respectively. For the chlorophyll contents, the increment was 5–28% and 30–80% with conventional fertilizers and NPs application respectively in comparison to control plants. The results collected show that the dose of 40 mg.kg^{-1} for Mg and Fe fertilizers and 100 mg.kg^{-1} for Zn fertilizers recorded the highest increase in growth, contents of nutrients, and chlorophyll in plants.

2.3. Effect of Active Dry Yeast on Plants

All over the world, using natural and safe environmental substances is a lofty target to enhance the quantity and quality of plants (Dawood et al., 2013). The use of bio/organic fertilizers is increasing all over the world for environmental and human health safeguard purposes, which has become endangered as a result of the excessive use of chemical fertilizers and pesticides (Agamy et al., 2013). Bio-stimulants influence plant metabolism if used in low concentrations through the prompting of natural plant growth regulators driving and vigor, reinforcement of nutrient absorption, enhancement of root growth, and increasing resistance to stress as abnormal conditions. In addition, these materials could be used as systemic agents when they are applied as foliar application (Hassan et al., 2020). Yeast extract provides benefits over traditional plant growth regulators and soil conditioners, including being ecologically friendly, bioactive, nourishing, safe for humans, and practical to use (Agamy et al., 2013; Xi et al., 2019). Yeast *Saccharomyces cerevisiae* extract, which is plant nutritious as well as environmentally friendly, and convenient to use, has a feature over common plant growth regulators and soil conditioners (Xi et al., 2019) and includes natural plant hormones i.e., free and associated IAA, free GA3 and associated GA3 (Tawfiq, 2010) and vitamins, amino acids, necessary macro and micronutrients for plant growth, and

growth stimuli such as Cytokinins (Medani and Taha, 2015) and it is counted as a natural source of bio-stimulants that motivate some enzymes, cell expansion and division, synthesis of pigments, and nucleic acid and protein formation (Wanas, 2007) and also it releases CO₂ which leads to improvement of photosynthesis (Kurtzman and Fell, 2006).

El-Tohamy and El-Greadly (2007) conducted the experiments under sandy soil conditions to investigate the effects of foliar application of (0, 5, and 10 g.L⁻¹) yeast on snap bean (*Phaseolus vulgaris* L.) plants. The results showed that foliar application of yeast treatment especially at the higher doses markedly improved vegetative growth (plant fresh weight, plant height, and leaves number) and yield (pod length, pods fresh weight, and pods number) of bean plants compared to control. Additionally, the yeast treatment resulted in a higher total content of the chlorophyll of leaves as compared to the control. For the hormonal changes in response to the yeast treatment, there were significantly the highest contents of cytokinin, IAA, and GA3 in the leaves. Moreover, the authors showed that the treatments by yeast significantly increased plant concentration of N, P, and K.

El-Tohamy et al. (2008) conducted under sandy soil conditions the experiments to investigate the physiological responses, growth, and productivity of eggplant (*Solanum melongena* L.) to the foliar application of (0 as control, 5, and 10 g.L⁻¹) yeast under such sandy soil conditions. In comparison to control plants, yeast treatments produced the best outcomes in terms of plant growth and yield. The vegetative growth (plants fresh weight, plant height, and leaves and branches number per plant) and productivity of eggplant dramatically increased in plants foliarly treated by yeast compared to control plants. The amount of cytokinins in eggplant leaves was enhanced by all treatments. Plant leaves' N, P, and K contents significantly increased after the yeast treatments.

Mady (2009) evaluated the effect of foliar application with yeast extract (25 and 50 ml.L⁻¹) on the growth and productivity of faba bean (*Vicia faba* L cv. Giza 3) plants. Results revealed that foliar application of yeast extract at 75 and 95 days after sowing during the two years significantly increased various morphological traits such as the number of leaves per plant, dry weights of both stems and leaves per plant, and total leaf area as well, as compared with the control plants. Chemically, at 75 and 95 days after sowing of the plant life cycle, spraying of yeast on faba bean at 50 ml.L⁻¹ dose increased leaves contents of total sugars,

photosynthetic pigments, total free amino acids, N, P, K, Zn, and crude protein. In addition, Yeast treatment lowered the inhibitor one ABA (abscisic acid) and boosted endogenous phytohormones (Auxins and cytokinins). Although all treatments increased i.e., set pods per plant and formed flowers number, percentage shedding of both flowers and immature pods per plant decreased, consequently, it changed as plant pod weight per plant and seed output overall increased.

Ezz El-Din and Hendawy (2010) studied the effect of various concentrations of dry yeast on borage (*Borago officinalis*) plants. The results pointed out that using the dose of 6 g.L⁻¹ of dry yeast gave the best value of the growth parameters (plant height, shoot fresh and dry weight, and flowers and number of branches and suckers) and oil%.

Ghoname et al. (2010) carried out an experimental trial in two successive years to investigate the enhancing effects of Yeast (1, 2, and 3 g.L⁻¹) on the growth and yield of sweet pepper plants (*Capsicum annuum* L. cv. California Wonder). The applied concentration and the response of the plant growth parameters to the yeast treatment were correlated positively. Data showed that all applied yeast concentrations increased vegetative growth of the plant i.e., fresh and dry weights, number of leaves and branches, and plant height. Moreover, the fruits number per plant and weight of individual fruit were improved.

Ahmed et al. (2011) conducted two field experiments during the two winter years to investigate the response of potato plants (*Solanum tuberosum* L. cv. Valor) to the effects of foliar application of (0, 1, 2, 3, 4, and 5 g.L⁻¹) yeast. Results showed that with increasing dry yeast concentration from zero to 5 g.L⁻¹, in terms of leaf area per plant, plant length, stem and leaf number per plant, and fresh and dry weight of the entire plant, the vegetative growth characteristics of potato plants improved. In addition, the productivity of potato plants gradually rose as yeast concentrations were raised. Also, potato tubers' quality in terms of specific gravity, starch, protein, and dry matter contents as well as concentrations of N, P, K, and Zn showed a good improvement as a response to various doses of yeast.

Nassar et al. (2011) performed field experiments to study the effect of foliar application of different doses (25, 50, 100, and 150 ml.L⁻¹) of active yeast extract (AYE) on kidney bean (*Phaseolus vulgaris* L. cv. Giza 6) plants. The results showed that foliar application of active yeast extract at a median used concentration of 50 ml AYE/L and the

relatively high concentrations of 100 and 150 ml AYE/L significantly improved both morphological growth characters (shoot dry weight per plant, plant height, leaves and branches per plant, and total leaf area per plant) and productivity ones (pods and seeds per plant, seed yield per plant, green pods yield per plant, and the seeds crude protein content).

Sarhan et al. (2011) experimented with the plastic house to determine the effect of 6 g.L⁻¹ bread yeast on cucumber (*Cucumis sativus* L. C.V. Shadi). The findings demonstrated that, in comparison to untreated plants, bread yeast spraying resulted in a positive significance of shoot parameters (plant height and total chlorophyll content) and all yield traits.

Abdel-Hakim et al. (2012) planted snap bean (*Phaseolus vulgaris* L. cv. Poulista) plants with foliar sprayed with different concentrations of yeast (4, 8, and 12.0 g.L⁻¹). The results showed that both low and high quantities of yeast promoted growth (plant height, NO. branches/plant, plant fresh and dry weights), yield and yield components (pod length and average pod weight/plant) in addition to the chemical makeup of fresh or dried plants, and green pods (N, P, and K %).

Abou EL-Yazied and Mady (2012) sprayed different doses of yeast solution (0, 2.5, and 5 ml.L⁻¹) on broad bean (*Vicia faba* L. cv Super Aquadulse) in a field experiment. Results revealed that foliar application of yeast solution markedly promotes various growth parameters as plant height, both stems and leaves dry weights per plant, plant leaves numbers, total plant leaf area, and rate of absolute growth in comparison to control plants, where the concentration of 5 ml.L⁻¹ was the most favorable. Moreover, When compared to various yeast doses over the course of the two years, the concentration of 5 ml.L⁻¹ considerably produced the largest quantities of carotenoids and chlorophyll a, b. Authors noticed that foliar application of 5 ml.L⁻¹ yeast solution was superior in improving the mineral values (N, P, K, and B) and bio-constituents (total sugars, total free amino acid, crude protein, auxins, and cytokinins), yet, abscisic acid was decreased when compared with control plants.

Al-Tawaha and Ababneh (2012) treated soybean plants with different doses (1, 2, 3, and 4 mg.ml⁻¹) of yeast extract at two stages of development [early podding (R3); and mid podding (R4). All applied treatments improved the soybean seed yield when compared to control untreated plants. The 2 mg.ml⁻¹ dose of the foliar application of yeast extract at the

R3 stage recorded the greatest seed yield with an increment of 25% compared to the untreated control. This increase in seed yield was due to increases in seeds per pod, plant pod numbers, and 1000 seed weight.

Fawzy et al. (2012) carried out two field experiments to study the response of onion plants to foliar spraying of yeast at three rates (1, 2, and 3 g.L⁻¹) on growth, and quality as well as chemical composition. Results revealed that foliar application treatment had positive effects on growth, yield, and quality of that yield as well as on all chemical composition when compared to control plants. Additionally, Giza 20 cv. and foliar sprays of yeast at rates of 1 g.L⁻¹ in the first year and 3 g.L⁻¹ in the second year resulted in the maximum plant height being measured. Also, the highest amount number of leaves and fresh weight of leaves were detected when plants were treated with 3 g.L⁻¹ of yeast compared to control (foliar spray of water). In addition, compared to other treatments, employing yeast at a rate of 3 g.L⁻¹ resulted in the greatest T.S.S values. On the contrary, the lowest value of T.S.S% and Cu mg.kg⁻¹ were recorded by control plants (sprayed with water). The highest growth characteristics are obtained when utilizing yeast at a rate of 3 g.L⁻¹, it may be inferred.

Ibrahim et al. (2012) studied how yeast (*Saccharomyces cerevisiae*) affected the production of sugar beets (*Beta vulgaris* L.) grown in salty calcareous soil. The yield of roots, leaves, sugar, and sucrose content considerably increased after yeast treatments, with increases of 22.1%, 30.4%, 28.4%, and 5%, respectively. The scientists came to the conclusion that the dangerous effects of soil salinity conditions were satisfactorily mitigated by the organic fertilizer.

Shehata et al. (2012) carried out two successive years 2010 and 2011 to study the effect of foliar application of various rates (1, 2, 3, and 4 g.L⁻¹) of yeast on growth, yield, and quality as well as chemical constituents of cucumber (*Cucumis sativus* L) plants. The study's findings demonstrated that foliar yeast spray greatly enhanced cucumber plant height, vegetative growth (fresh and dry weight of leaves and stems, number of leaves), and the quantity and quality of fruits (weight, diameter, and length of fruit). Meanwhile, the dose of 4 g.L⁻¹ of active dry yeast resulted in the best values of Fe, Zn, Cu, and Mn (mg/kg) concentrations in cucumber fruits.

Abbas (2013) studied the effect of spraying with yeast (5 g.L^{-1}) on *Vicia faba* CV. Giza 3 beans plants. The growth of plants was increased. On the other hand, this treatment significantly decreased ABA, while auxins and gibberellins concentrations in treating plant shoot increased. The addition of biostimulants significantly increased concentrations of total carbohydrates, carotenoids, and pigments. Using a biostimulant significantly increased the contents of protein compared with the control. Magnesium, nitrogen, and phosphorus contents significantly increased as compared with untreated.

Dawood et al. (2013) evaluated the effect of exogenous application of 1, 2, 3, and 4% of bread yeast extract on the growth and chemical compositions of soybean (*Glycine max* L. cv. Giza 111) plants. The treatment of 4% yeast extract recorded greatest plant dry weight growth over control. Moreover, at 4% yeast extract, total photosynthetic pigments were significantly increased by 115.3% over control followed by 3% yeast extract that improved the total photosynthetic pigments by (77.9%). At treatments 3 and 4 % yeast extract, the highest significant promotion in yield and yield attributes was achieved, because the weight of the seeds per plant rose over the control by 90.7 and 106.7%, respectively. Additionally, using yeast extracts increased the antioxidant activity of the yielded seeds as well as the contents of carbohydrates, phenolic, protein, oil, and flavonoid.

Mahmoud et al. (2013) tested spraying with yeast extracts at 0, 1%, and 2% on growth, yield, and pod quality of pea (*Pisum sativum* L. cv. Little Marvel). The obtained results demonstrated that all vegetative growth parameters (plant length, leaves and shoots numbers, total fresh and dry weight) were gradually and considerably raised by increasing the concentration of yeast extracts in spraying solution from 0 up to 2%. Moreover, the results clear that, with the increase of the concentration of yeast extracts, the productivity of early and total pods significantly and gradually increased. On another hand, the concentration of yeast extracts in the spraying solution is raised from 0 to 1% up to 2% lead to a gradually and significantly increased pods' physical properties (100 seeds weight, pod length, as well as weight and number of seeds/pod) and chemical constituents i.e. N%, P%, K%, Fe (mg.kg^{-1}) and total protein. The previously described metrics were enhanced and reached their highest value at the highest dose of yeast extracts.

Hammad and Ali (2014) performed pots and field experiments to investigate the effect of foliar spray with biostimulant as 3 and 6 g.L⁻¹ yeast to reduce the negative effects of drought stress on bread wheat (*Triticum aestivum* L. cv. Sakha 94). The obtained results revealed that the application of yeast extracts significantly increased all studied characters of growth, wheat grain quality and quantity, and chemical components (minerals NPK% and uptakes, enzymes activities, total soluble sugars (TSS), total free amino acids (TAA), total carbohydrates (TC), and photosynthetic pigments) at the rate of 6 g.L⁻¹ yeast as compared to untreated plants in both experiments. Most physiological parameters and yield and its components were considerably impacted by the interaction between the studied water stress and biostimulants. Also, It was found that, for all the investigated characters, the application of yeast (6 g.L⁻¹) produced the best outcomes under normal water supply. Additionally, it can be advised to use natural ingredients like yeast to mitigate the effects of drought, which would improve both the productivity and quality of wheat.

Marzauk et al. (2014) conducted two field experiments on broad bean (*Vicia faba* L cv Cyprus) to understand the effect of combined foliar applications of yeast extract (0, 3, and 6 ml.L⁻¹) on growth, yield, and some biochemical constituents. The results showed that 6 ml.L⁻¹ was the concentration that increased plant growth the most, as measured by plant length (cm), the number of leaves and branches, and the fresh and dry weights (g) of the leaves, branches, and entire plant. As well as the number of pods per plant, total pods yield/plant and total yield per (ton/fed.) as well as green pod length, weight, and width in both two years increased with 6 ml.L⁻¹ yeast extract compared to other foliar yeast extract treatments that have been examined and control ones. Moreover, foliar application of dry yeast resulted in slight increases in bread bean seeds content of N and protein %.

Neseim et al (2014) investigated the impact of potassium fertilization doses (50, 75, and 100 kg.Fed⁻¹) and foliar spray of (0, 10, and 14 g.L⁻¹) yeast on vegetative growth, chemical composition, and sugar beet yield as well as its attributes under drought stress. The application of 100 kg.Fed⁻¹ potassium fertilization in combination with 10g.L⁻¹ yeast recorded the highest root yield and white sugar yield, water use efficiency as well, under sufficient irrigation. Authors recommended K dose (75 kg.Fed⁻¹) in combination with yeast

(14 g.L⁻¹) recorded the highest yield, sucrose %, water use efficiency, and the lowest impurities % under drought stress.

El-Nemr et al. (2015) evaluated the effects of applying fertilizer in the stander form in comparison to different bio-stimulators as active dry yeast at rates of 1, 2, and 4 g.L⁻¹ on growth, yield, and quality of eggplant fruits (*Solanum melongena* var. *esculenta* L) Egypt cv. "Black Balady" in field experiments. Data showed that all morphological character parameters of eggplant plants (leaves and branches numbers per plant, plant length, and leaves fresh, and dry weight per plant) were improved by using biostimulator treatments compared to the control non-treated plants. Yield and its components of eggplant plants also followed the same above trend. The high concentration of yeast (4 g.L⁻¹) treatment recorded the highest compared to yeast at 1 g.L⁻¹ and 2 g.L⁻¹ except for the fresh and dry weight of leaves a significant effect on vegetative growth of eggplant plants.

El-Tohamy et al. (2015) tested some morphological, physiological, and productivity characters of sweet potato plants (*Ipomoea batatus* L.) in response to spraying of different doses of 5 and 10 g.L⁻¹ yeast extract under sandy soil conditions. The results revealed that all plant growth parameters (plant height, number of branches, fresh weight of plants, and total yield) and root productivity characters, such as e.g., root length and diameter were improved in response to the treatments especially the high level of yeast. In addition, plants treated with yeast recorded significantly higher roots total soluble solids and leaves content of relative water and total chlorophyll compared to unsprayed plants as control.

Mahmoud et al. (2015) sprayed Manzanillo olive trees (*Olea euroea* L.) two times with (20 and 40 g.L⁻¹) dry yeast extract and (60 and 80 mg.kg⁻¹) benzyladenine at the stage of full bloom and two weeks later. Results showed that the 40 g.L⁻¹ foliar applications of dry yeast extract are recommended for enhancing olive fruit productivity and quality (fruit flesh, fruit and seed weight, percentage of fruit moisture and pulp per seed, and fruit diameter and length) and concentration of oil in olive fruit. Improving the specific leaf dry weight, leaf area, leaf concentrations of total chlorophyll and macro-micro nutrients (N, P, K, Mg, Fe, Zn, and Mn) as well as flowering density, percentage of perfect flowers, and fruit set of the olive may be attributed increase productivity.

El-Shafey et al. (2016) investigated the effects of foliar yeast spraying (5 and 10 g.L⁻¹) on faba bean cultivar growth, yield, and some biochemical components. Morphological growth in faba bean cultivars after 65 and 85 days of sowing significantly increased on plants treated with yeast extract as compared to control group plants. At the age of 65 days, chlorophyll and phytohormone contents resulted from foliar spraying with 10g.L⁻¹ yeast extract increased in all faba bean cultivars. Yield parameters and also the content of seeds from carbohydrates and protein are positively affected by foliar yeast application on plants.

Nassar et al. (2016) investigated adapting the growth of *Leucaena* plants to different levels (2000, 4000, and 8000 mg.kg⁻¹) of saline water in irrigation by foliar application of 100 ml.L⁻¹ active yeast solution. The obtained results revealed that there is a negative effect of increasing the level of salt on all investigated growth parameters (plant biomass, plant compound leaves developed number, plant height, stem diameter, and fresh weight of leaves and stems per plant), crude protein% and chloroplast pigments content in leaves. While the yeast sprayed plants' growth enhanced under saline stress conditions. Moreover, it is worth mentioning that salinity stress, that yeast solution treatment played a remarkable role in the recovery of vegetative growth reduction.

Abo EL-Fadl et al. (2017) investigated the response of growth, quality, and productivity of two sweet potato cultivars to foliar application of 8 g.L⁻¹ yeast extract. Results pointed out that spraying of yeast gave the highest mean values of all vegetative studied characters (plant length, number of shoots, and foliage fresh weight per plant) of both cultivars during the two years. Furthermore, the total roots plant productivity, number and weight of marketable roots per plant, and chemical roots contents (starch%, total and reducing sugar %, dry matter %, and carotene %) detected the highest significant means values when plants sprayed with yeast extract as compared to other studied treatments of both cultivated years.

AL-Amery and Mohammed (2017) carried out a field experiment to study the influence of adding 12 g.L⁻¹ of bread yeast extract in snap bean (*Phaseolus vulgaris* L. cv. primel) under irrigation with different levels (tap water, 4, and 8 ds/m) of NaCl salty water during spring year. Results showed that all studied traits of yield, morphological growth, the concentration of proline in leaves, and viability of rhizobia were significantly and gradually

reduced by increasing salinity levels. Using yeast solution recorded the distinction of morphological (dry weight and root nodules per plant), reproductive (pod yield and pod number per plant, and pod weight), the viability of rhizobia, and proline content.

AL-Karawi et al. (2018) studied the effect of spraying with two concentrations of dry yeast (*Saccharomyces cerevisiae*) (1, 2 g.L⁻¹) on the growth and production of the strawberries plant under the conditions of protected agriculture. The results showed that spraying the plants with dry yeast led to a significant increase in the plant height and the number of leaves at the concentration of (1 g.L⁻¹), while the spraying treatment with concentration (2 g.L⁻¹) gave a significant increase in the dry weight of the total vegetative, the leaves content of chlorophyll and the fruits content of total sugars, The average production of one plant and the average production of the greenhouse.

Lens culinaris plants were treated by Abed Nasser et al. (2019) using concentrations (0,10,20) g.L⁻¹ of yeast solution and by foliar application or glaucoma around roots after 20 days from sowing. The method of integration between the one and the other plants took place over a period of 10 days with tripled separations between them. Results showed that in plants treated with a dose of 10 g.L⁻¹ of spray, the greatest stem value reached (43.90 cm, 6.59 cm; 10.98) for the length and length of the internodes and the number of nodes, respectively. Concerning the leaf characteristics, in comparison to control plants, results showed a good impact of the extract of dry bread yeast which reported significant differences in the aspects of leaves. As well as the previous treatment gave the biggest value of the fresh and dry weight with 0.0382 and 0.462 g, respectively. The largest number of leaflets, plant leaf area, and total chlorophyll concentration were (26.00, 11.840 cm², and 154.67% wet weight), respectively, when plants were treated with both spray and glaucoma around roots with 10 g.L⁻¹. Additionally, the best percentages of nitrogen, phosphorus, and potassium were found in the 10 g.L⁻¹ treatment for yeast and glaucoma, with values of 1.23, 2.67, and 3.08, respectively, while plants treated with dry bread yeast showed a significant difference in the chemical composition of the leaves. Moreover, the mixed yeast and glaucoma treatment detected the highest level of total proteins and carbohydrates with 8.889 and 16.90, respectively compared to other transactions.

Abu Khouder et al. (2019) examined the effect of N-Fertilization (in the form of ammonium sulfate, 20.5% N; 0, 50, and 100 kg.ha⁻¹) and foliar application with dry yeast extracts (0, 2, and 4 g.L⁻¹), and its combined effect on growth, yield and its attributes, as well as, quality traits of snap bean (bronco cultivar). The results showed that applying N-Fertilizer and foliar application with dry yeast extract gave significant differences in all studied traits compared to the untreated plants as a control in favor of 100 kg N.ha⁻¹ and 4 g.L⁻¹ dry yeast extract in both years. Concerning the combined effect between N-Fertilization and dry yeast extract, there were significant impacts in most of the investigated traits in the two years. The combination of 100 kg N.ha⁻¹, and 4 g.L⁻¹ dry yeast extract recorded the highest mean values of vegetative growth characters yield components, total yield, and pod quality in both years. Conclusively: it could be concluded that the treatment of N fertilization in the form of ammonium sulfate (20.5% N) at 100 kg N/ha and foliar application with dry yeast extract at the level of 4 g.L⁻¹, as well as the combined effect between 100 kg N.ha⁻¹ and 4 g.L⁻¹ dry yeast extract enhancing the studied characters of snap bean.

Alt-madhagi (2019) sprayed cucumber with (0, 2000, and 4000 mg.L⁻¹) yeast. As compared to control, yeast at 4000 mg.L⁻¹ alone resulted in the significantly highest of the plant (88.2%), plant height, and higher yield (number and weight) (91.00%). Yeast at 2000 mg.L⁻¹ enhanced leaves DM% (26.6%) significantly. Meanwhile, the application of yeast had a significant increase in the content of chlorophyll SPAD, 4000 mg.L⁻¹ produced about 6% more than control.

Al-Shaheen et al. (2019) sprayed three doses (0, 50, and 100 mg.L⁻¹) of nano-iron and three concentrations (0, 100, and 150 g.L⁻¹) of yeast extract on the leaves. The results showed that the sprayed with NPs recorded the highest concentration of chlorophyll, and the ratio of seed (protein and oil). Applying dry yeast extract also gave a significant level of the studied characters. The highest values of oil content in the seeds (%), chlorophyll, and the seeds protein rate (%) were recorded under interaction transaction of 100 mg of nanotube and 150 g.L⁻¹ dry yeast extract as compared to other treatments.

Alsaady et al. (2020) studied the effect of foliar spraying of different levels (0, 3, and 6 g.L⁻¹) of bread yeast suspension on the vegetative growth traits of cabbage plants. Results of this study showed that foliar application with yeast significantly increased the vegetative

growth and yield of cabbage. Meanwhile, active yeast extract spraying at doses of 3 and 6 g.L⁻¹ gave the highest leaf area (width and length), head diameter, plant height, head weight, and productivity per hectare, which reached (36.4, 36.5 cm), (31.0, 32.3 cm), (29.7, 32.5 cm) (19.9, 21.0 cm), (1916.6, 2122.2 g), (82.1, 90.9 ton/hectare) respectively as compared with non-spraying 0 g.L⁻¹.



3. MATERIALS AND METHODS

3.1. Climate and Some Soil Properties of the Experimental Site

3.1.1. Experimental site

Two field experiments were performed in the experimental field of Van Yüzüncü Yıl University (VYYU-Campus), Faculty of Agriculture, Field Crops Department as well as in the Science Application and Research Center labs, Van, Türkiye in two successive maize/corn growing summer years 2019 and 2020. The coordinates of the experimental site are at 38°34'18.8" north latitude and 43°17'17.5" east longitude.

3.1.2. Climatic features of the research

Table 3.1. Climatic information for the studied area (Temperature (C°) and rainfall (mm) for the studied area (Van city) during the growing year and through the long term)

Month	Average Temperature (°C)			Total Precipitation (mm)			Average Humidity (%)		
	2019	2020	Long Years	2019	2020	Long Years	2019	2020	Long Years
April	7.2	8.6	8.4	36.2	50.9	57.4	66.1	65.4	59.3
May	15.4	14.5	13.4	15.3	27.8	45.3	51.9	54.0	55.1
June	21.4	19.3	18.8	7.2	13.4	16.4	45.4	44.4	47.1
July	23.0	23.0	22.7	0.4	17.9	6.9	39.0	46.4	42.3
August	23.7	21.6	22.9	0.9	10.0	5.3	40.2	44.5	40.5
September	18.8	20.1	18.3	0.8	5.6	20.4	43.9	41.3	43.9
October	13.4	13.3	12.0	24.1	1.8	48.2	52.9	47.2	57.3
Mean	17.6	17.2	16.6	12.1	18.2	28.6	48.4	49.0	49.3
Total	122	120	116	85	127	199	-	-	-

* Van Meteorology Regional Directorate records.

The long-term average of some climatic data was measured in the Van Province meteorology station and the average temperature (°C), monthly total precipitation (mm), and relative humidity (%) of the years in which the research was carried out are given in Table

3.1. The average temperature in Van city in the 2019 and 2020 years (17.6 and 17.2 °C, respectively) was higher than the average temperature in the long years (16.6 °C). While total precipitation in the experimental years (85 mm in 2019 and 127 mm in 2020) was lower than the long-term one (199 mm). The same trend was recorded for the average humidity during the 2019 and 2020 years (48.4 and 49.0%, respectively) was lower compared to the long-year average (49.3%) as shown in Table 3.1.

3.1.3. Soil properties of the research site

Soil samples were randomly taken each year before cultivation from the two depths of 0-20 and 20-40 cm, and were subjected to some physical and chemical analysis (VYYU, Fac. Agric., Dep. Soil Science and Plant Nutrition) and it was illustrated in Table 3.2. Experiments soil pH ranged between 8.16 and 8.30 in the 0-20 cm and 20-40 cm, respectively. The experiment's soil texture was sandy-clay in VYYU-Campus as Table 3.2 shows.

Clay, sand, lime, and silt (%) fractions in soil samples were determined by the hydrometric method (Bouyoucos, 1951). Soil reaction (Mclean, 1982), electrical conductivity (Richards, 1954), and organic matter (Nelson, 1982) were determined in Van Yüzüncü Yıl University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition. Macronutrient (Ca+Mg) concentrations were determined using wet digestion inductively coupled plasma-optical emission spectrometer (ICP-OES) and atomic absorption spectrophotometer (AAS) in VYYU, Science Application, and Research Center labs.

Table 3.2. Some physical and chemical analyses of the soil experimental field

Deep (cm)	pH Sat.	Clay %	Silt %	Sand %	Lime %	Texture class	CEC cmol.kg ⁻¹	Organic Matter %
0-20	8.16	45.08	31.95	25.97	21.06	clay	16.00	1.87
0-40	8.30	40.76	27.88	29.39	21.41	clay	17.00	1.69

3.2. Materials

3.2.1. Field experiments

Two field experiments were carried out to evaluate the effects of active dry yeast and Nano iron oxide (Fe_3O_4) on the growth, morphological, and chemical constituents of maize (*Zea mays* L. Cv. Tuano) plants for silage purposes under alkaline soil conditions. The experiments were performed in the research and experimental field of VYYU-Campus, Fac. Agric., Field Crops Department as well as in the Science Application and Research Center labs, Van, Türkiye during the two successive summer years 2019 and 2020. The materials were as follows:

Maize seeds cultivar Tuano is a silage and grain cultivar obtained from the Van Directorate of Provincial Agriculture and Forestry. The cultivar is an FAO 650 group, silage yield is very high, tall, and has a very good green retention at harvest, the grain ratio. The amount of starch and protein is high.

Nano iron oxide Fe_3O_4 has used Iron (II, III) oxide, which was purchased from Sigma-Aldrich, Darmstadt, Germany. Its properties are as follow: Nanopowder spherical, 50-100 nm particle size (SEM), 97% trace metals basis, Empirical Formula (Hill Notation): Fe_3O_4 . CAS Number: 1317-61-9, Molecular Weight: 231.53, Surface area: BET surf. area 6-8 m^2/g (estimated), Density: 4.8-5.1 g/mL at 25 °C (lit.), Bulk density: 0.84 g/mL , SMILES string: $\text{O}=[\text{Fe}].\text{O}=[\text{Fe}]\text{O}[\text{Fe}]=\text{O}$, InChI 1S/3Fe.4O. EC Number: 215-277-5, MDL Number: MFCD00011010, PubChem Substance ID: 24882829, and NACRES: NA.23.

Active dry yeast (*Saccharomyces cerevisiae*) was obtained from local markets, country of origin Türkiye (Made in Türkiye). It is known as dry bread yeast. It contains 99% natural yeast (*Saccharomyces cerevisiae*) and 1% herbal emulsifier (Sorbitan Monostearate). It does not contain gluten.

3.3. Methods

3.3.1. Experimental methods

This research aimed to study the effect of spraying bio-fertilizers (active dry bread yeast) and nano iron oxide Fe_3O_4 in improving the growth of maize crops for silage purposes under alkaline soil conditions. Maize seeds were sown on 15th May in both years (2019 and 2020) and all experimental plots were 5.0×3.5 m and contained 6 rows (70 cm between rows) and 12 cm between plants. The distance between parcels has been arranged as two meters and between blocks as three meters. There were 16 parcels in each block.

Three different doses of Nano iron oxide Fe_3O_4 (N1: 0.4, N2: 0.6, and N3: 0.8 g.L^{-1}) were applied to foliar maize plants at two intervals, the first application was 54 days after planting (DAP) when the plants had 8-10 leaves. The second application was 15 days later, and with tap water as control plants.

Active dry yeast extract was prepared from bread's yeast (*Saccharomyces cerevisiae*), dissolved in water (M1: 5, M2: 7.5, and M3: 10 g.L^{-1}), then added sugar in a 1:1 ratio and kept in a warm place for 24 hours for growth according to the methods Morsi et al. (2008) and sprayed two times as Fe_3O_4 above.

Nine mixture treatments (Interaction or combined) between the active dry yeast and Nano iron oxide Fe_3O_4 as follows (N1M1, N1M2, N1M3, N2M1, N2M2, N2M3, N3M1, N3M2, N3M3) sprayed in the previous dates at every year.

3.3.2. Agricultural processes

After the main crop harvest, the experiments field was plowed deeply with a plow with sockets in the autumn. In this way, the soil remained empty until spring. Then soil was pulled with a cultivator from the field in the spring, and it was made ready for planting by passing a disc harrow before planting, and ridges were drawn (Figure 3.1).



Figure 3.1. Preparing the seed bed.

Before planting, plots were marked, and rows were determined. Then, after preparing the seed bed with the cultivator, the sowing process was carried out in the arid soil in May with a trial sowing seeder (Figure 3.2).



Figure 3.2. The sowing process

Experiments were irrigated with sprinklers after planting for the emergence of plants (Figure 3.3).



Figure 3.3. Sprinkler irrigation.

The field rows were fully covered with fibrous wire until the corn was a few inches high to keep maize seed/seedlings from birds digging/feeding (Figure 3.4).



Figure 3.4. Covering the field with fibrous wire.

After germination is completed (within 10-14 days after planting), gapping/replanting was done with seeds of the same maize cultivar prior to irrigation to replace the ungerminated seeds to leave desired density in the field. When the plant height was 7-8 cm after emergence to avoid crowding, a handle thinning was done to one plant remains per hill. It is worth it to have the corn beds full of plants growing at the same rate.

With the planting, fertilizers were applied to all parcels at the rate of 8 kg pure N da⁻¹ at the first batch of nitrogen fertilizer and 8 kg pure P₂O₅ da⁻¹ of phosphorus fertilizer. When corn is 50-60 cm tall, the second dose of nitrogen fertilizer was applied by hand at the rate of 10 kg pure N da⁻¹ (Sabancı, 2015). Moreover, foliar application of Nano iron oxide Fe₃O₄ and active dry yeast have been conducted as mentioned before (Figure 3.5).



Figure 3.5. Applying Nano iron and active dry yeast to maize.

In both years, hoeing has been done two times to cover the bottom of the plant stem, aerate the soil, and fight weeds. The firsthand hoe was conducted in the 4-6 leaf period of the

plant's life cycle and the second one was applied after 20-25 days from the first hoe (8-10 leaves per plant) (Figure 3.6).



Figure 3.6. Hoeing.

Plants were directly irrigated with a sprinkler irrigation system, then later irrigations were done each 2-3 days after the first watering for the guarantee of seeds emergence because the surface of Van soil becomes hard upon drying. Then sprinkler irrigation was applied once in 10 days until covering the bottom of the plant stem period to keep the soil moist. Then irrigation was done in the form of a furrow irrigation system. The last irrigation was completed 10-14 days before the harvest of both experiments in the 2019 and 2020 years (Etebari and Tansı, 1994) (Figure 3.7).



Figure 3.7. Furrow irrigation.

At the dough stage (117-123 DAP) in the two planting years. Reached the harvest stage plants were handled harvested by taking two rows from each plot with a distance of two meters, removing the edge effects, and determining the yield examined parameters (Figure 3.8).



Figure 3.8. Harvest process.

3.3.3. The characteristics examined in the evaluation of the effects on the yield and quality of maize/corn plants in different periods

In both experiments, three samples on randomly ten plants per plot, i.e., at 64, 74, and 84-DAP were identified and read from the middle three rows in each treatment, 10 days after each application. Each one was represented by three replicates for the morphological studies as below:

Plant height (cm) was measured from the ground surface to the endpoint of the top of the plant for the identified ten plants per plot.

The number of leaves per plant was measured from the ground surface to the flag leaf for the ten identified plants per plot (Gökçora, 1959).

Total chlorophyll SPAD through chlorophyll meter SPAD-502 Plus Konica Minolta made in Japan (9229-A1RT-12) for the ten identified plants per plot (Figure 3.9).



Figure 3.9. Measuring Total chlorophyll SPAD.

3.3.4. The characteristics examined in the evaluation of the effects on the yield and quality of maize/corn plants in dough harvest periods

At the dough stage (117-123 DAP), a sample was taken from the identified ten plants in each parcel (at the end of the experiment, the weight of the ten plants was taken separately and the average was written) for recording the following:

Plant height (cm), measured from the ground surface to the endpoint of male inflorescence (tassel) at the top of the plant for ten plants per plot.

The number of leaves per plant, measured from the ground surface to the flag leaf for the ten identified plants per plot.

The number of cobs per plant and all maize ears were recorded for every single plant from the identified ten plants for all plots.

Stem weight per plant (g), each plant from the ten identified plants was divided into its parts and stem weight by a sensitive digital scale (Karayığit, 2005).

Leaves weight per plant (g), the separated leaves were weighted by a sensitive digital scale for the ten identified plants in each plot.

Cobs weight per plant (g), was obtained by weighing the cobs harvested from the ten identified plants separately per plot and expressed as g (Karayığit, 2005).

Plant weight (g) was calculated by adding the weight of the leaves, stems, and cobs for each plant.

Stem diameter (mm) was estimated at a 10 cm high level above ground between the first two nodes of the stem by using a BTS Metal cover digital caliper 0-150 MM/0-6" (inch) (Figure 3.10) for the ten identified plants per plot (Keskin, 2001).



Figure 3.10. Recording the stem diameter.

Leaf Ratio (%) was calculated by dividing the leaves of the ten randomly selected plants from each plot of treatments, separated from the stem and cobs, and proportioning to the whole plant weight.

Stem/Stalk Ratio (%), was calculated by dividing the stems of ten randomly selected plants from each plot of treatments, separated from the leaf and cob, and proportion to the whole plant weight.

Cob Ratio (%), was calculated by dividing the stems and leaves of 10 randomly selected plants from each parcel of treatments and weighing them in proportion to the whole plant weight.

For herbage yield in the two successive years, two middle rows from each plot with two meters distance were handled harvested and calculated the production in one decare as a ton.da^{-1} according to (Acar, 1995; Keskin, 2001).

Green herbage yield (ton.da^{-1}), two meters of maize plants (including stem, leaves, and cobs) were cut with the soil surface, put in plastic bags, weighted using a digital hanging scale in kilograms, and then converted to a ton.da^{-1} , a general view of the experiment (Figure 3.11).



Figure 3.11. A general view of the experiment.

Dry herbage yield ($\text{ton} \cdot \text{da}^{-1}$), half a kilogram of the maize/corn shoots were dried at 70°C until a constant weight was obtained, and the dry weight was recorded and then transformed into tons per decare (Figure 3.12).



Figure 3.12. Drying plants in the lab.

Macronutrients (P, K, Ca, Mg) and micronutrients (Fe, Cu, Mn, Mo, Se, Zn) concentrations were determined in maize plant shoots (shoot will be used in silage) using by wet digestion inductively coupled plasma-optical emission spectrometer (ICP-OES) and atomic absorption spectrophotometer (AAS) in VYYU, Science Application and Research Center labs.

3.4. Statistical Analysis

The field experiments were arranged in the Randomized Complete Block Design (RCBD) with three replications. Three different doses of active dry bread yeast (*Saccharomyces cerevisiae*) and three doses of nano iron oxide Fe_3O_4 and their combined as well as control (tap water), were sprayed on maize plants. One-way analysis of variance (ANOVA) and Duncan multiple comparison tests were used to evaluate the treatment effects. The differences among treatment mean values were compared using Duncan's multiple range test and a p-value of 5% was used for statistical significance as reported by Gomez and Gomez (1984). All statistical analysis was performed by using the analysis of variance (ANOVA) technique of SAS Software package Stat-view-9.0.1 (SAS Institute, 2002).

4. RESULTS

4.1. Impact of Nano Iron, and Active Dry Yeast on Growth of Maize Plants in the 64, 74, and 84 DAP

4.1.1. Plant height

The effects of nano iron and active dry yeast data in Table 4.1, reveal that there is a significant improvement in the plant height by using all concentrations of either nano iron Fe_3O_4 , active dry yeast, or their combined on maize plants grown in high pH soil conditions for silage purposes in both years 2019 and 2020. The results presented in Table 4.1 show that at the 64 DAP, the foliar application of Fe_3O_4 and active dry yeast applications on maize plants under alkaline soil stress was a non-significant effect among all concentrations compared to control non-treated plants; in contrast, some mixed concentrations between the two treatments such as N1M1, N3M1 and N2M2 caused a significant increase in plant height in two years.

Using nano Fe_3O_4 on maize plants at 74 DAP significantly increased the plant height compared to control plants. The highest plant was recorded when the plant sprayed by N3: 0.8 g.L^{-1} of nano iron with 240.93 and 166.00 cm in 2019 and 2020 years, respectively. While the slight difference was detected for plant height between the N1: 0.4 g.L^{-1} nano iron and control unsprayed plants in both years. As well as between N2: 0.6 and N3: 0.8 g.L^{-1} no significant difference was noted as shown in Table 4.1.

Data in Table 4.1 reveal that the plant height significantly increased compared with control non-sprayed plants due to the use of nano iron at 84 DAP in the 2019 and 2020 years. The plant height increased with increasing Fe_3O_4 levels from N1 to N2 (from 0.4 to 0.6 g.L^{-1}) in comparison to control at the stage (84 DAP) of the two years.

The effects of active dry yeast applications on plant height (cm) are given in Table 4.1 and were carried out on 64, 74, and 84 DAP in two successive years 2019 and 2020.

Table 4.1. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on plant height (cm) of maize grown under high pH soil conditions at 64, 74, and 84 days after planting (DAP) during 2019 and 2020 years

Year		2019 Year			2020 Year			Mean of 2019 and 2020		
Character		Plant height (cm)			Plant height (cm)			Plant height (cm)		
Treatments		64 DAP	74 DAP	84 DAP	64 DAP	74 DAP	84 DAP	64 DAP	74 DAP	84 DAP
Control		138.53	170.69 e	195.15 j	137.13	155.60 e	197.47 e	137.83	163.15	196.31
N1: 0.4 g.L ⁻¹		149.00	181.99 de	218.33 i	138.53	159.20 de	199.20 de	143.77	170.60	208.77
N2: 0.6 g.L ⁻¹		151.67	227.47 abcde	244.02 efgh	132.73	169.13 ab	207.87 bcde	142.20	198.30	225.95
N3: 0.8 g.L ⁻¹		142.40	240.93 abcd	256.50 def	130.20	166.00 abcd	213.13 bcde	136.30	203.47	234.82
N Mean		147.69	216.80	239.62	133.82	164.78	206.73	140.76	190.79	223.18
M1: 5 g.L ⁻¹		138.27	228.39 abcde	234.26 fghi	135.80	164.33 abcd	207.27 bcde	137.04	196.36	220.77
M2: 7.5 g.L ⁻¹		156.93	240.80 abcd	254.93 efg	136.07	167.67 abc	211.33 bcde	146.50	204.24	233.13
M3: 10 g.L ⁻¹		128.60	263.87 ab	279.08 abcd	135.33	169.07 ab	216.27 bcd	131.97	216.47	247.68
M Mean		141.27	244.35	256.09	135.73	167.02	211.62	138.50	205.69	233.86
N1M1		149.40	237.13 abcd	250.36 efg	141.73	171.87 a	208.83 bcde	145.57	204.50	229.60
N1M2		126.67	218.60 abcde	260.98 cde	125.00	167.27 abcd	213.73 bcde	125.84	192.94	237.36
N1M3		120.13	247.40 abc	299.91 a	125.87	170.47 a	237.13 a	123.00	208.94	268.52
N2M1		118.33	226.73 abcde	267.50 bcde	128.40	167.87 abc	215.33 bcd	123.37	197.30	241.42
N2M2		133.20	261.87 ab	280.03 abc	138.27	166.60 abcd	216.67 bc	135.74	214.24	248.35
N2M3		165.20	212.52 bcde	231.95 ghi	139.47	161.73 bcde	206.07 bcde	152.34	187.13	219.01
N3M1		141.67	278.67 a	287.72 ab	128.73	168.40 ab	219.60 b	135.20	223.54	253.66
N3M2		139.60	201.33 bcde	225.61 hi	142.60	165.13 abcd	203.67 bcde	141.10	183.23	214.64
N3M3		142.73	189.11 cde	216.78 i	141.27	159.80 cde	201.47 cde	142.00	174.46	209.13
NM Mean		137.44	230.37	257.87	134.59	166.57	213.61	136.02	198.47	235.74
P-Value		0.3728	0.0151	<.0001	0.0980	0.0022	0.0014			
Minimum		118.33	170.69	195.15	125	155.6	197.47	121.67	163.15	196.31
Maximum		165.2	278.67	299.91	142.6	170.47	237.13	153.90	224.57	268.52
SE		7.15	13.57	11.30	3.09	2.14	4.25			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

The differences between applied treatments on the mentioned studied character were found statistically significant in (74 and 84 DAP), while insignificant differences were recorded in the 64 DAP stage. Progressive significant height of maize plant was achieved with the foliar application of active dry yeast; when 10 g of yeast was sprayed on the plant above soil, the plant height of maize reached 279.08 and 216.27 cm, in 2019 and 2020 respectively at 84 DAP, which was significantly higher than the control treatment, but no significant differences were recorded between plant height when treated by M2: 7.5 and M3: 10.0 g.L⁻¹ of yeast in both years at 74 DAP and 84 DAP in the second year.

The mixed doses of nano iron Fe₃O₄ and active dry yeast on maize is grown were better than the singular treatment by either dry yeast or nano iron. The data in Table 4.1 pointed out that there is an increase in the plant height by using all doses of nano iron and yeast on the corn plant grown under alkaline soil conditions in Van, Türkiye. The highest value of these characters was obtained by N1M3 (0.4 g.L⁻¹ of Fe₃O₄ and 10 g.L⁻¹ of dry yeast) then followed by N3M1 (0.8 g.L⁻¹ of Fe₃O₄ and 5 g.L⁻¹ of dry yeast) and N2M2 (0.6 g.L⁻¹ of Fe₃O₄ and 7.5 g.L⁻¹ of dry yeast) at all stages (64, 74 and 84 DAP) of both years (2019 and 2020), but the differences were not significant for spraying of N3M3 at (0.8 g.L⁻¹ of Fe₃O₄ and 10 g.L⁻¹ of dry yeast) dose and N1: 0.4 g.L⁻¹ of Fe₃O₄.

4.1.2. Number of leaves per plant

Foliar application of nano iron Fe₃O₄ on maize plants grown under high pH soil conditions, the treatment gave a slight difference in the number of leaves per plant compared to control non-sprayed plants at 64 and 74 DAP in both years 2019 and 2020 as Table 4.2 shown. While the foliar application of nano iron significantly increased the No leaves per plant at 84 DAP in the two studied years (2019 and 2020) in comparison to non-treated plants as control.

However, foliar spraying of active dry yeast at concentrations of 5.0, 7.5, and 10 g.L⁻¹ had a remarkable effect on the number of leaves per corn plant of the all-vegetative stages than the yeast-free treatment, control, while the differences among the yeast concentrations in the leaves number were insignificant. M3: 10 g.L⁻¹ of dry yeast treatment recorded the

highest value of the leaf number per plant at 64, 74, and 84 DAP in both years, except at 64 and 74 DAP in the first year where the dose M2: 7.5 g.L⁻¹ of yeast gave the highest value of the studied character as shown in Table 4.2.

Table 4.2. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on the number of leaves per plant of maize grown under high pH soil conditions at 64, 74, and 84 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year			2020 Year			Mean of 2019 and 2020		
Character	Number of leaves per plant			Number of leaves per plant			Number of leaves per plant		
Treatments	64 DAP	74 DAP	84 DAP	64 DAP	74 DAP	84 DAP	64 DAP	74 DAP	84 DAP
Control	11.87	13.21 abcd	13.93 bc	8.53	10.47	12.73	10.20	11.84	13.33
N1: 0.4 g.L ⁻¹	11.80	13.14 bcd	13.93 bc	8.40	11.00	13.13	10.10	12.07	13.53
N2: 0.6 g.L ⁻¹	12.20	12.67 cd	13.33 c	8.47	10.87	12.80	10.34	11.77	13.07
N3: 0.8 g.L ⁻¹	12.80	13.67 ab	14.37 abc	8.33	11.00	13.60	10.57	12.34	13.99
N Mean	12.27	13.16	13.88	8.40	10.96	13.18	10.33	12.06	13.53
M1: 5 g.L ⁻¹	12.00	13.38 abcd	13.67 bc	8.60	10.67	13.20	10.30	12.03	13.44
M2: 7.5 g.L ⁻¹	12.73	13.80 ab	14.16 abc	8.87	10.87	12.93	10.80	12.34	13.55
M3: 10 g.L ⁻¹	12.67	13.73 ab	14.45 ab	9.13	11.73	14.13	10.90	12.73	14.29
M Mean	12.47	13.64	14.09	8.87	11.09	13.42	10.67	12.36	13.76
N1M1	12.20	12.53 d	14.27 abc	8.60	11.07	13.53	10.40	11.80	13.90
N1M2	11.67	13.33 abcd	13.89 bc	8.07	10.87	12.87	9.87	12.10	13.38
N1M3	12.20	12.67 cd	13.67 bc	8.13	10.13	12.67	10.17	11.40	13.17
N2M1	12.80	13.47 abcd	14.13 abc	8.47	10.87	13.40	10.64	12.17	13.77
N2M2	13.00	14.07 ab	15.07 a	8.60	11.00	14.00	10.80	12.54	14.54
N2M3	12.40	13.99 ab	14.57 ab	8.47	11.00	13.53	10.44	12.50	14.05
N3M1	13.20	14.13 a	15.07 a	8.60	11.40	14.20	10.90	12.77	14.64
N3M2	12.27	13.60 abc	13.75 bc	9.13	11.47	13.60	10.70	12.54	13.68
N3M3	12.13	13.74 ab	14.68 ab	8.73	11.33	13.20	10.43	12.54	13.94
NM Mean	12.43	13.50	14.34	8.53	11.02	13.44	10.48	12.26	13.89
P-Value	0.2004	0.0037	0.0151	0.1340	0.2324	0.1083			
Minimum	11.67	12.53	13.33	8.07	10.13	12.67	9.87	11.33	13.00
Maximum	13.2	14.13	15.07	9.13	11.73	14.2	10.90	12.73	14.635
SE	0.24	0.22	0.23	0.15	0.20	0.24			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

Concerning the interaction effect of nano iron Fe_3O_4 and active dry yeast on maize, the data in Table 4.2 reveal that using all mixed doses of nano iron and yeast enhanced the number of leaves per plant parameter. The highest value of the number of leaves per plant was recorded when N1M3 (0.4 g.L^{-1} of Fe_3O_4 and 10 g.L^{-1} of dry yeast) was applied to plants in the 2019 and 2020 years for all stages, except in the stages 64 and 74 DAP for the second year where yeast M3: 10 g.L^{-1} dose gave the highest value of the studied character.

4.1.3. SPAD value

For the total chlorophyll as a SPAD value indicator, the results presented in Table 4.3 show that the foliar application of nano Fe_3O_4 on corn plants grown under alkaline soil stress increased the SPAD value (total chlorophyll) compared to control. All applied doses of nano iron on maize plants had less effect compared to control at stage 64 DAP in both years 2019 and 2020 but it was not significant.

However, a significant enhancement of total chlorophyll content was detected at 74 DAP in both years. The dose N3: 0.8 g.L^{-1} of nano Fe_3O_4 gave the highest increment with 26.65 and 10.15% compared to untreated plants as a control in 2019 and 2020 respectively. Moreover, no significant differences in SPAD value at 74 DAP between control and N1: 0.4 g.L^{-1} of nano iron as well as between N2: 0.6 g.L^{-1} and N3: 0.8 g.L^{-1} in both years.

The SPAD value significantly increased with increasing Fe_3O_4 levels from N1 to N3 (from 0.4 to 0.8 g.L^{-1}) in the two years. The high value of total chlorophyll was recorded in N3 in the two years; however, no significant differences were detected among (N2 and N3) levels in the third stage of 84 DAP in both years.

On the other hand, spraying maize plants with active dry yeast positively improved the maize leaf chlorophyll content (SPAD value) as reflected in Table 4.3. Progress increasing of applied dry yeast doses from M1: 5 to M3: 10 g.L^{-1} has increased the SPAD value at all vegetative stages in the two years 2019 and 2020. The increment of this character was statistically significant in both 74 and 84 DAP while was insignificant at 64 DAP. M3: 10.0 g.L^{-1} of yeast in both years at 74 DAP and 84 DAP two years recorded the highest SPAD value. The highest leaf chlorophyll content was found in the maize treated with M3: 10 g.L^{-1}

¹ of active dry yeast (50.98 at 74 DAP and 51.99 at 84 DAP in 2019 and 2020 year respectively), while the lowest values of SPAD were in control (33.54 at 74 DAP and 42.13 at 84 DAP in 2019 and 2020 respectively).

Table 4.3. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on total chlorophyll as SPAD value of maize grown under high pH soil conditions at 64, 74, and 84 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year			2020 Year			Mean of 2019 and 2020		
Character	SPAD value			SPAD value			SPAD value		
Treatments	64 DAP	74 DAP	84 DAP	64 DAP	74 DAP	84 DAP	64 DAP	74 DAP	84 DAP
Control	44.52	33.54 i	34.98 i	37.62	38.67 j	42.13 k	41.07	36.11	38.56
N1: 0.4 g.L ⁻¹	45.47	37.27 hi	41.14 h	38.84	39.92 ij	43.39 jk	42.16	38.60	42.27
N2: 0.6 g.L ⁻¹	47.07	43.52 efg	45.08 efg	36.91	41.75 hig	46.47 fgh	41.99	42.64	45.78
N3: 0.8 g.L ⁻¹	43.55	45.73 ef	47.17 cdef	37.88	43.04 efg	48.08 ef	40.72	44.39	47.63
N Mean	45.36	42.17	44.46	37.88	41.57	45.98	41.62	41.87	45.22
M1: 5 g.L ⁻¹	40.47	43.24 efg	44.06 fgh	37.16	41.15 hig	45.99 fghi	38.82	42.20	45.03
M2: 7.5 g.L ⁻¹	48.94	45.13 ef	46.72 def	37.35	42.62 fgh	47.78 f	43.15	43.88	47.25
M3: 10 g.L ⁻¹	45.63	50.98 bcd	50.17 abc	38.94	45.93 cd	51.99 cd	42.29	48.46	51.08
M Mean	45.01	46.45	46.98	37.82	43.23	48.59	41.42	44.84	47.79
N1M1	46.16	44.43 efg	44.24 fgh	38.84	41.99 hig	47.17 fg	42.50	43.21	45.71
N1M2	47.07	46.24 def	47.93 cde	38.77	44.11 def	50.06 de	42.92	45.18	49.00
N1M3	42.19	60.81 a	53.12 a	38.61	48.52 a	60.01 a	40.40	54.67	56.57
N2M1	47.95	48.11 cde	48.57 bcd	38.02	44.90 cde	51.31 cd	42.99	46.51	49.94
N2M2	46.41	51.95 bc	51.28 ab	37.11	46.42 bc	52.57 c	41.76	49.19	51.93
N2M3	46.53	42.11 fgh	42.74 gh	38.45	40.62 hij	44.97 ghij	42.49	41.37	43.86
N3M1	47.41	55.27 b	51.34 ab	37.84	47.98 ab	55.95 b	42.63	51.63	53.65
N3M2	44.25	40.87 fgh	42.44 gh	37.46	40.50 ij	44.51 hij	40.86	40.69	43.48
N3M3	44.96	39.57 gh	42.39 gh	37.51	40.10 ij	43.92 ijk	41.24	39.84	43.16
NM Mean	45.88	47.71	47.12	38.07	43.90	50.05	41.97	45.81	48.58
P-Value	0.9321	<.0001	<.0001	0.9554	<.0001	<.0001			
Minimum	40.47	33.54	34.98	36.91	38.67	42.13	38.82	36.11	38.56
Maximum	48.94	60.81	53.12	38.94	48.52	60.01	43.15	54.67	56.57
SE	1.70	2.50	1.64	0.57	1.08	1.66			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

Data given in Table 4.3 reveal that the mixture effect of nano iron Fe_3O_4 and active dry yeast on maize grown for silage purposes have more chlorophyll content than control and/or singular foliar application of the studied materials. The highest chlorophyll concentration was detected by using the dose N1M3 (0.4 g.L^{-1} of Fe_3O_4 and 10 g.L^{-1} of dry yeast) in comparison to all other treatments for all stages (64, 74, and 84 DAP) in both years (2019 and 2020) under alkaline soil conditions in Van city, Türkiye.

4.2. Impact of Nano Iron, and Active Dry Yeast on Morphological Growth of Maize Plants at the Dough Stage

The plant height and stem weight per plant of corn plants grown under a high level of pH and sprayed with different doses of nano iron and yeast are represented in Table 4.4. The results pointed out that the foliar application of yeast and nano iron incrded the plant height and stem weight per plant compared to control, while the opposite trend was obtained for the plant stem ratio % where the control recorded the highest value.

Due to the foliar application of nano iron Fe_3O_4 , the results in Table 4.4 stated that the plant height and stem weight per plant were significantly increased with increasing the level of nano iron from N1: 0.4 g.L^{-1} to N2: 0.6 g.L^{-1} , while no significant differences between N2: 0.6 g.L^{-1} and N3. On the contrary, plant stem ratio % was significantly reduced when increasing the concentration of Fe_3O_4 where the highest value was detected in the control non-treated plants with 52.23 and 43.23% in the 2019 and 2020 years, respectively.

For active dry yeast, data presented in Table 4.4 indicate that spraying of maize plants with yeast (M1, M2, and M3) under alkali soil stress conditions significantly increased the plant height and stem weight per plant compared to control non-sprayed plants in the fourth sample (117 DAP) in 2019 and 2020 years. The highest value of mentioned characters was obtained in the M3: 10 g.L^{-1} of yeast. Results in Table 4.4 were shown non-significant differences between M1: 5 g.L^{-1} and M2: 7.5 g.L^{-1} treatments at the dough stage in the two years for the studied measurements.

Table 4.4. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M) and their combined (NM) on plant height, stem weight per plant, and plant stem ratio % of maize grown under high pH soil conditions at the dough stage 117 days after planting

Year	2019 Year			2020 Year			Mean of 2019 and 2020		
Character	Plant height (cm)	Stem weight/plant (g)	Plant stem ratio %	Plant height (cm)	Stem weight/plant (g)	Plant stem ratio %	Plant height (cm)	Stem weight/plant (g)	Plant stem ratio %
Treatments									
Control	223.40 g	220.53 h	52.23 a	217.40 i	220.53 i	43.23 a	220.40	220.53	47.73
N1: 0.4 g.L ⁻¹	226.58 g	257.87 gh	48.67 b	229.53 h	255.33 hi	42.54 ab	228.06	256.60	45.61
N2: 0.6 g.L ⁻¹	254.87 def	292.00 efg	43.46 hij	254.00 ef	294.53 fgh	37.98 g	254.44	293.27	40.72
N3: 0.8 g.L ⁻¹	266.13 cdef	322.53 def	42.80 ijk	261.27 de	324.27 def	38.36 g	263.70	323.40	40.58
N Mean	249.19	290.80	44.98	248.27	291.38	39.63	248.73	291.09	42.30
M1: 5 g.L ⁻¹	244.47 efg	286.67 efg	44.69 efg	249.47 fg	293.07 fgh	38.64 g	246.97	289.87	41.67
M2: 7.5 g.L ⁻¹	273.73 bcd	317.60 defg	43.59 ghi	258.33 def	315.87 efg	38.49 g	266.03	316.74	41.04
M3: 10 g.L ⁻¹	291.42 abc	405.60 bc	44.21 efgh	274.40 bc	387.87 c	40.14 cdef	282.91	396.74	42.18
M Mean	269.87	336.62	44.16	260.73	332.27	39.09	265.30	334.45	41.63
N1M1	266.60 cdef	300.00 defg	41.96 kl	257.53 def	300.13 efgh	38.17 g	262.07	300.07	40.07
N1M2	268.20 cde	342.80 de	44.84 ef	266.27 cd	342.80 de	38.74 fg	267.24	342.80	41.79
N1M3	314.06 a	487.33 a	41.20 l	290.20 a	515.60 a	42.89 ab	302.13	501.47	42.05
N2M1	281.23 bcd	360.20 cd	42.24 jkl	273.07 bc	360.20 cd	39.28 defg	277.15	360.20	40.76
N2M2	283.56 bcd	470.00 a	46.40 cd	282.20 ab	430.93 b	40.65 cd	282.88	450.47	43.53
N2M3	239.53 fg	280.67 efgh	45.22 de	249.20 fg	278.00 gh	39.14 efg	244.37	279.34	42.18
N3M1	299.28 ab	438.67 ab	43.94 fghi	291.20 a	467.20 b	41.57 bc	295.24	452.94	42.76
N3M2	238.87 fg	272.40 fgh	46.13 cd	248.20 fg	268.53 h	38.89 fg	243.54	270.47	42.51
N3M3	221.00 g	264.93 fgh	47.28 c	242.07 g	264.93 h	40.38 cde	231.54	264.93	43.83
NM Mean	268.04	357.44	44.36	266.66	358.70	39.97	267.35	358.07	42.16
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001			
Minimum	221	220.53	41.2	217.4	220.53	37.98	220.40	220.53	40.07
Maximum	314.06	487.33	52.23	291.2	515.6	43.23	302.13	501.47	47.73
SE	12.31	29.95	0.403	6.93	29.95	0.481			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

Also, there were differences in plant stem ratio % of corn plants under high pH soil conditions in response to different concentrations of yeast, but the highest value was recorded in control in both years 2019 and 2020.

Table 4.5. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M) and their combined (NM) on plant weight (g) and stem diameter (mm) of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP) during 2019 an 2020 years

Year	2019 Year		2020 Year		Mean of 2019 and 2020	
Character	Plant weight (g)	Stem diameter (mm)	Plant weight (g)	Stem diameter (mm)	Plant weight (g)	Stem diameter (mm)
Treatments						
Control	422.40 j	23.48	505.13 k	25.65	463.77	24.57
N1: 0.4 g.L ⁻¹	529.20 i	21.64	599.07 j	23.71	564.14	22.68
N2: 0.6 g.L ⁻¹	672.33 efg	22.46	772.80 fgh	24.35	722.57	23.41
N3: 0.8 g.L ⁻¹	753.73 de	21.70	841.93 def	23.90	797.83	22.80
N Mean	651.75	21.93	737.93	23.99	694.84	22.96
M1: 5 g.L ⁻¹	644.00 fgh	21.45	755.60 fgh	24.98	699.80	23.22
M2: 7.5 g.L ⁻¹	728.80 de	21.21	816.67 ef	24.08	772.74	22.65
M3: 10 g.L ⁻¹	916.80 c	24.67	963.27 c	24.83	940.04	24.75
M Mean	763.20	22.44	845.18	24.63	804.19	23.54
N1M1	712.40 def	22.27	782.47 fg	24.55	747.44	23.41
N1M2	768.27 d	23.77	883.27 cde	22.85	825.77	23.31
N1M3	1180.93 a	21.62	1209.60 a	25.82	1195.27	23.72
N2M1	857.13 c	24.25	915.07 cd	22.06	886.10	23.16
N2M2	1018.40 b	23.77	1061.07 b	25.03	1039.74	24.40
N2M3	623.07 gh	23.91	708.40 ghi	23.74	665.74	23.83
N3M1	1000.53 b	22.33	1126.93 ab	23.98	1063.73	23.16
N3M2	593.60 ghi	22.21	689.33 hi	25.23	641.47	23.72
N3M3	562.40 hi	23.56	654.27 ij	23.52	608.34	23.54
NM Mean	812.97	23.08	892.27	24.09	852.62	23.58
P-Value	<.0001	0.7886	<.0001	0.5248		
Minimum	422.4	21.21	505.13	22.06	463.77	22.65
Maximum	1180.93	24.67	1209.6	25.82	1195.27	24.75
SE	73.65	0.76	63.93	0.66		

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

Concerning the mixture effect of foliar application of nano Fe₃O₄ and active dry yeast on maize in alkaline soil on plant height, stem weight per plant, and plant stem ratio %, the

obtained data indicate that there were significant differences among all treatments. The data in Table 4.4 indicated that under high pH stress plants, the foliar application of nano Fe_3O_4 and active dry yeast increased plant height and stem weight per plant compared to control plants, while the decreased plant stem ratio %. The highest value of plant height and stem weight were detected by N1M3 in the two years followed by N3M1 and N2M2, but the lowest values of the plant stem ratio % were recorded when plants were sprayed with N1M3 in the first year, and N1M1 in the second year.

Concerning the effects of nano iron, data in Table 4.5 reveal that there is a significant increase in plant weight by using all concentrations of Fe_3O_4 on maize plants grown in high pH soil conditions for both years as compared to control plants. The highest value of plant weight was obtained by N3: 0.8 g.L^{-1} of Fe_3O_4 then followed by N2: 0.6 g.L^{-1} and then N1: 0.4 g.L^{-1} respectively with no difference between N2 and N3. On the other hand, no significant difference was recorded in the stem diameter of maize after applying Fe_3O_4 at 117 DAP in both years (2019 and 2020).

The response of the maize plant weight to different active dry yeast foliar treatments is given in Table 4.5. The corn plant weight parameter at 117 DAP was significantly increased in two years (2019 and 2020) as compared to control non-treated plants. The highest plant weight was recorded in the M3: 10 g.L^{-1} dry yeast treatment, where it recorded 916.80 and 963.27 g in 2019 and 2020 respectively, while the lowest value of the mentioned character was detected with the control plants. The stem diameter of the maize plant did not differ due to spraying all doses of active dry yeast at the dough stage (117 DAP) during the 2020 and 2021 years.

Both sprayings of nano Fe_3O_4 and active dry yeast have a promoting effect on maize plant weight compared to control non-treated plants grown under alkali soil stress conditions for the dough stage in two years. The highest value of plant weight was recorded at N1M3, and N2M2, respectively. It is worth noticing that plants without being sprayed with nano Fe_3O_4 and active dry yeast recorded the lowest values regarding the previously mentioned plant weight. This increment in plant weight was significant, where N1M3 increased the plant weight by 64.23% in the first year and 58.23% in the second year in comparison to the control plant. For N2M2, the enhancement of maize plant weight was 58.52% in 2019 and 52.39%

in 2020 at 117 DAP. While the combined between all doses of both nano iron and yeast were insignificant in the fourth sample at 117 DAP of the first and second year for stem diameter (Table 4.5).

The obtained data in Table 4.6 declared generally, that nano iron Fe_3O_4 foliar spray significantly increased leaves weight in the dough maize stages of the two successive years under high pH soil level, while the number of leaves per plant was insignificant compared to control untreated plants. The highest increase in leaf weight per plant was recorded by Fe_3O_4 N3: 0.8 g.L^{-1} in the 2019 year and by Fe_3O_4 N2: 0.6 g.L^{-1} , with 147.20 and 160.00 g in 2019 and 2020, respectively. On contrary, the plant leaf ratio % for the treated corn plants by nano iron recorded lower than control plants were recorded the highest value, 22.69 and 22.37% in 2019 and 2020, respectively. While the lowest plat leaf ratio was recorded in N2M2 and N1M3 in 2019 and 2020, respectively. No significant differences were recorded between sprayed plants by nano iron and control on the number of leaves per plant parameter at the dough stage (117 DAP) during the 2020 and 2021 years.

For active dry yeast foliar application, plant leaf weight was statistically increased in the 'Tuano' maize cultivar when compared to the control. The lowest value of the leaves weight per plant was recorded on the control and this weight gradually increased with the increase of the applied yeast doses from 5 g.L^{-1} to 10 g.L^{-1} . While no significant difference was detected between the M1: 5 g.L^{-1} and M2: 7.5 g.L^{-1} of dry yeast on the plant leaf weight in the first year and between all dry yeast doses in the second year (Table 4.6). The highest values of leaves weight per plant were detected when plants were treated with M3: 10 g.L^{-1} of active dry yeast with 163.60 and 152.40 g in the first year and second one, respectively. On the other hand, there was not a significant difference between maize plants treated with all dry yeast concentrations and control on the number of leaves per plant of maize plants grown under alkaline soil conditions at the dough stage during the 2019 and 2020 years as Table 4.6 shown. For plant leaf ratio % of maize grown under high pH soil conditions at the dough stage (117 DAP) during 2020 and 2021 years, the highest value recorded under control plant, and this parameter decreased with increasing dry yeast doses from 5 to 10 g.L^{-1} as a foliar application.

Table 4.6. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M) and their combined (NM) on the number of leaves per plant, leaves weight per plant, and plant leaf ratio % of maize grown under high pH soil conditions at the dough stage

Year		2019 Year			2020 Year			Mean of 2019 and 2020		
Character		NO. leaves per plant	Leaves weight/plant (g)	Plant leaf ratio %	NO. leaves per plant	Leaves weight/plant (g)	Plant leaf ratio %	NO. leaves per plant	Leaves weight/plant (g)	Plant leaf ratio %
Treatments										
Control		14.33	92.00 h	22.69 a	13.53 b	114.07 d	22.37 a	13.93	103.04	22.53
N1: 0.4 g.L ⁻¹		14.18	104.00 gh	19.78 bc	14.20 ab	126.27 cd	21.02 b	14.19	115.14	20.40
N2: 0.6 g.L ⁻¹		13.63	127.00 def	19.07 cd	14.33 a	160.00 abc	20.61 b	13.98	143.50	19.84
N3: 0.8 g.L ⁻¹		14.55	147.20 cd	19.78 bc	14.47 a	140.00 abcd	16.68 e	14.51	143.60	18.23
N Mean		14.12	126.07	19.54	14.33	142.09	19.44	14.23	134.08	19.49
M1: 5 g.L ⁻¹		14.34	120.40 efg	18.92 cde	14.13 ab	138.67 abcd	18.41 cd	14.24	129.54	18.67
M2: 7.5 g.L ⁻¹		15.02	136.53 de	18.87 cdef	14.33 a	146.67 abcd	18.00 d	14.68	141.60	18.44
M3: 10 g.L ⁻¹		14.83	163.60 bc	17.88 efg	14.53 a	152.40 abcd	15.87 ef	14.68	158.00	16.88
M Mean		14.73	140.18	18.56	14.33	145.91	17.43	14.53	143.05	17.99
N1M1		14.46	144.00 cd	20.39 b	14.07 ab	149.60 abcd	19.14 c	14.27	146.80	19.77
N1M2		14.27	142.27 d	18.65 def	14.33 a	135.47 abcd	15.31 f	14.30	138.87	16.98
N1M3		14.12	210.53 a	17.79 fg	14.47 a	170.27 ab	13.97 f	14.30	190.40	15.88
N2M1		14.35	162.27 bc	19.02 cd	14.07 ab	142.40 abcd	15.56 f	14.21	152.34	17.29
N2M2		15.17	169.73 b	16.62 h	14.40 a	166.67 abc	15.71 ef	14.79	168.20	16.17
N2M3		14.72	118.00 efg	19.05 cd	14.33 a	130.67 bcd	18.47 cd	14.53	124.34	18.76
N3M1		15.25	173.07 b	17.29 gh	14.60 a	174.13 a	15.43 f	14.93	173.60	16.36
N3M2		13.97	117.20 efg	19.95 bc	14.40 a	129.07 bcd	18.75 cd	14.19	123.14	19.35
N3M3		14.78	112.67 fg	20.23 b	14.40 a	126.80 cd	19.37 c	14.59	119.74	19.80
NM Mean		14.57	149.97	18.78	14.34	147.23	16.86	14.45	148.60	17.82
P-Value		0.1065	<.0001	<.0001	0.3708	0.0522	<.0001			
Minimum		13.63	92.00	16.62	13.53	114.07	13.97	13.93	103.04	15.88
Maximum		15.25	210.53	22.69	14.60	174.13	22.37	14.93	190.40	22.53
SE		0.22	11.31	0.372	0.16	8.21	0.333			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

The mixed foliar treatments of nano iron Fe_3O_4 and active dry yeast on corn plants significantly increased leaves weight per plant as shown in Table 4.6 under the alkaline soil conditions in Van, Türkiye in comparison to control non-stressed plants. The mixed treatment of 0.4 g.L^{-1} of Fe_3O_4 and 10 g.L^{-1} of dry yeast (N1M3) recorded the highest values in the 2019 year and N3M1 (0.8 g.L^{-1} of Fe_3O_4 and 5 g.L^{-1} of dry yeast) in the second year (2020) compared with non-sprayed plants as control.

No. leaves per plant parameter were slightly impacted due to using either nano iron Fe_3O_4 and active dry yeast as an individual or as a mixed treatment but the effect was insignificant compared to control. For plant leaf ratio % of maize, the N3M3 compound treatment recorded the highest value in comparison to other mixed treatments, while still, the control is the highest at 117 DAP in both years.

Data in Table 4.7 pointed out that by spraying nano iron Fe_3O_4 on corn plants under high pH soil conditions, there was a significant increase in the number of cobs per plant, cobs weight per plant, and plant cob ratio %. The third dose from nano Fe_3O_4 recorded the highest values of the previous characters in comparison with control untreated plants which it was recorded the lowest values of the number of cobs per plant, cobs weight per plant, and plant cob ratio %. It is clear that there were no significant differences between all doses of nano iron-on cobs number per plant.

For active dry yeast foliar application, using the three doses of dry yeast have a positive effect on the number of cobs per plant, cobs weight per plant, and plant cob ratio % of the maize plants growth for silage purposes in comparison with the control treatment (Table 4.7). The data is presented in Table 4.7. that, the cobs number per plant increased with increasing the concentration of active dry yeast from 5 to 10 g.L^{-1} on maize, the highest value of the number of ears per plant (1.53 and 1.60) were recorded at 10 g.L^{-1} in 2019 and 2020 year respectively, while the lowest values of the number of cobs per plant (1.00 and 1.13 in a first and second year respectively) were obtained in the control non-application of dry yeast. On the other hand, it is seen that there are no statistically significant differences between all yeast doses on the number of cobs per plant and plant cob ratio %.

Table 4.7. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M) and their combined (NM) on the number of cobs per plant, cobs weight per plant, and plant cob ratio % of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year			2020 Year			Mean of 2019 and 2020		
Character	NO. cobs per plant	Cobs weight/plant (g)	Plant cob ratio %	NO. cobs per plant	Cobs weight/plant (g)	Plant cob ratio %	NO. cobs per plant	Cobs weight/plant (g)	Plant cob ratio %
Treatments									
Control	1.00 b	109.87 h	25.09 i	1.13 d	170.53 j	34.39 i	1.07	140.20	29.74
N1: 0.4 g.L ⁻¹	1.00 b	167.33 g	31.55 h	1.13 d	217.47 i	36.44 h	1.07	192.40	34.00
N2: 0.6 g.L ⁻¹	1.27 b	253.33 de	37.47 cde	1.27 cd	318.27 fg	41.41fg	1.27	285.80	39.44
N3: 0.8 g.L ⁻¹	1.27 b	284.00 cd	37.42 cde	1.40 bcd	377.67 de	44.96 abc	1.34	330.84	41.19
N Mean	1.18	234.89	35.48	1.27	304.47	40.94	1.22	269.68	38.21
M1: 5 g.L ⁻¹	1.07 b	236.93 def	36.39 ef	1.40 bcd	323.87 fg	42.95 de	1.24	280.40	39.67
M2: 7.5 g.L ⁻¹	1.27 b	274.67 d	37.55 cd	1.33 cd	354.13 ef	43.51 de	1.30	314.40	40.53
M3: 10 g.L ⁻¹	1.53 ab	347.60 b	37.90 bc	1.60 abc	423.00 cd	44.00 bcd	1.57	385.30	40.95
M Mean	1.29	286.40	37.28	1.44	367.00	43.49	1.37	326.70	40.38
N1M1	1.27 b	268.40 d	37.65 bc	1.33 cd	332.73 fg	42.69 def	1.30	300.57	40.17
N1M2	1.33 b	283.20 cd	36.51 def	1.40 bcd	405.00 d	45.95 a	1.37	344.10	41.23
N1M3	1.87 a	483.07 a	41.01 a	1.93 a	523.73 a	43.14 de	1.90	503.40	42.08
N2M1	1.47 ab	334.67 bc	38.73 b	1.33 cd	412.47 d	45.16 ab	1.40	373.57	41.95
N2M2	1.53 ab	378.67 b	36.98 cde	1.80 ab	463.47 bc	43.64 cde	1.67	421.07	40.31
N2M3	1.07 b	224.40 defg	35.74 f	1.13 d	299.73 gh	42.39 ef	1.10	262.07	39.07
N3M1	1.87 a	388.80 b	38.77 b	1.80 ab	485.60 ab	42.99 de	1.84	437.20	40.88
N3M2	1.07 b	204.00 efg	33.92 g	1.07 d	291.73 gh	42.36 ef	1.07	247.87	38.14
N3M3	1.13 b	184.80 fg	32.49 h	1.13 d	262.53 h	40.25 g	1.13	223.67	36.37
NM Mean	1.40	305.56	36.87	1.44	386.33	43.17	1.42	345.94	40.02
P-Value	0.0047	<.0001	<.0001	0.0002	<.0001	<.0001			
Minimum	1.00	109.87	25.09	1.07	170.53	34.39	1.07	140.20	29.74
Maximum	1.87	483.07	41.01	1.93	523.73	45.95	1.90	503.40	42.08
SE	0.12	35.38	0.372	0.11	33.15	0.453			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

While no significant differences were found between the M1: 5.0 g.L⁻¹ and M2: 7.5 g.L⁻¹ of dry yeast doses on the weight of the cob per plant. Also, the minimum value of the cobs' weight per maize plant and plant cob ratio % in untreated control plants were detected. The compound treatments of nano iron and dry yeast were the highest values of the number of cobs per plant, cobs weight per plant, and plant cob ratio % of maize grown under high pH soil conditions for silage purposes in Van, Türkiye when compared to singular treatments by nano iron or dry yeast or unsprayed plant as control. The N1M3 treatment resulted from the highest values of the previous indicators in both years at 117 DAP of maize plants. While the application of N1M2 gave the highest value of the plant cob ratio % of maize in the 2020 year. Moreover, N3M1 and N1M3 doses recorded the highest measurement of the number of cobs per plant in the 2019 harvest year for silage as Table 4.7. shown.

The presented data in Table 4.8 refer to the impact of using nano iron and/or dry yeast on green and dry grass yield/da of maize for silage in Van, Türkiye. Concerning the effects of spraying nano iron Fe₃O₄ on corn plants, the studied characters significantly increased with increasing the nano iron dose from 0.4 to 0.8 g.L⁻¹ except for the green grass yield/da in 2019 was insignificant. The highest green and dry grass yield/da were detected in corn treated with active dry yeast (0.8 g.L⁻¹ of nano Fe₃O₄) with no differences between N2 and N3 for the green grass yield/decare in the first year.

For active dry yeast, the samples in both years are in Table 4.8. indicated that the foliar application of yeast significantly increased the green and dry grass yield/da of maize compared to the control in the non-sprayed plants at 117 DAP. M3: 10 g.L⁻¹ of yeast recorded the highest values with 9.77 and 8.84 tons for green grass yield/da, and 2.94 and 3.43 tons for dry grass yield/da in 2019 and 2020, respectively. While the smallest values were the control non-sprayed plants (7.82 and 7.20 tons of green grass yield/da, 1.41 and 1.85 tons of dry grass yield/da, in 2019 and 2020 respectively). However, all doses of active dry yeast improved the mentioned parameters in Table 4.8., but there are slight differences (no significant difference) between the M1 and M2 concentrations of active dry yeast for green grass yield/da and between M2 and M3 for the same character.

The compiled treatments between nano iron and active dry yeast in Table 4.8 showed that the effects of the compiled treatments on green and dry grass yield/da of maize were

significant in the fourth stage at 117 DAP. However, the N1M3 (0.4 g.L⁻¹ of Fe₃O₄ and 10 g.L⁻¹ of dry yeast) interaction effects of the nano iron and active dry yeast were recorded at the highest values of the studied characters at both years in the dough stage but not at the first year for the green grass yield/da where the N3M1 treatment has resulted in the highest value (0.8 g.L⁻¹ of Fe₃O₄ and 5 g.L⁻¹ of dry yeast) in Van city under high pH soil (Table 4.8).

Table 4.8. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on green and dry grass yield/decare of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year		2020 Year		Mean of 2019 and 2020	
Character	Green grass yield/da (tons)	Dry grass yield/da (tons)	Green grass yield/da (tons)	Dry grass yield/da (tons)	Green grass yield/da (tons)	Dry grass yield/da (tons)
Treatments	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
Control	7.82	1.41 k	7.20 j	1.85 i	7.51	1.63
N1: 0.4 g.L ⁻¹	8.38	1.52 jk	7.52 ij	2.11 h	7.95	1.82
N2: 0.6 g.L ⁻¹	8.77	2.22 ef	8.05 gh	2.68 f	8.41	2.45
N3: 0.8 g.L ⁻¹	9.09	2.43 d	8.69 de	2.94 de	8.89	2.69
N Mean	8.75	2.06	8.09	2.58	8.42	2.32
M1: 5 g.L ⁻¹	9.21	2.17 fg	8.37 efg	2.30 g	8.79	2.24
M2: 7.5 g.L ⁻¹	8.94	2.38 de	8.87 d	2.88 e	8.91	2.63
M3: 10 g.L ⁻¹	9.77	2.94 bc	8.84 d	3.43 b	9.31	3.19
M Mean	9.31	2.50	8.69	2.87	9.00	2.68
N1M1	9.65	2.33 def	8.46 ef	2.80 ef	9.06	2.57
N1M2	9.34	2.51 d	8.23 fg	3.08 cd	8.79	2.80
N1M3	9.62	3.61 a	9.98 a	3.72 a	9.80	3.67
N2M1	9.18	2.82 c	9.41 b	3.14 c	9.30	2.98
N2M2	9.56	3.10 b	8.89 cd	3.51 b	9.23	3.31
N2M3	8.94	1.98 gh	7.72 hi	2.29 g	8.33	2.14
N3M1	10.01	3.14 b	9.24 bc	3.56 b	9.63	3.35
N3M2	8.44	1.88 hi	7.80 hi	2.13 h	8.12	2.01
N3M3	8.91	1.68 ij	7.35 j	2.11 h	8.13	1.90
NM Mean	9.29	2.56	8.56	2.93	8.93	2.74
P-Value	0.1572	<.0001	0.0015	<.0001		
Minimum	7.82	1.41	7.20	1.85	7.51	1.63
Maximum	10.01	3.61	9.41	3.56	9.59	3.59
SE	0.155	0.067	0.116	0.049		

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

4.3. Impact of Nano Iron, and Active Dry Yeast on Chemical Characters of Maize Plants at the Dough Stage.

The result of foliar application of nano iron and/or active dry yeast on the concentrations of macro and microelements of maize plants grown under high pH levels for silage during the 2019 and 2020 years at the dough stage (117 DAP) are given in Tables 3.9, 3.10, 3.11 and 4.12.

For using nano iron as a foliar application on corn plants, Table 4.9 shows that phosphorus, potassium, and calcium concentrations g/100 g (%) significantly increased where the Fe_3O_4 doses increased from N1 to N3. N3: 0.8 g.L⁻¹ of nano iron detected the highest concentration of the precious mineral in maize at 117 DAP in both planting years, except phosphorus and calcium concentrations when sprayed by N2: 0.6 g.L⁻¹ for the 2020 year in comparison to control plants. It is noticeable that no significant differences were recorded between N2: 0.6 and N3: 0.8 g.L⁻¹ of nano iron for corn phosphorus concentration in the 2019 harvest year, while the potassium, and calcium concentrations in maize plant when sprayed by N2: 0.6 and N3: 0.8 g.L⁻¹ of nano iron were found significant only in the first year (Table 4.9).

The impact of active dry yeast on maize plants, Table 4.9 reported that all sprayed doses of dry yeast significantly increased the phosphorus, potassium, and calcium concentrations in corn compared to the control. M3: 10 g.L⁻¹ of active dry yeast recorded the highest values of the P, K, and Ca concentrations with 0.27 and 0.23 g/100 g for phosphorus, 1.23 and 1.31 g/100 g for potassium, and 1.19 and 1.23 g/100 g for calcium in the 2019 and 2020 year, respectively. On the other hand, it was determined that there was an insignificant difference in the concentrations of P element between all yeast doses in the 2020 year, between N1: 0.4 and N2: 0.6 g.L⁻¹ of nano iron for potassium in both years, and between N2: 0.6 and N3: 0.8 g.L⁻¹ as well as between N1: 0.4 and N2: 0.6 g.L⁻¹ for calcium in the second 2020 year.

Table 4.9. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on Phosphorus, Potassium, and Calcium concentration g/100 g (%) of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year			2020 Year			Mean of 2019 and 2020		
Character	P	K	Ca	P	K	Ca	P	K	Ca
Treatments									
Control	0.15 h	0.82 i	0.59 i	0.19 e	0.74 i	0.62 h	0.17	0.78	0.61
N1: 0.4 g.L ⁻¹	0.18 g	0.90 h	0.71 h	0.19 e	1.03 h	0.74 gh	0.19	0.97	0.73
N2: 0.6 g.L ⁻¹	0.23 e	1.06 g	0.89 g	0.23 bcd	1.18 cdefg	1.11 cd	0.23	1.12	1.00
N3: 0.8 g.L ⁻¹	0.24 de	1.16 de	1.10 de	0.20 de	1.28 cd	1.08 cde	0.22	1.22	1.09
N Mean	0.22	1.04	0.90	0.21	1.16	0.98	0.21	1.10	0.94
M1: 5 g.L ⁻¹	0.21 f	1.05 g	0.88 g	0.22 bcde	1.11 fgh	0.91 efg	0.22	1.08	0.90
M2: 7.5 g.L ⁻¹	0.24 de	1.08 fg	1.08 e	0.21 cde	1.23 cdef	1.07 cde	0.23	1.16	1.08
M3: 10 g.L ⁻¹	0.27 c	1.23 cd	1.19 c	0.23 bcd	1.31 c	1.23 bc	0.25	1.27	1.21
M Mean	0.24	1.12	1.05	0.22	1.22	1.07	0.23	1.17	1.06
N1M1	0.23 de	1.14 ef	0.97 f	0.22 bcde	1.21 cdefg	1.07 cde	0.23	1.18	1.02
N1M2	0.25 d	1.19 cde	1.12 de	0.20 de	1.19 cdefg	1.06 cde	0.23	1.19	1.09
N1M3	0.33 a	1.63 a	1.39 a	0.27 a	1.48 b	1.52 a	0.30	1.56	1.46
N2M1	0.26 c	1.24 c	1.15 cd	0.23 bc	1.16 defg	1.05 cde	0.25	1.20	1.10
N2M2	0.27 c	1.36 b	1.27 b	0.24 ab	1.31 c	1.30 b	0.26	1.34	1.29
N2M3	0.21 f	0.96 h	0.89 g	0.19 e	1.14 efgh	0.94 def	0.20	1.05	0.92
N3M1	0.30 b	1.35 b	1.27 b	0.27 a	1.66 a	1.50 a	0.29	1.51	1.39
N3M2	0.21 f	0.98 h	0.87 g	0.21 cde	1.26 cde	0.90 efg	0.21	1.12	0.89
N3M3	0.19 fg	0.96 h	0.74 h	0.21 cde	1.08 gh	0.86 fg	0.20	1.02	0.80
NM Mean	0.25	1.20	1.07	0.23	1.28	1.13	0.24	1.24	1.10
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001			
Minimum	0.15	0.82	0.59	0.19	0.74	0.62	0.17	0.78	0.61
Maximum	0.33	1.63	1.39	0.27	1.66	1.52	0.30	1.65	1.46
SE	0.001	0.008	0.001	0.010	0.022	0.001			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

The analysis of variance results in Table 4.9 shown, that the combined effects of the nano iron Fe₃O₄ and active dry yeast treatment on maize plants' P, K, and Ca concentrations were significant at the dough stage in the two summer years (2019 and 2020) in comparison

to control where no foliar treatments were used. The highest values of the mentioned elements were detected when maize plants were sprayed with N1M3 in the first year and N1M3 and N3M1 in the second year for phosphorus and calcium concentrations, and by N1M3 in the first year and N3M1 in the second year for potassium concentration in maize plant at 117 DAP.

Table 4.10. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on Magnesium and Iron concentration g/100 g (%) of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year		2020 Year		Mean of 2019 and 2020	
Character	Mg	Fe	Mg	Fe	Mg	Fe
Treatments						
Control	0.55 h	0.08 j	0.46 g	0.07 l	0.51	0.08
N1: 0.4 g.L ⁻¹	0.66 cd	0.09 ij	0.58 f	0.11 k	0.62	0.10
N2: 0.6 g.L ⁻¹	0.64 defg	0.13 f	0.66 cde	0.17 gh	0.65	0.15
N3: 0.8 g.L ⁻¹	0.65 cdef	0.15 de	0.66 cde	0.20 def	0.66	0.18
N Mean	0.65	0.12	0.63	0.16	0.64	0.14
M1: 5 g.L ⁻¹	0.64 def	0.12 fg	0.61 ef	0.15 hi	0.63	0.14
M2: 7.5 g.L ⁻¹	0.72 b	0.16 d	0.71 bcd	0.19 efg	0.72	0.18
M3: 10 g.L ⁻¹	0.66 cd	0.19 c	0.72 bc	0.22 cd	0.69	0.21
M Mean	0.67	0.16	0.68	0.19	0.68	0.17
N1M1	0.63 defg	0.14 ef	0.70 bcd	0.18 fgh	0.67	0.16
N1M2	0.69 bc	0.16 d	0.69 bcd	0.21 cde	0.69	0.19
N1M3	0.78 a	0.38 a	0.83 a	0.29 a	0.81	0.34
N2M1	0.73 ab	0.19 c	0.74 b	0.22 cd	0.74	0.21
N2M2	0.61 efg	0.30 b	0.73 b	0.24 bc	0.67	0.27
N2M3	0.59 gh	0.11 gh	0.66 de	0.14 ij	0.63	0.13
N3M1	0.74 ab	0.29 b	0.86 a	0.25 b	0.80	0.27
N3M2	0.66 cde	0.10 hi	0.61 ef	0.13 ijk	0.64	0.12
N3M3	0.61 fg	0.09 ij	0.61 ef	0.12 jk	0.61	0.11
NM Mean	0.67	0.20	0.71	0.20	0.69	0.20
P-Value	<.0001	<.0001	<.0001	<.0001		
Minimum	0.55	0.08	0.46	0.07	0.51	0.08
Maximum	0.78	0.38	0.86	0.29	0.81	0.335
SE	0.001	<.0001	0.002	0.001		

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

For the maize magnesium and iron concentrations, the data presented in Table 4.10 indicated that the foliar application of nano iron Fe_3O_4 on corn has recorded a positive effect on the Mg and Fe contents in plants in both years. However, it was found that there was an insignificant difference in the concentrations of magnesium elements between the all-nano iron Fe_3O_4 doses in the 2019 year, and also between N2 and N3 in the second year-2020. On the other hand, no significant difference in the concentrations of iron as g/100 g (%) between N1 and the control-untreated plants in the second year at the dough stage of maize (117 DAP) under alkaline soil conditions.

It should be noted that there was a significant difference between dry yeast foliar application treatments and control plants. So that the highest plant content of magnesium was obtained from the M2: 7.5 g.L^{-1} of yeast in the first year and from the M3: 10 g.L^{-1} yeast in the second year compared to control plants. While the concentration of iron in maize was detected from the M3: 10 g.L^{-1} yeast dose treatment at the dough stage in both years. Furthermore, the lowest amount of plant magnesium and iron was obtained from the controlled level, indicating the positive effects of the spraying of active dry yeast on the corn plant magnesium and iron content in alkaline soils in Van, Türkiye (Table 4.10).

The data in Table 4.10 found that the plants foliar treated with both nano iron and active dry yeast exhibited higher magnesium and iron concentrations in 2019 and 2020 in comparison to the controlled treatment. The highest Mg plant contents were detected when used N1M3 in the first year, and N1M3 and N3M1 in the second year. While the highest concentration of Fe in maize was recorded by using N1M3 in both summer years at the dough stage (117 DAP). The lowest amount of magnesium and iron g/100 g (%) was observed for the control under alkaline soils in Van, Türkiye.

Manganese, molybdenum, and selenium concentrations (mg.kg^{-1}) of maize in the dough stage differed significantly according to doses of yeast and control applications in both years 2019 and 2020 (Table 4.11). The concentration of selenium significantly increased when maize plants were sprayed with nano iron Fe_3O_4 compared to the control non-sprayed plants. The highest plant concentration of selenium was detected in corn treated with N3: 0.8 g.L^{-1} dose of nano iron, followed by (N2: 0.6 g.L^{-1}) of nano Fe_3O_4 , while the smallest value

was the control non-sprayed plants of selenium concentration with no significant difference between N1: 0.4 g.L⁻¹ of nano Fe₃O₄ and control treatment in both years at 117 DAP.

Table 4.11. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M), and their combined (NM) on Manganese, Molybdenum, and Selenium concentration (mg.kg⁻¹) of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP)) during 2019 and 2020 years

Year	2019 Year			2020 Year			Mean of 2019 and 2020		
Character	Mn	Se	Mo	Mn	Se	Mo	Mn	Se	Mo
Treatments									
Control	90.71 i	0.58 j	0.78 a	141.39 a	0.08 j	0.72 a	116.05	0.33	0.75
N1: 0.4 g.L ⁻¹	104.09 defg	0.68 j	0.71 a	125.23 cd	0.38 ij	0.59 b	114.66	0.53	0.65
N2: 0.6 g.L ⁻¹	126.18 a	0.94 gh	0.31 def	116.60 de	0.89 gh	0.38 cdef	121.39	0.92	0.35
N3: 0.8 g.L ⁻¹	108.34 cde	1.05 ef	0.24 f	147.77 a	1.56 de	0.50 bc	128.06	1.31	0.37
N Mean	112.87	0.89	0.42	129.87	0.94	0.49	121.37	0.92	0.46
M1: 5 g.L ⁻¹	116.15 abc	0.86 hi	0.34 cde	115.23 de	0.76 ghi	0.45 cd	115.69	0.81	0.40
M2: 7.5 g.L ⁻¹	104.54 defg	0.98 fg	0.30 def	125.53 bcd	1.44 ef	0.78 a	115.04	1.21	0.54
M3: 10 g.L ⁻¹	96.39 fghi	1.19 d	0.36 cd	135.11 abc	2.46 c	0.44 cde	115.75	1.83	0.40
M Mean	105.69	1.01	0.33	125.29	1.55	0.56	115.49	1.28	0.45
N1M1	114.08 bcd	0.97 fg	0.26 ef	112.07 de	1.08 fg	0.37 def	113.08	1.03	0.32
N1M2	101.30 efghi	1.06 ef	0.29 def	64.84 g	1.80 de	0.25 f	83.07	1.43	0.27
N1M3	106.23 cdef	2.70 a	0.26 ef	89.83 f	3.77 a	0.31 ef	98.03	3.24	0.29
N2M1	101.75 efgh	1.14 de	0.75 a	121.72 cde	1.92 d	0.44 cde	111.74	1.53	0.60
N2M2	103.28 efgh	1.30 c	0.35 cd	110.53 e	3.00 b	0.44 cde	106.91	2.15	0.40
N2M3	93.23 hi	0.85 hi	0.37 cd	143.47 a	0.65 hi	0.49 bcd	118.35	0.75	0.43
N3M1	95.86 fghi	1.90 b	0.47 b	138.77 ab	3.23 b	0.43 cde	117.32	2.57	0.45
N3M2	94.98 ghi	0.83 i	0.41 bc	112.55 de	0.57 hi	0.39 cde	103.77	0.70	0.40
N3M3	120.11 ab	0.82 i	0.72 a	117.14 de	0.47 hij	0.38 cde	118.63	0.65	0.55
NM Mean	103.42	1.29	0.43	112.32	1.83	0.39	107.87	1.56	0.41
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001			
Minimum	90.71	0.58	0.24	64.84	0.08	0.25	99.43	0.45	0.32
Maximum	126.18	2.7	0.78	147.77	3.77	0.78	130.75	2.85	0.72
SE	0.354	0.034	0.042	0.445	0.013	0.078			

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

On another hand, the foliar application of nano Fe_3O_4 on maize has recorded a negative effect on molybdenum concentrations at 117 DAP, where the highest concentration of molybdenum was detected in the control (untreated plants), and the concentrations decreased with increasing the doses of nano Fe_3O_4 . The same trend was recorded for the manganese concentrations in the second year where the control is the highest level of Mn plant content, while the N2: 0.6 g.L⁻¹ recorded the highest amount of manganese in the 2019 year (Table 4.11). Concerning the foliar application of active dry yeast on maize plants, data in Table 4.11 shows that the selenium concentration significantly increased with gradually increasing the doses of active dry yeast from M1: 5 to M3:10 g.L⁻¹. The highest value of Se was detected in M3 compared to untreated plants as the control in the 2019 and 2020 years under alkaline soil conditions in Van, Türkiye. In the 2019 and 2020 summer years, molybdenum and manganese concentrations as mg.kg⁻¹ significantly decreased with increasing the spraying of dry yeast doses on corn plants for silage purposes in the first year but on contrary for the second year at the dough stage as Table 4.11 has shown.

In this study, the maize plant under the conditions using nano iron and dry yeast in both years for silage showed more enhancement for selenium concentration than in the control condition and simple treatment by either nano Fe_3O_4 or active dry yeast. Since the plant's selenium content resulted from combined treatment had a higher rate, N1M3 dose has produced the highest value in the 2019 and 2020 harvest years (Table 4.11). On contrary, molybdenum amount in corn plants at the dough stage was decreased in comparison to control which recorded the highest value of Mo concentration as mg.kg⁻¹. For the impact of mixed treatment on manganese plant content, an unclear trend was detected between doses and years. However, N3M3 recorded the highest concentration of Mn in comparison to other integration doses in the first year but N2M3 dose resulted in the biggest concentration in the second year compared to other combined treatments under alkaline soil conditions in Van city, Türkiye.

Data in Table 4.12 show, that the zinc and copper concentrations (mg.kg⁻¹) in both 2019 and 2020 years significantly impacted as a result of nano iron Fe_3O_4 and/or active dry yeast foliar application on corn plants at 117 DAP in the alkaline soils in Van, Türkiye.

Applying nano iron positively improved the zinc concentration in the maize plant in the dough stage (at 117 DAP). Although the control recorded the highest value of Zn concentration, there is no significant difference among all doses of nano iron as well as controlled treatment for 2019 and 2020 harvest years. For copper maize plant content, the N2: 0.6 g.L⁻¹ doses in the first year and N3: 0.8 g.L⁻¹ were recorded as the highest concentration of copper in maize plants grown under high pH levels (Table 4.12).

Table 4.12. Effect of foliar application of nano iron Fe₃O₄ (N), active dry yeast (M) and their combined (NM) on Zinc and Copper concentration (mg.kg⁻¹) of maize grown under high pH soil conditions at the dough stage 117 days after planting (DAP) during 2019 and 2020 years

Year	2019 Year		2020 Year		Mean of 2019 and 2020	
Character	Zn	Cu	Zn	Cu	Zn	Cu
Treatments						
Control	73.63 efgh	24.73 fg	79.60 c	29.65 fg	76.62	27.19
N1: 0.4 g.L ⁻¹	67.98 hi	26.63 fg	56.87 de	33.69 ef	62.43	30.16
N2: 0.6 g.L ⁻¹	68.26 hi	35.91 d	48.55 ef	27.04 gh	58.41	31.48
N3: 0.8 g.L ⁻¹	70.24 fghi	20.63 g	56.77 de	47.81 a	63.51	34.22
N Mean	68.83	27.72	54.06	36.18	61.45	31.95
M1: 5 g.L ⁻¹	65.78 i	38.61 d	103.36 a	28.46 g	84.57	33.54
M2: 7.5 g.L ⁻¹	76.73 ef	52.16 abc	90.62 bc	40.25 bc	83.68	46.21
M3: 10 g.L ⁻¹	94.36 d	57.24 ab	65.27 d	40.77 bc	79.82	49.01
M Mean	78.96	49.34	86.42	36.49	82.69	42.92
N1M1	69.97 fghi	28.49 ef	41.88 fg	27.43 gh	55.93	27.96
N1M2	73.20 efgh	35.08 de	93.11 ab	19.15 i	83.16	27.12
N1M3	115.08 b	49.12 c	56.48 de	38.70 cd	85.78	43.91
N2M1	77.91 d	51.40 bc	58.44 de	26.54 gh	68.18	38.97
N2M2	103.01 c	59.26 a	59.09 de	36.99 cde	81.05	48.13
N2M3	70.25 fghi	53.24 abc	40.23 fg	35.71 de	55.24	44.48
N3M1	69.19 ghi	48.32 c	63.44 d	43.24 b	66.32	45.78
N3M2	161.30 a	38.60 d	34.53 g	23.46 hi	97.92	31.03
N3M3	76.12 efg	35.60 de	55.18 de	32.79 gh	65.65	34.20
NM Mean	90.67	44.35	55.82	31.56	73.25	37.95
P-Value	<.0001	<.0001	<.0001	<.0001		
Minimum	65.78	20.63	34.53	19.15	54.08	19.89
Maximum	161.30	59.26	103.36	47.81	81.68	53.54
SE	0.236	0.237	0.665	0.297		

The means within each column within main effects and compounds followed by the same letter are not significant at $P \leq 5\%$. SE: standart error.

Increasing the active dry yeast concentration from 0 (control) to 10 g.L⁻¹ significantly increased the zinc concentrations in the first year but it was at the opposite in the second year 2020 in maize plants where the zinc concentrations were decreased. For copper concentrations, it is observed from Table 4.12 that, the use of active dry yeast on corn plants increased the copper plant contents. The highest rate of copper in maize was found with M3: 10 g.L⁻¹ yeast in both harvesting years, with no significant difference was showed between M2: 7.5 and M3: 10 g.L⁻¹ active dry yeast in the two years.

For the mixed treatments from nano iron Fe₃O₄ and active dry yeast, the data is presented in Table 4.12 indicated that because of the applying mixed material on maize, the highest value of the zinc concentration as mg.kg⁻¹ was recorded at N3M2 in the 2019 year with 161.30 mg.kg⁻¹, while the N1M2 dose gave the higher concentration of Zn in the second year with 93.11 mg.kg⁻¹ compared to other mixed treatments on maize plant for silage purposes in alkaline soil.

However, it was determined that there was a significant difference in the concentrations of the copper element between the combined yeast and nano iron doses and the control-untreated plants. Where the N2M2 resulted from the highest value of copper content with 59.26 mg.kg⁻¹ in the 2019 harvest year and the N3M1 dose gave the biggest concentration of Cu with 43.24 mg.kg⁻¹ in the second year 2020 at the dough stage (117 DAP) in comparison to other single or mixed treatments under high pH soil level.

5. DISCUSSION AND CONCLUSION

Corn/Maize (*Zea Mays* L.) is an important plant used as silage material in animal nutrition in the world. Starch, glucose, and corn oil obtained from the grain of corn are of great importance in terms of raw materials in the economy (Süzer, 2004). Most of the animal products are produced in Eastern Anatolia in Türkiye. Corn, for silage, is very important in animal feeding because winter season conditions last longer in Eastern Türkiye (Kaya et al., 2010). The pH of most of the soils of Türkiye is above seven and their lime content is high (Güçdemir, 2006). The application of bio-stimulators such as yeast can be expected to minimize environmental contamination by decreasing the use of synthetic fertilizers and chemicals in plant production (El-Nemr et al., 2015). One of them is yeast, it is stated that the application of yeast extracts increases the negative effects of adverse environmental conditions such as drought and increased yield of plants (Hammad and Ali, 2014). Moreover, in recent years, nano fertilizers have been started to be produced in order to obtain the highest amount and quality products from the cultivated area. Substances with a size below 100 nm are called nanomaterials, and it has been seen that they can be utilized within the generation, handling, bundling, and transportation of rural products (Scott and Chen, 2003; Wiesner et al., 2006). Inquire about appears that Nano fertilizers cause an increment within the productivity of the utilization of plant supplements, decrease poisonous soil quality, minimize the potential negative impacts of over-the-top fertilizer utilization, and diminish the recurrence of fertilizer application. Nano fertilizers are important in farming to extend trim surrender and supplement utilize proficiency, and diminish the utilization of chemical fertilizers utilized in over-the-top dosages (Dağhan, 2017). On another hand, it has been suggested that nano-fertilizers can become resistant to variable and severe atmospheric conditions, biotic-abiotic stress, and diseases with their mechanism of action at the enzymatic and hormonal level, based on their positive contribution to the development of the plant throughout its life period (Mukherjee et al., 2015).

Data from the present investigation showed that the using Fe_3O_4 or/and dry yeast increased most of the studied parameters of maize plants grown under the high level of soil

pH in Van Province eastern Türkiye. Results presented by many researchers such as Doğan et al. (1997) stated that the average plant height was 188.30 cm in their experiment which was carried out on different silage corn varieties as the main product in Bursa conditions, Turan and Yılmaz (2000) conducted a study on different silage corn varieties as the main and second product in Van conditions, and the average plant height was 228.50 cm. Also, Yılmaz and Akdeniz (2000) determined the plant height as 205.10 cm in the research they conducted as the main crop in Van conditions. Also, Demir et al (2011) harvested maize during the milk stage in Van Province in Eastern Türkiye, the mean plant high was 195.5 to 203.1 cm. In our study, the average plant height of maize plants at the dough stage was found above these values with a value of 259.02-262.06 cm (Table 4.4). Plant height is very important in terms of yield in silage maize. It has been reported by some researchers that plant height directly affects yield in maize and this effect is 35% (Kara et al., 1999). Plant height in maize is an inherited trait that is affected by the environment and growing conditions. Silage aims to obtain more green parts per unit area. For this reason, high plant height is important along with other features in our current study under Van city conditions.

Nanotechnology has a wide range of applications and uses such as medicine, industry, and agriculture. Nano fertilizers are one of the most important products of this technology, especially in terms of meeting the nutritional needs of the increasing population in the agricultural field, increasing the yield and quality of the product, and reducing the amount and cost of chemical fertilizers. Ultra-Small sizes make nanoparticles tremendously useful (Dağhan, 2017). Plaksenkova et al. (2019) moreover found that Fe_3O_4 NPs ($1\text{-}2\text{ mg.L}^{-1}$) had a positive impact on the development and improvement of the rocket (*Eruca sativa*). At the same time, Fe_3O_4 NPs significantly expanded the concentration of root polysaccharide and the dispersion of its dry matter, which appeared that Fe_3O_4 NPs advanced the blend of natural materials. This could explain the reason for the promotion of the growth of plant root tubers due to easily entering the NPs iron into plants and boosting organic matter synthesis, distribution, and accumulation to roots. Konate et al. (2018) found that Fe_3O_4 NPs enhance plant root growth through increased elasticity of root cell wall and increase pectin declination. All previous could be a result of the reaction between plant and Fe_3O_4 NPs to produce OH^- ROH (free radicals). Like the study by Chen et al. (2018), our findings showed

that plant shape was impacted by various Fe_3O_4 NP concentrations. Where the maize plant height, leaf, stem, and weight were increased in comparison to control untreated plants. One hypothesis was that Fe_3O_4 NPs increased the activity of iron oxygen reductase, facilitating the reduction and utilization of iron while also indirectly promoting the anabolism and catabolism of porphyrin to produce the chlorophyll precursor -aminolevulinic acid (Maswada et al., 2018). The primary natural pigment involved in the photosynthesis process that gives plants their color is chlorophyll. The building blocks for absorbing and converting light energy into chemical energy are photosynthetic pigments (Ruiz-Espinoza et al., 2010). The chlorophyll (Chl) and its components Chla/Chlb concentrations are critical pointers to depict the physiological status of plant photosynthetic tissues, which enormously affect plant photosynthesis (Feng et al., 2003). The improved chloroplast size, yield, and rubisco protein concentration may be to blame for the increased photosynthetic activity (Timperio et al., 2007). The chlorophyll content of maize plants in our study increased to foliar application of either nano iron or dry yeast or their interaction doses at the 84 DAP stage of the maize plant life cycle.

Also, the number of leaves is an important factor in silaged corn. Because the increase in the number of leaves will increase plant growth and silage quality. However, besides the number of leaves, leaf weight and leaf ratio are of great importance as mentioned by (Orak and İptaş 1999, Sade et al. 2002, Güneş 2004, Öztürk and Orak, 2020). Many previous works have recorded the leaf number per plant i.e., Ayrancı (1999) determined that the number of leaves in corn varieties varied between 14.00 and 17.13 per plant during the main crop growing year in Konya conditions. Şahin and Kara (2021) mentioned that the number of leaves per plant for the silage horse female corn varieties in 2019 and 2020 is 12.9-15.2 and 13.3-15.6 leaves/plant, respectively. Additionally, Öztürk and Orak (2020) cultivated some important corn varieties as the second crop in Tekirdag conditions were not found statistically significant among corn varieties in terms of the number of leaves per plant (11.62-12.20 leaves) in both years of the study. Moreover, Meşe (2021) carried out agriculture trials in Bilecik ecological conditions of 18 silage corn varieties, the plants were harvested during the pulping period. The average number of leaves was 14.33 in 2019 and 14.22 in 2020. In our research, the number of leaves changed between 14.29-14.50 leaves per plant, and the values

obtained with this research during the dough period (Table 4.6). These research findings were close to the findings of Taş (2010) were recorded at 12.49-18.49 leaves/plant and Öner and Güneş (2019) with 11.67-13.63 leaves. Furthermore, because yeast produces cytokinin, which delays the senescence of leaves by slowing down the breakdown of chlorophyll and speeding up the production of RNA and proteins, the considerable increase in leaf growth brought on by yeast solution may be explained by an increase in photosynthetic pigments (Marzauk et al., 2014). Because yeast includes essential growth regulators that influence the balance between anabolism and catabolism of plant material, the amount of chlorophyll in leaves may have increased (photosynthesis and respiration) (Abou EL-Yazied and Mady, 2012).

The illustrated parameters in Tables 4.1, 4.2, and 4.3 are in agreement with the findings presented by (Abu Khouder et al., 2019; Ghareeb, 2019; Al-Shaheen et al., 2019; Al-madhagi, 2019; Hassan et al., 2020), they pointed out that the application of yeast increased the plant height, the number of leaves/plant and rate of chlorophyll in the plant leaves. In this study, it is thought that the lowest amount of the studied variables in the untreated control plants group is due to the alkalinity of the soil where the corn is grown. Bavaresco and Poni (2003) mentioned that it is generally known that chlorophyll synthesis is adversely affected in alkaline soils. On the other hand, the highly impactful CO₂ release was due to the use of active dry yeast which subsequently leads to an increase the net plant photosynthesis (Ferguson et al., 1995; Vas and Papanas, 2019). The increase in the concentration of chlorophyll when the foliar application of yeast is because it contains the natural hormones that motivate chlorophyll formation. Moreover, Yeast includes Cytokinin, which is vital for chloroplast upgrowth and is the backbone of chlorophyll synthesis. Moreover, it contains nitrogen, which is involved in chlorophyll creation, and this may have led to an increase in the chlorophyll concentration in plants, these results are in the same trend as those (Ezz EL-Din and Hendawy, 2010) results. Dry yeast's potential impact on the signaling of the nutritional signal that makes up growth regulators could explain why it can activate the vegetative growth of plants (El Ghadban et al., 2003). Furthermore, Sarhan and Abdullah (2010) found that analyzing yeast into various beneficial materials i.e., plant growth

regulators, vitamins, and amino acids after applying it to plants may cause a positive impact of it on plant shoots indicators. El-Tohamy and El-Greadly (2007) stated that applied of dry yeast at (5 and 10 g.L⁻¹.) doses resulted in enhancing the quality of snap beans (*Phaseolus vulgaris*) plants pods in terms of chlorophyll, protein, carbohydrates, and decreased fiber content. Increasing dry materials formation in the plant leaves could be a result of yeast action in motivating the manufacturing of carbohydrates and proteins (Sarhan et al., 2011) and activating the process of photosynthesis, which participates in leaf dry matter aggregation. The reason may also be that the foliar application of yeast caused an increase in the level of internal stimulators plant hormones in leaves such as cytokinin and Auxins and reduced their content of inhibitor hormones such as abscisic acid (Mady, 2009). The yeast solution includes many different inorganic minerals that are crucial for plant growth (Marzauk et al., 2014) moreover, they produce a few plant growth regulators that encourage the plants, like cytokines and gibberellins. Enhance physiological activity, accrete cell division and expansion, and in consequence increasing vegetative growth of the plant (Chapman and Pratt, 1982). The good impact of yeast extract in improving the growth of plant stem may be due to the direct or indirect effect of yeast through its ability to alter the roots' environment and change the soil pH then the elements' availability increase that positively affects plant growth (Amadi, 1991) if it is applied on the soil. Additionally, yeast contains the Trehalose-6-phosphate enzyme, a crucial component in the production of trehalose, which promotes plant growth (Al-Nuaimi, 1984).

Host range experiments were conducted to study the ability of nano irons to improve the growth of several plants. It is possible to describe nano fertilizers as nanomaterials that give plants one or more nutrients and promote their growth (Liu and Lal, 2015; Chhipa and Joshi, 2016). These fertilizers are slowly soluble and highly effective as fertilizers. Slow-release Nano fertilizers if they are applied on soil, are easily absorbed by plants without losing through washing or altering from the soil, without binding to substances such as organic matter, clay, and lime, creating compositions with other elements and becoming useless, have the potential to be preferred more (Mukherjee et al., 2015). In one of three ways, nano fertilizer delivers nutrients to the plant: (i) The nutrient element can be enclosed in nanomaterials like nanotubes or nonporous materials; (ii) it can be shielded from the

environment by a thin polymer film; or (iii) it can be delivered to the plant as nanoscale particles or emulsions (Jampilek and Kráľová, 2015; Valizadeh and Milic, 2016). Our study's results appeared that spraying maize with different concentrations of nano Fe_3O_4 ($0.4\text{--}0.8 \text{ g.L}^{-1}$) could significantly enhance chlorophyll (SPAD value), thereby promoting morphological characters under high soil pH field conditions. The results of this study support the findings of Li et al. (2021a) on *Pseudostellaria heterophylla* plants by foliar spraying of NPs Fe_3O_4 under field conditions. They mentioned that the foliar application of iron NPs greatly enhanced growth, root dry matter distribution, and root tuber production per cultivated area. Iron Fe_3O_4 improved the net photosynthetic rate (P_n) by increasing the amount of chlorophyll in plants. The fluorescence parameters of the chlorophyll revealed that the used nano iron lightened photoinhibition by boosting the photochemical excessive energy use and enhancing the photochemical activity of PSII. Additionally, Ghafariyan et al. (2013) mentioned that even low doses of Fe-NPs significantly promoted the content of chlorophyll in soybean leaves under hydrophobic conditions. Thus, Fe-NPs can be used as an iron source in soybeans and have been shown to reduce the chlorotic manifestations of iron deficiency. As well as, in comparison to the control, Delfani et al. (2014) discovered that foliar treatment of 500 mg Fe-NPs/L in peas raised the chlorophyll content by 10%. Those results were likely due to our findings shown in Tables 4.1, 4.2, and 4.3.

Concerning the weight of leaves, stems, cobs, and plant shoots shown in Tables (4.4, 4.5, 4.6, and 4.7), using either nano iron oxide or/and active dry yeast increased the previous parameters of maize plants compared to control (unsprayed plants) at the dough stage in the two years (2019 and 2020) in the dough production period.

Similar results were obtained by Saedpanah (2016) on maize plants who reported that the leaf dry weight increased due to the use of nano iron, and total dry biomass increased as well in corn plants (Sharifi et al., 2016), leaf fresh weight and dry weight increased in peppermint plants (Askary et al, 2017), biomass (shoot and root) of maize plants was enhanced (Elanchezhian et al. 2017), shoot dry weight of wheat plants was promoted (Fathi et al., 2017; Rizwan et al., 2019; Al-Amri et al., 2020), vegetative growth and root quality (diameter and weight) of red radish plants increased (Mahmoud et al., 2019), fresh and dry

weights of paper plant parts improved (Sajyan et al., 2020), and the fresh and dry weight of sweet basil increased (Farshchi et al., 2021).

For application of active dry yeast, exogenous application of dry yeast improved the previous studied characteristics as that in harmony with the findings of many pieces of research i.e. plant fresh weight, and fresh weight of pods and average pod weight/plant of snap bean (El-Tohamy and El-Greadly, 2007; Abdel-Hakim et al., 2012; AL-Amery and Mohammed, 2017; Abu Khouder et al, 2019), fresh and dry weight of leaves of eggplant plants (El-Tohamy et al., 2008; El-Nemr et al., 2015), dry weights of both stems of faba bean (Mady, 2009), fresh and dry weight of aerial parts of borage plants (Ezz El-Din and Hendawy, 2010), fresh and dry weights and individual fruit weight of sweet paper plants (Ghonomie et al., 2010), fresh and dry weight of whole potato plant (Ahmed et al., 2011), shoot dry weight per kidney bean plant (Nassar et al., 2011), fresh and dry weights of both stems and leaves and pods yield per broad bean plant (Abou EL-Yazied and Mady, 2012; Marzauk et al., 2014), fresh and dry weight of leaves and stems and fruit weight of cucumber (Shehata et al, 2012; Al-madhagi, 2019), and total fresh and dry weight of pea plants (Mahmoud et al., 2013).

In this context, there are many studies regarding the application of yeast on different plants, their results indicated that plants growth is positively affected such as maize, rose, olive, potato, cucumber, broad bean, sweet potato, and cassava plants reported by (Ghareeb, 2019; Al-Shaheen et al., 2019; Mahmoud et al., 2015; Ahmed et al., 2011; Shehata, et al., 2012; Marzauk et al., 2014; Abo EL-Fadl et al., 2017; Hassan et al., 2020). In this context, yeast extract is considered one of the natural cytokinin sources and it has a catalytic effect on the growth of plants. Additionally, yeast extracts were recommended to take a part in the beneficial roles of cell division (Khedr and Farid, 2002; Wanas, 2002; Amer, 2004). Also, this result was parallel with Abed and Zeboon (2020), who reported that for yeast, the growth characteristics e.g., plant height, stem diameter, number of leaves, leaf area, and leaf area index, were increased with the use of the yeast spray on the sunflower plants. Our results mentioned in Tables (4.4, 4.5, 4.6, and 4.7) are in the same trend. Moreover, Altunlu et al. (2019) reported that biological fertilizer application had a positive effect on plant growth in sweet corn. Plant height and stem diameter increased with the application of all biological

fertilizer doses compared to the control. In addition, the effect of applications in terms of the number of ears per plant is statistically insignificant. Furthermore, Seadh et al. (2015 and 2017) investigated that foliar application of yeast on maize significantly increased corn plant growth, yield, and its components, and this treatment recorded the highest values of the studied parameters. This result is in similarity Al-Ani et al. (2020) mentioned, that corn productivity improves when using some factors such as yeast extract as foliar fertilization with natural growth stimulants. The yeast spray's potential to create phytohormones including auxins, gibberellic acid, cytokinin, and certain vitamins may be to blame for the increase (EL-Kholy et al., 2007), they encourage cell proliferation and elongation by their physiological activity. Additionally, they include minerals like nitrogen and amino acids that promote plant growth, this finding is in line with that of Ahmed et al. (2011) and Hammad and Ali (2014), who found that yeast played a significant impact in boosting plant height, stem diameter, and leaf area for various plants. The researchers may attribute this increase in plant growth to the effect of biological fertilizer (yeast), which may be related to the increase of water and nutrient uptake in alkaline soil, and the positive effect on producing secondary metabolites such as hormones, enzymes etc. In addition, studies have illustrated that yeast improved the plant's resistance to high levels of temperature and salinity (Omar, 2003; Samra et al., 2014). In this context, in addition to increasing the concentration of leaf pigments, which in turn led to an improvement in the efficiency of photosynthesis in the leaves and the aggregation of total soluble sugars, which are the immediate products of photosynthesis, yeast may also have increased the area of plant leaves exposed to photosynthesis, which may have contributed to the rise in total carbohydrates (Mady, 2009). Alternatively, it's possible that the yeast catalyzes the release of CO₂ during fermentation, which will eventually aid in photosynthesis and enhance the amount of goods produced by the process (Khalil and Ismael, 2010).

In the study, high yields (9.10 and 8.41 ton.da⁻¹ in 2019 and 2020, respectively) of green herbage and dry herbage (2.38 and 2.78 ton.da⁻¹ in 2019 and 2020, respectively) per decare of maize were obtained when foliar treated by nano iron oxide or/and active dry yeast as average at the dough stage (117 DAP). Many previous works have recorded the green and dry herbage yields at the corn i.e., Zorer Çelebi et al. (2009) found that the corn green herbage

varied between 5068.1 and 3033.3 Kg.da⁻¹. Where the dry herbage ranged between 1057.0 and 783.2 Kg.da⁻¹ during the lactation production period in Van province, Türkiye. Kaya et al. (2010) in Van province mentioned that the average corn fresh herbage was 25980.1 to 38849.3 kg.ha⁻¹ in 2007 year and between 27086.1 and 37683.3 kg.ha⁻¹ in 2008 at the milk production stage. Zorer Çelebi et al. (2010) worked on maize plants in Van conditions and recorded that during the milk production period, the green herbage yields of maize were (26960 to 34980.3 kg.ha⁻¹ in 2007) and (27360.3 to 34610.4 kg.ha⁻¹ in 2008). While were ranged (from 5840.8 to 7600.3 kg.ha⁻¹ in 2007) and (from 5570.0 to 7460.0 kg.ha⁻¹ in 2008). Demir et al. (2011) investigated the green herbage yield as kg/ha in 2009 (25780.1-38170.5) and 2010 (25970.8-38040.0). Whilst the dry one was (5400.7-8460.8 kg.ha⁻¹ in the 2009 year) and (5330.8-8260.3 kg.ha⁻¹ in 2010 year) for maize in the milky plant maturity stage. Our current findings are more than the previous ones in the same area conditions in Van city eastern Türkiye. Yıldız and Erdoğan (2018) found that silage corn (6586.55 Kg.da⁻¹, 1796.21 Kg.da⁻¹) was found in terms of green grass and dry matter yield at the dough stage. Ağırağaç and Zorer Çelebi (2022) established field corn experiments in the province of Van in 2019 and 2020 as the second crop after the wheat harvest. An average corn wet grass yield of 5293.8-5966.6 Kg.da⁻¹ was found in the milk production period. But the average dry grass yield was between 1484.8 and 1573.6 Kg.da⁻¹.

According to Hatwar et al. (2003), the application of nanoparticles can produce an increase in growth because of the enhanced photosynthetic and other metabolic activities that result in a rise in the number of plant metabolites necessary for plant cell division and elongation. The overall results showed that iron fertilizer NPs (nano iron chelate) is more effective than micro-ones (EDDHSA chelate) on saffron plants (Farahani et al., 2015). Moreover, Manjili et al. (2014) have arranged iteratively. Local pistachio seed m variety (NC2) was used as plant material. Half of the nitrogenous fertilizers (0-30-60 kg/ha N) are applied in the form of urea and as base fertilizer, and the remaining part is applied 20, 30, and 40 days after the growing period, while nano-chelated Mo fertilizer (0, 1, 2 and 3 g is applied). Half of the L⁻¹ nano-Mo) was applied from the leaves during the branching period and the remainder during the flowering period. The results of the analysis of variance obtained at the end of the experiment, the plant height, number of capsules per plant, number of mature capsules per

plant, hundred seed weight, number of seeds per plant, seed length, seed and capsule yield, number of lateral branches and biological have a significant impact on properties. In addition, when the averages of different values of nano-chelate Mo fertilizer were compared, it was shown that the highest capsule and seed yield (2320 and 3715 kg.ha⁻¹, respectively) were obtained from the application of 3 g.L⁻¹ nano-Mo fertilizer. Furthermore, Hassani et al. (2015) applied chemical fertilizers (Fe, Zn, and K) and nano (Fe, Zn, and K) fertilizers separately or in combination on the peppermint (*Mentha piperita* L.) plant. The results showed that the chemical and nano fertilizers positively affected plant morphology and yield characteristics. According to the results which obtained, the researchers reported that although chemical fertilizer application did not have a negative effect, nano fertilizer applications were more effective on plant yield. Researchers Armin et al. (2014), Fathi et al. (2017), Hussain et al. (2019), Rizwan et al. (2019) on wheat, Roozbahani and Mohammadkhani (2015), Sharifi et al. (2016), Elanchezhian et al (2017), Jayarambabu et al. (2018), Al-Shaheen et al. (2020), Hasan et al. (2020), Yan et al. (2020) on corn, Shahrekizad et al. (2015) on sunflower, Rui et al. (2016) on peanut plants, and Soliemanzadeh and Fekri (2021) on sorghum plants, highlighted that the application of Nano-Fe increased the biological yield, aerial organ dry biomass, and fresh and dry biomass (shoots and roots) and seeds, while the lowest values were achieved in the control untreated plants. Moreover, Soliman et al. (2015) mentioned that Moringa plants sprayed with Fe₃O₄ Nanoparticles figure out an improvement in growth parameters either under normal or abiotic stress as saline conditions when compared to control. Furthermore, Jalali et al. (2016) pointed out that foliar-sprayed of maize plants with or without ethylene diamine-N and 100 µg.g⁻¹ of Fe₃O₄ NPs, Fe-EDDHA has grown in calcareous soil, Accelerated vegetative development and an earlier transition into the production phase where the results of iron treatment. Additionally, partially, maize growth development might be imputed to the use of Fe₃O₄ NPs, to the boost in ferritin and its important function in the maintenance of Fe homeostasis and balance of the plant redox system. Furthermore, Joshan et al. (2016) revealed that using iron nanoparticles on maize gave the highest amount of seed dry weight, chlorophyll a, b, carotenoid, and peroxidase and (Jalali et al., 2017) hydrogen peroxide (H₂O₂) scavenging capacity and reduced the membrane lipid peroxidation rate in comparison to control untreated plants. Rui

et al. (2016) stated that the Fe_2O_3 NPs enhanced the peanuts growth through organizing internal plant hormone contents and activity of antioxidant enzyme in peanut plants. Also, Sharifi et al. (2016) pointed out that the increment of crude protein, soluble carbohydrates concentrations, and phosphorus uptake were obtained in the nano-iron spraying treatment, compared with the control in maize plants. Using nano-iron oxide Fe_3O_4 significantly increased cucumber biomass and the antioxidant enzymes superoxide dismutase (SOD) and peroxidase (POD) (Konate et al., 2018). The zero-valent (Cu, Fe, and Co) NPs treatment significantly enhanced the rate of seed germination and early growth. Furthermore, both activities of the SOD and APX enzymes were increased in leaves, and improved of the superoxide metabolism, resulting in the promotion of maize plants' resistance against drought (Hoang et al., 2019). This previous evidence may explain the reasons for the high green yield of maize obtained in our study as referred to in Table 4.8. Our results show that the green and dry yield increased when the nano Fe_3O_4 dose increased from 0.4 to 0.8 g.L^{-1} compared to control but without a significant difference between 0.6 and 0.8 g.L^{-1} doses.

For the effects of dry yeast on the yield as shown in Table 4.8, these results are similar to the previous review. El-Tohamy and El-Greadly (2007), Abdel-Hakim et al. (2012), AL-Amery and Mohammed (2017) on the snap bean, El-Tohamy et al (2008), El-Nemr et al (2015) on eggplant, Mady (2009) on faba bean, Ezz El-Din and Hendawy (2010) on borage, Ghoname et al. (2010) on sweet paper, Ahmed et al. (2011) on potato, Nassar et al. (2011) on kidney bean, Abou EL-Yazied and Mady (2012), Marzauk et al. (2014) on the broad bean, Fawzy et al. (2012) on onion, Ibrahim et al. (2012) on sugar beet, Shehata et al. (2012), Al-madhagi (2019) on cucumber, Dawood et al. (2013) on soybean, and Nassar et al. (2016) on Leucaena, who reported that foliar application of yeast treatment significantly improved vegetative growth characters and yield components (plant height, number of leaves, plant fresh and dry weight for both shoots and roots, number of fruit, and fresh weight of fruit) of plants compared to control untreated-plants.

We observed that the foliar application of various dry yeast dosages increased both green/fresh and dry weight per unit area as a ton per decare as shown in Table 4.8.

The benefits of dry yeast application were demonstrated by the fact that it was regarded as a natural source of cytokinin, which encourages cell division and growth as well

as the development of proteins, chlorophyll pigment, and nucleic acids (Kraig and Heber, 1980; Spencer et al., 1983; Castelfranco and Beale, 1983; Fathy and Farid, 1996). Furthermore, it includes vitamins, proteins, amino acids, and sugar (Shady, 1978). Amer (2004) concluded that the improvement of the vegetative growth parameters of snap beans plants by increasing the level of yeast extract application may be due to the that, Many of the nutrients and cytokinin are naturally present in yeast extracts, which are natural components that had an important role in cell elongation and division, consequently increased the plant growth. The trends of obtained results are in good accordance with the previous investigators, such as Shafeek (2015), Marzauk et al. (2014), and Attala et al. (2000), the benefits of dry yeast application were demonstrated by the fact that it was regarded as a natural source of cytokinin, which encourages cell division and growth as well as the development of proteins, chlorophyll pigment, and nucleic acids. These results in our study are in agreement with those obtained by Al-Amery and Mohammed (2017), who illustrated that yeast or yeast extraction is the natural source of hormones that increased the vegetative growth characteristics of legumes planets. Also, previous research has demonstrated that dry yeast contains a variety of plant growth factors, including GAs, auxin, and others, which promote the growth and activity of the plant cells (Václavík et al., 2014). These results are consistent with the results of the dry yeast extract which has led to a net growth in the leaf weight ratio. Important characteristics that are dependent on the plant's capacity for growth, development, and production define this influence.

The yeast expands the photosynthetic exposed plant part as the leaf area and the content of carbohydrates increases. Furthermore, yeast has a role in incrementing the pigment concentration in the leaf that boosts the photosynthesis process efficiency and eventually enhances the accumulation of the direct components of photosynthesis (which are sugars) (Mady, 2009). Or that the yeast motivates CO₂ release from the process of fermentation which considers a key and backbone item of photosynthesis. CO₂ will later engage in the process of photosynthesis and increase the overall photosynthetic products (Khalil and Ismael, 2010). Yeast composition includes amino acids and fats moreover as vitamins and a few mineral components. This may explain the improvement in the protein contents in plant leaves as a result of yeast application (Abd El-Motty et al., 2010). The yeast also has

motivating impacts on the division of cells and the enlargement and building up of protein from amino acids, this causes the proteins in the treated plants to aggregate more (Fathy and Farid, 1996).

Concerning the impacts of foliar spraying of iron Fe_3O_4 NPs, active dry yeast, and their interaction on macro and micronutrients concentration of maize grown under high pH soil conditions at the dough stage 117 DAP during 2019 and 2020 years, results in Tables (4.9, 4.10, 4.11, and 4.12) showed enhancement of almost minerals in the shoots.

For nano iron, our findings agree with those results obtained by Shahrekizad et al. (2015) on sunflower, Soliman et al. (2015) on Moringa, Elanchezhian et al. (2017), Hasan et al. (2020) on maize, Fathi et al. (2017), Hussain et al. (2019), Rizwan et al. (2019), Al-Amri et al. (2020), Manzoor et al. (2021) on wheat, De Souza et al. (2019) on bean plants, who demonstrated that increased N, P, K, Ca, Mg, Fe, and Zn content of plants relative to the control non sprayed plants. Joshan et al. (2016) reported that foliar using 0.01% iron nanoparticles yielded the greatest content of soluble leaf proteins and total soluble solids in fodder maize leaves. Moreover, Elanchezhian et al. (2017) on maize stated that when using iron NPs, there is potential to reduce the amount of iron added to plants. The efficiency of iron utilization is boosted in important grain crops such as corn. Sheykhbaglou et al. (2018) stated after spraying five doses of ferrous nano-oxide (nano- Fe_2O_3) on soybean plants, that patterns in the profile of fatty acids have changed (linolenic acids, oleic, palmitic, and linoleic), contents of chlorophyll, and many elements (Fe, Mg, Ca, and P) were similar to lipid and protein levels which, by an increase in ferrous nano-oxide content from 0 to 0.75 g.L^{-1} all studied indicators increased as well, but the decrease in all parameters was noticed in the high Fe dose from 0.75 to 1 g.L^{-1} , this finding in agreement with our results that show no significant difference between N2 and N3 (0.6 and 0.8 g.L^{-1}) on maize plants at the dough stage (117 DAP). Manzoor et al. (2021) showed that the application of 100 mg.kg^{-1} of the bioengineered FeO-NPs in saline soil promoted the growth of wheat plants, plant high increased by 36.7% compared to the control plants, by softening the harmful effects of environmental stresses and thus reprogramming the morphophysiological wheat plants status.

Askari et al. (2014) applied iron oxide NPs (Fe_3O_4) at six different concentrations (0, 5, 10, 20, 30, and 40 μM) to *Catharanthus roseus* plant grown in Hogland nutrient medium (containing Fe-chelate) under controlled conditions for 70 days and evaluated the results obtained in comparison with the control plant. It was reported that the application of Fe_3O_4 nanoparticles significantly increased the leaf growth parameters and carbohydrate content, but the application of Fe nonfertilizer did not have any effect on the proline amount, antioxidants, and stomal density of the leaf. In this context, inorganic chemical fertilizers are lost and rendered unavailable to plants in considerable quantities after being introduced to the soil. For instance, the amount of nitrogen (N), phosphorus (P), and potassium (K) fertilizers that are lost or absorbed in soils is 40–70%, 80–90%, and 50–90%, respectively (Ombódi and Saigusa, 2000). Also, using Fe_3O_4 in nano form has improved the photosynthesis of maize (*Zea mays*) plants, has reduced the membrane lipid peroxidation rate, and has been protective from the negative impacts of salinity stress (Mahboobeh et al., 2016). Therefore, it will add more fertilizers to the soil to recover lost fertilizers, which will negatively affect the balance of the soil between nutrients (Baruah and Dutta, 2009). Previously, Tarafdar et al. (2012) showed that nanomembranes can be used to encapsulate conventional fertilizer molecules to ease the slow release of the addendum. Due to the slow discharging rate of nutritional supplements during plant crop production, these slow-release nano-fertilizers could be a considerable substitution for soluble inorganic traditional fertilizers. Therefore, plants would be able to take in most of their nutritional needs without wastage (Huiyuan et al., 2018). Fertilizer molecules coated with nanomaterials are stronger than conventional ones due to their higher surface tension, which enhances and controls the nutrient release efficiency (Brady and Weil, 1999). Mannose and amino acids are also frequently utilized because they facilitate plants' nutrition uptake. Additionally, nanocomposites enhance the nutrients' solubility and dispersion in soils, boosting plants' ability to absorb them. El-Saadony et al. (2021) stated that many mineral micronutrients, i.e., silica, zinc, copper, and iron have been synthesized at the nanoscale and used in plant growth management. Additionally, Nano-fertilizers perform a crucial action in the physiological and biochemical processes of plant crops by rising nutrient availability. Heidari et al. (2018) investigated the effects of plant growth-promoting rhizobacteria (PGPR) and/or Fe-chelated

nanoparticles (NPs) on maize growth, grain yield, and physiological responses. They discovered that spraying *Azospirillum brasilens* and nano increased the maize plant's growth and productivity. Additionally, adding bioagents and nano Zn-Fe oxide to salt-stressed wheat plants greatly boosted photosynthesis, seed development, and the presence of stimuli such as antioxidant enzymes, soluble carbohydrates, and proline (Babaei et al., 2017). Metal complexes can penetrate plant cells thanks to the negative charge on their surface, which facilitates the flow of negatively charged substances across their membranes (Tandy et al., 2006). The antioxidant capacity in rice plants is enhanced by using nano fertilizers (Weisany et al., 2012). Antioxidants are secondary organic metabolites synthesized and increased in plants under stress circumstances such as salinity, drought, and deficiency of nutrients. The nano fertilizer supplies enough nutrients to stimulate antioxidant activity since plant cells can more easily absorb it (Benzon et al., 2015). According to Drostkar et al. (2016), the pointed out that spraying of nano Zn, Fe, and NPK fertilizers positively influences the growth of chickpea plants, resulting in good impacts on productivity and its ingredients. In this regard, Yağmur et al., (2005) found that the total N and P, K, Ca, and Mg contents of the leaf blade and stem were at the lowest level in the control and increased in parallel with the increase in the applied dose as a result of foliar iron (Fe) applications. Furthermore, Nano-based fertilizers are more reactive and soluble, and they may penetrate the cuticle more deeply, enabling targeted administration and controlled release. Utilizing nano-fertilizers promotes crop growth, productivity in both quantity and quality, and nutrient usage efficiency while reducing environmental stress (El-Saadony et al., 2021), this is in agreement with our findings in the current study. In this context, although iron does not enter the structure of the chlorophyll molecule, it plays an important role in the synthesis of chlorophyll in the plant (Marschner, 2002). The amounts of chlorophyll and ferredoxin in plant leave change depending on the iron content, and as the concentration of iron increases, the amounts of chlorophyll and ferredoxin also increase (Kacar and Katkat, 2006). Iron is also an essential component of many proteins, and some enzymes are present during respiration and photosynthesis. Iron is immobile in plants and mobility in soil decreases, pH increases, and excessive phosphorus can cause deficiency. Iron deficiency is an important nutritional disorder in crops, especially in plants grown on calcareous soils, which causes a decrease in

vegetative growth, significant yield, and quality losses (Abadia et al., 2011). However, when applied as an iron leaf method, it reacts very strongly to maize growth parameters (Jamshidzadeh et al., 2014, Daliwal et al., 2013, Song et al., 2017). Akat et al. (2013) In *Limonium sinuatum* plant in arid areas with high pH, even if there is no direct interaction between iron fertilization and plant growth, yield and flower quality when evaluated in terms of the effect of the number of leaves, the improvement in fresh and dry weight of the upper part and nutrient uptake, the iron application It was observed that it was sufficient in the cultivation of *L. sinuatum*. This may explain the reasons for the increased maize plant growth in this experiment in Van city.

Concerning the effects of active dry yeast on improving concentrations of minerals in maize plants are achieved in our investigation in Tables (4.9, 4.10, 4.11, and 4.12). Similar results were obtained by other researchers El-Tohamy and El-Greadly (2007) and Abdel-Hakim et al. (2012) on snap bean, El-Tohamy et al (2008) on eggplant, Mady (2009) on faba bean, Ahmed et al. (2011) on potato, Abou EL-Yazied and Mady (2012) on the broad bean, Shehata et al. (2012) on cucumber, Mahmoud et al. (2013) on pea, Abbas (2013) on beans, Mahmoud et al. (2015) on olive, Abed Nasser et al. (2019) on lentils who pointed out that the yeast treatment resulted in a higher N, P, K, B, Fe, Mg, Mn, and Zn content of plants compared to control plants. Matter and El Sayed (2015) reported that the application of (2 and 4 g.L⁻¹) dry yeast increased the caraway plants' concentration of phosphorus and potassium in comparison to the control treatment. Abed Nasser et al. (2019) mentioned that the 10 g.L⁻¹ by both inoculating around the roots and foliar applying treatments of lentils showed the greatest significant difference in the concentration of the macronutrients of plants i.e., N, P, and K which reached (3.08, 2.67, and 1.23) respectively. While the lowest rate of nitrogen, phosphorus, and potassium at a percentage of (1.27, 1.55, and 0.50) respectively recorded in non-treated plants as control.

In this regard, the application of yeast (live or dead) to fertilized soil substantially boosted the N and P percentages of sub and above-ground parts of tomato and small sugarcane plants (Lonhienne et al., 2014). Moreover, the yeast might be included some macronutrients such as N, P, K, vitamins, and sugars, which lead to an increase of these elements post-plant treatment (Mostafa and Abou Raya, 2003). The role of yeast could also

be referred to its impact on the activity of enzymatic, some natural plant hormones producing, improving the ability to absorb nutrients, diversion of phosphorus from an unsolvable state to a dissolvable one, and increasing the plants to intake its, all of these increase the mineral content in plants (Abbas, 2013). Ryan (2002) stated that foliar fertilizers act in the role of secondary fertilizing, significantly increasing the soil's reduction of components and elements present in the soil. This method is not a replacement for fertilizing the land, but indeed a supplement to it and enhances the fertilizer's efficiency added to plants. In this context, Reed and Nagodawithana (1991) reported that the increase in the leaf area because of spraying with yeast may be due to its containing stimulants for growth such as Thiamin, Riboflavin, and Niacin. In addition to folic acid, minerals, and enzymes are necessary for carbon fixation processes. Sarhan (2008) noticed a significant increase in the physical and chemical characteristics of the potato and some vegetative growth parameters and yield traits when spraying plants with yeast suspension. Yazdani et al, (2009) confirmed that the spraying of yeast suspension on corn led to an increase in the content of the seeds from the mineral elements. Salim et al. (2018) reported that the cabbage yield significantly increased in response to the biofertilizer (*Pseudomonas fluorescens* and *Azotobacter chroococcum*) which played a significant role in improving the status of plant nutrients and promoting cabbage plant growth. Moreover, yeast spraying increased the concentrations of Mg^{2+} and Fe^{2+} which are substantial for the creation of chlorophyll, activation of enzymes, and chloroplast (Elhindi, 2012).

The enhancement of mineral compositions of maize plants due to spraying nano iron oxide Fe_3O_4 and/or active dry yeast would be directly reflected in the quantity of the green and dry herbage yield as that should be in our study's results. In consequence, the quality of corn silage would be increased because calcium, sulfur, and potassium are essential mineral elements in human and animal nutrition as reported by Duru (2000). P is a vital part of adenosine triphosphate (ATP), phospholipids, nucleic acids, and many other coenzymes. Purplish veins in older leaves, flower output from seeds and fruits, and reduced growth are signs of a P deficit.

K affects osmosis, and the operation of stomata by its role as a cofactor involved in protein formation, enzyme activation, and main solute functioning in water balance. Reduced

growth, older leaves that are twisted, mottled, or spotty, scorching leaf margins, and weak roots and stems are signs of K shortage. Fast-growing animals seem to have higher potassium requirements, and an increased protein level increases the demands. Potassium is the main cation in intracellular fluid and actions in acidic medium, organization of contraction of muscle, osmotic pressure, the transmission of the nerve impulse, especially the heart muscle, cell membrane function, and Na^+/K^+ -ATPase. Additionally needed for the formation of glycogen is potassium (Soetan et al., 2010).

Ca is necessary for cell wall building, consistency, and membrane composition, and permeability maintenance. It also stimulates some enzymes and coordinates a variety of cellular responses to stimuli. Symptoms of Ca deficiency are disfigured leaves, death of terminal buds, and root growth is decreased (Soetan et al., 2010). Bones, teeth, and the control of nerve and muscle function all contain calcium. Calcium participates in the coagulation of milk as well as the blood coagulation process, activating the conversion of prothrombin to thrombin. It plays a crucial function in the activating of enzymes. Calcium stimulates numerous enzymes such as lipase, succinic dehydrogenase, ATPase, etc. (Hays and Swenson, 1985; Malhotra, 1998; Murray et al., 1999; Soetan et al., 2010).

In this regard, Mg is part of the chlorophyll particles; it activates many enzymes. The deficiency symptoms of Mg are chlorosis and drooping leaves. Magnesium is an active substance of various systems of enzymes in that thymine pyrophosphate is a cofactor. The absence of magnesium produced extremely reduced oxidative phosphorylation. In addition, Mg is considered a primary activator for the phosphate-transferring enzymes myokinase, creatine kinase, and diphosphopyridinenucleotide kinase. Furthermore, it stimulates pyruvic acid oxidase, pyruvic acid carboxylase, and the condensing enzyme for the reactions in the tricarboxylic acid cycle (TCA cycle) or the Krebs cycle. It is also a component of bones, teeth, cofactor of enzymes such as kinases, etc. (Murray et al., 1999; Soetan et al., 2010).

While in calcareous soils, the Fe availability is greatly low because the solubility of ions of Fe^{2+} and Fe^{3+} reduces with increasing pH, where remarkable plant Fe deficiency not adapted to these conditions occurs (Römheld and Nikolic, 2006). Fe is a part of cytochromes, is involved in electron transport, activates various enzymes, and helps chlorophyll develop. The deficiency symptoms of Fe are chlorosis and yellow and green stripes in the herbs. Iron

transports oxygen similarly to hemoglobin. Fe has a key role in cellular respiration as a component of enzymes like cytochrome C, C1, A1, etc., contributing to biological oxidation (Malhotra, 1998; Soetan et al., 2010).

Moreover, Cu is an ingredient of many vital redox and lignin-biosynthetic enzymes. Symptoms of Cu deficiency are infirm growth, chlorosis, terminal buds' death, dead spots in leaves, and newly leaves necrosis (Soetan et al., 2010). The amount of iron ingested is influenced by copper, which is a component of several enzymes including cytochrome C oxidase, amine oxidase, CAT, POX, ascorbic acid oxidase, plasma monoamine oxidase, erythrocytrophin (ceruloplasmin), lactase, uricase, tyrosinase, and others (Chandra, 1990). It is important for bone growth and development (Malhotra, 1998; Murray et al., 1999).

In plants, Selenium is integrated originally by sulfur substitution in the cysteine and methionine. High Se concentration in plants leads to blind ataxia in horses and de-hairing and sloughing of horses and cattle hooves. As well as toxic Se considers an indirect reason for starvation and sometimes death in animals due to movement impediments, because it leads to animals being lame (Soetan et al., 2010). Selenium is a component of the glutathione peroxidase enzyme (Murray et al., 2000). Selenium is a mineral that is a component of a complete defense system that shelters the lively organism from the hurtful effect of reactive oxygen species (ROS) (Levander, 1983; Schrauzer, 2000; Wycherly et al., 2004).

Here Malhotra (1998) and Soetan et al. (2010) indicated that Zn is effective in the construction of chlorophyll, invigorates some enzymes, and functions as a part of the creation of auxin, chloroplasts, and starch. But the zinc deficiency symptoms are chlorosis, mottled or bronzed leaves, and abnormal roots. Moreover, the absorbed zinc that enters the liver was exported to peripheral tissue in plasma, bound to albumin after being united into zinc metalloenzymes. These results may be reflected in that increasing the zinc concentration in the maize plants sprinkled with nano iron with or without active dry yeast could lead to good results on animals' health and production in the current study.

Likewise, Mo is crucial for nitrogen fixation, a nitrate-reducing cofactor, and is a unit of the enzyme units used in nitrogen anabolism and catabolism. Whereas a low concentration of Mo in plants causes potential nitrogen deficiency, pale green leaves, coiled or cupped leaves, mottling, and necrosis of the old leaves (Malhotra, 1998; Soetan et al., 2010).

Feeds include minerals that act a significant role in reproduction, the productivity of milk, the provision of energy in animals (Kronqvist, 2011), skeleton formation, protein, and lipids synthesis (Plaizier et al., 2004). The dairy animals' performance is dependent on the sufficient supply of minerals of fodder that might differ due to soil fertility, ripening of crops, and fertilization strategies (Holtenius et al., 2008).

Proteins are organic substances made up of amino acids and are crucial parts of animal feed. Nucleic acid, which contains phosphorus and is known to control the production of proteins, and as a consequence P is vital in moving energy (Ali et al., 2019). P deficiency restricts leaf growth, photosynthesis, and eventually forage yield (Plénet et al., 2000). According to recent research, orthophosphate soils are reduced when P levels are low (Yan et al., 1996). According to recent research, a P shortage lowers the amount of orthophosphate in the chloroplast stroma, which may inhibit the process of synthesizing ATP (Carstensen et al., 2018). Moreover, nutrient freeing is delayed (Efthimiadou et al., 2009).

The following are the ways that copper strengthens the immune system: energy manufacture, the productivity of neutrophils and liveliness, antibody development, production of antioxidant enzymes, and multiplication of lymphocytes (Nockels, 1994; Niederman et al., 1994). Collagen and elastin fibers, which give blood vessels and copulative tissue their structure and elasticity, are made possible by copper (Larson, 2005). In cattle, pregnancy reduces, delays, or prevents estrus, death of the embryo, and inability to conceive are the widespread symptoms of the lack of copper (Phillippo et al., 1987; Corah and Ives, 1991).

Conclusively: Alkalinity reduces the availability, mobility, and absorption of many important macro and micronutrients that are critical to maize growth. This deficiency causes a bad effect on corn plant growth and yield (qualitative and quantitative). In the present study, we observed that the application of active dry yeast and/or nano iron oxide Fe_3O_4 produced significantly higher corn yield for silage purposes compared to untreated control plants, largely through the increased leaf, stem, and plant weight, chlorophyll contents, and mineral elements, which consequently boosted maize forage productivity under high pH soil level in Van city, Türkiye.

The results of the current study show that spraying active dry yeast with a concentration of 10 g.L^{-1} has good effects on most vegetative development features and the amount of key minerals' nutrients in the treated plants compared to the control plant that was not treated. Foliar application on maize plants with 0.6 g.L^{-1} with nano iron oxide Fe_3O_4 recorded the best rates of vegetative growth and some internal food concentrations compared to control non-sprayed plants. The best treatment recorded is the interaction/mixed between nano iron oxide Fe_3O_4 and active dry yeast especially N1M3 have resulted in a clear and significant enhancement in all studied parameters i.e., plant growth and productivity, quality, and quantity of maize plant yield for silage purposes in high pH soil levels in Van city



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EXTENDED TURKISH SUMMARY (GENİŞLETİLMİŞ ÖZET)

Deneme Van Yüzüncü Yıl Üniversitesi Yerleşkesi Tarla Bitkileri Bölümü Araştırma ve Uygulama Arazisi'nde alkali toprak özelliğine sahip bir arazide kurulmuş ve silaj amaçlı mısır yetiştirilmiştir. Çalışma, 2019 ve 2020 yıllarında aktif kuru maya, nano demir oksit Fe_3O_4 ve iksisinin birlikte yaprak uygulamalarının mısır (*Zea mays* L. Cv. Tuano) bitkisinin büyüme, verim ve kimyasal bileşen üzerine etkilerini belirlemek amacıyla yürütülmüştür. Her iki yıl ekim 15 Mayıs'ta yapılmıştır. Deneme sahasının toprağı kumlu-killi yapıya sahiptir. Deney alanının koordinatları 38°34'18.8" kuzey enlemi ve 43°17'17.5" doğu boylamındadır. Saha deneyleri, Tesadüf Blokları Deneme Deseni'ne göre üç tekerrürlü olarak düzenlenmiştir. Denemede, parsel uzunluğu beş metre, parseller arası iki metre ve bloklar arası üç metre olacak şekilde uygulanmıştır. Her blokta 16 parsel bulunmaktadır. Ekim, altı sıralı ekim mibzeri ile sıra üzeri 12 cm, sıra arası 70 cm olacak şekilde yapılmıştır. Ekimle birlikte tüm parsellere 8 kg/da saf azot ve 8 kg/da saf fosfor oranında gübre verilmiştir. Mısır 50-60 cm boyuna ulaştığında 10 kg/da saf azot uygulanmıştır. Bitki toprağını havalandırmak ve yabancı otlarla mücadele için boğaz doldurma ve çapalama yapılmıştır (birincisi 4-6 yapraklı olduğu dönemde ve ikincisi 8-10 yapraklı olduğu dönemde). Bitkiler yağmurlama sulama sistemi ile sulanmıştır, daha sonra karık sulama sistemi şeklinde sulama yapılmıştır. Son sulama hasattan 10-14 gün önce yapılmıştır. Çalışmada nano demir oksit (Sigma-Aldrich, Darmstadt, Almanya'dan satın alınan) Fe_3O_4 'ün üç farklı dozu (N1: 0.4, N2: 0.6 ve N3: 0.8 g.L⁻¹), aktif kuru mayanın üç farklı dozu (menşei Türkiye olan yerel pazarlardan temin edilmiştir) (*Saccharomyces cerevisiae*) (M1: 5, M2: 7.5 ve M3: 10 g.L⁻¹) ve birlikte uygulama etkileşimleri (N1M1, N1M1, N1M2, N1M3, N2M1, N2M2, N2M3, N3M1, N3M2, N3M3) ve kontrol (musluk suyu püskürtme) uygulamaları yapılmıştır. İlk uygulama ekimden sonra 54. günde yapılmış ve ilk püskürtmeden 15 gün sonra ikinci uygulama yapılmıştır. Her iki yılda da on bitki tesadüfen seçilmiş, incelenen parametreler (bitki boyu, bitkideki yaprak sayısı ve SPAD değeri olarak klorofil içeriği) her iki yılda üçer kez (ekimden 64, 74 ve 84 gün sonra) kaydedilmiştir. Hasat işlemi, her iki yılda hamur olum döneminde yapılmıştır (ekimden 117-123 gün sonra). Çalışmada, bitki boyu (cm), yaprak/bitki sayısı (adet), koçan/bitki sayısı (adet), bitki başına yaprak ağırlığı (g), bitki

başına gövde ağırlığı (g), bitki başına koçan ağırlığı (g), toprak üstünde yaş ve kuru ağırlığı (g), yaprak, sap ve koçan oranı (%), gövde çapı (mm). yaş ve kuru ot verimi (ton.da⁻¹) değerlendirilmiştir. Yeşil ot verimi her parselde kenar tesirler atıldıktan sonra kalan tüm bitkiler biçilerek ve arazide ağırlıkları tartılarak kaydedilmiştir. Kuru ot verimleri bitki örneği 70°C'de sabit ağırlığa gelinceye kadar kurutularak belirlenmiştir. Ayrıca bitkide, kritik kimyasal bileşimlerin konsantrasyonu da kaydedilmiştir. Makrobesin (P, K, Ca ve Mg) ve mikrobesein (Fe, Cu, Mn, Mo, Se ve Zn) konsantrasyonları indüktif eşleşmiş plazma optik emisyon spektrometre (ICP-OES) ve atomik absorpsiyon spektrofotometre (AAS) kullanılarak, VYYÜ, Bilim Uygulama ve Araştırma Merkezi Laboratuvarlarında belirlenmiştir. Uygulanan faktörlerin etkilerini değerlendirmek için tek yönlü varyans analizi (ANOVA) ve Duncan çoklu karşılaştırma testi kullanılmıştır. Uygulamalar arasındaki farklılıkların belirlenmesinde Duncan Çoklu Karşılaştırma Testi kullanılmıştır. Tüm istatistiksel analizler, SAS Yazılım paketi Stat-view-9.0.1'in varyans analizi (ANOVA) tekniği kullanılarak yapılmıştır. Van ekolojik şartlarında denemeye alınan Tuano silaj mısır çeşidinde verim, kalite ve bunlarla ilişkili özellikler incelenmiş ve elde edilen sonuçlar aşağıda özetlenmiştir.

Silaj amacıyla yetiştirilen mısırın bitki boyu, nano demir Fe₃O₄ ve aktif kuru mayanın birlikte kullanım dozlarında, kuru maya veya nano demir tekil uygulamalarından daha iyi olmuştur. Çizelge 4.1'deki veriler, alkali toprak koşullarında yetiştirilen mısır bitkisinde nano demir ve mayanın tüm dozlarında bitki boyunda artış olduğuna işaret etmiştir. Bitki boyuna ait en yüksek değer N1M3 (0,4 g.L⁻¹ Fe₃O₄ ve 10 g.L⁻¹ kuru maya), ardından N3M1 (0,8 g.L⁻¹ Fe₃O₄ ve 5 g.L⁻¹ kuru maya) ve N2M2 (0,6 g.L⁻¹) uygulamalarından elde edilmiştir.

Çizelge 4.3'te SPAD değerine ait veriler incelendiğinde, silaj amaçlı yetiştirilen mısırdan nano demir Fe₃O₄ ve aktif kuru mayanın birlikte kullanımının, çalışılan kontrol ve tekli uygulamalara göre daha fazla klorofil içeriğine sahip olduğunu ortaya koymaktadır.

Alkali topraklarda, nano demir ve aktif kuru mayanın tekli ve birlikte kullanımının mısır bitkisinin hamur olum dönemindeki morfolojik büyümesi üzerine etkilerinin belirlenmesinde incelenen karakterler ayrıntılı olarak sunulmuştur. Çizelge 4.4, 4.5 ve 4.6' da sunulan sonuçlar, yapraktan maya ve nano demir uygulaması ile bitki boyu (cm), bitki

başına gövde ağırlığı (g), bitki başına yaprak ağırlığı (g) ve bitki ağırlığındaki (g) artışın kaydedildiğine işaret ederken, bunun tersi bir eğilim bitki sap oranı için elde edilmiştir.

Çizelge 4.4'teki sonuçlar nano demir Fe_3O_4 'ün yaprağa uygulanması ile, N1: 0.4 g.L⁻¹'den artan nano demir seviyesi ile bitki boyu, bitki başına gövde ağırlığı, bitki başına yaprak ağırlığı ve bitki ağırlığının önemli ölçüde arttığını göstermektedir. Buna karşılık, 2019 ve 2020 sezonlarında sırasıyla % 52.23 ve % 43.23 ile kontrolden en yüksek bitki sap oranı değerinin tespit edildiği, Fe_3O_4 konsantrasyonu artırıldığında ise bitki sap oranının önemli ölçüde azaldığı belirlenmiştir. Aktif kuru maya için, Tablo 4.4, 4.5 ve 4.6'da sunulan veriler, alkali toprak koşulları altında mısır bitkilerine maya (M1, M2 ve M3) püskürtülmesinin bitki boyunu, bitki başına gövde ağırlığını ve bitki ağırlığını kontrole göre önemli ölçüde arttırdığını göstermektedir. Belirtilen karakterlerin en yüksek değerleri M3: 10 g.L⁻¹ maya ile elde edilmiştir. Kontrol ise en yüksek sap oranı % değerini kaydetmiştir. Ayrıca, nano Fe_3O_4 ve aktif kuru mayanın yapraktan uygulanması, kontrol parsellerine kıyasla bitki boyunu, bitki başına gövde ağırlığını, bitki başına yaprak ağırlığını ve bitki ağırlığını arttırırken, bitki sap oranını % oranını azaltmıştır. Bitki boyu, bitki başına gövde ağırlığı ve bitki ağırlığının en yüksek değerleri her ik yılda da N1M3, N3M1 ve N2M2 uygulamalarından saptanırken, en düşük bitki gövde oranı % değerleri ilk yıl N1M3, ikinci yıl N1M1 uygulamalarından kaydedilmiştir.

Öte yandan, alkali toprak koşullarında yetiştirilen mısır bitkilerinin hamur olum döneminde her iki yılda da tüm kuru maya ve nano demir oksit Fe_3O_4 konsantrasyonları uygulamaları ile kontrol arasında, bitki başına yaprak sayısı açısından a önemli bir fark bulunmamıştır (Çizelge 4.6).

Çizelge 4.7'deki veriler, nano demir Fe_3O_4 'ün yüksek toprak pH'sına sahip koşullarda yetiştirilen mısır bitkisine püskürtülmesinin, bitki başına koçan sayısı, bitki başına koçan ağırlığı ve % bitki koçan oranında önemli bir artış sağladığına işaret etmiştir. Nano Fe_3O_4 'ün üçüncü dozu, bitki başına koçan sayısı, bitki başına koçan ağırlığı ve bitki koçan oranı %' sinin en düşük değerlerinin kaydedilmiştir. Bitki başına koçan sayısı üzerine nano demir dozları arasında önemli bir fark olmadığı açıktır. Aktif kuru maya yaprak uygulaması, bitki başına koçan sayısı, koçan ağırlığı üzerinde olumlu bir etkiye sahiptir. Silaj amaçlı yetiştirilen mısırdaki koçan ağırlığı ve koçan oranı kontrol uygulamasına göre farklılık

gösterirken, bitki başına koçan sayısı için fark önemsizdir (Çizelge 4.7). Nano demir ve kuru mayanın birlikte uygulamaları, silaj amaçlı yüksek pH'ya sahip toprak koşullarında yetiştirilen mısırın bitki başına koçan sayısı, bitki başına koçan ağırlığı ve bitki koçan oranı bakımından tekli maya kullanımına göre en yüksek değerleri vermiştir. N1M3 muamelesinden, mısır bitkilerinin hamur olum döneminde her iki yılda da en yüksek değerler elde edilmiştir.

Çizelge 4.8'de sunulan veriler, silajlık mısırdaki nano demir ve kuru maya kullanımının yeşil ve kuru ot verimi üzerindeki etkilerini göstermektedir. Nano demir Fe_3O_4 püskürtmenin mısır bitkileri üzerindeki etkileri ile ilgili olarak, 2019 yılında yeşil ot veriminin önemsiz olması dışında, nano demir dozunun 0,4'ten 0,8 g.L^{-1} 'ye yükseltilmesiyle önemli ölçüde artmıştır. En yüksek yeşil ve kuru ot verimi 0,8 g.L^{-1} nano Fe_3O_4 ile muamele edilen mısırdan alınırken, ilk yıl yeşil ot verimi açısından N2 ve N3 arasında fark olmadığı tespit edilmiştir. Aktif kuru maya için her iki yılda elde edilen sonuçlar Çizelge 4.8'de verilmiştir. Mayanın yaprak uygulanmasının mısırın yeşil ve kuru ot verimini kontrole göre önemli ölçüde arttırdığı belirlenmiştir. M3: 10 g.L^{-1} maya uygulaması ile 2019 ve 2020 yıllarında elde edilen en yüksek yeşil ot verimi değerleri sırasıyla 9,77 ve 8,84-ton/da ve kuru ot verimi için sırasıyla 2,94 ve 3,43-ton/da olarak belirlenmiştir. En düşük değerler ise kontrol uygulamasından alınmıştır. Çizelge 4.8'de nano demir ve aktif kuru mayanın birlikte kullanımının, yeşil ve kuru ot verimi üzerindeki etkilerinin, hamur olum döneminde önemli olduğu görülmektedir. İlk yıl N3M1 uygulamasından en yüksek yaş ot verimi alınmış, bununla birlikte, nano demir ve aktif kuru mayanın N1M3 (0,4 g.L^{-1} Fe_3O_4 ve 10 g.L^{-1} kuru maya) uygulamasından , her iki yılda da en yüksek kuru ot ve ikinci yıl en yüksek yaş ot verimi elde edilmiştir. (Çizelge 4.8).

Alkali topraklarda, nano demir, aktif kuru maya ve birlikte uygulamalarının mısır bitkilerinin hamur olum dönemindeki fosfor, potasyum ve kalsiyum konsantrasyonları üzerine karakterleri üzerine etkisi incelenmiştir. Nano demirin mısır bitkilerine yapraktan uygulama sonuçlarına göre (Çizelge 4.9), Fe_3O_4 dozlarının N1'den N3'e yükseldiği durumlarda fosfor, potasyum ve kalsiyum konsantrasyonlarının $\text{g}/100 \text{ g}$ (%) önemli ölçüde arttığını göstermektedir. Aktif kuru maya uygulamasının mısır bitkileri üzerindeki etkisiyle ilgili olarak, püskürtülen tüm kuru maya dozlarının, kontrole kıyasla

mısırdaki fosfor, potasyum ve kalsiyum konsantrasyonlarını istatistiksel olarak önemli ölçüde arttırdığı rapor edilmiştir. M3: 10 g.L⁻¹ aktif kuru maya dozu 2019 ve 2020 yıllarında, fosfor için sırasıyla 0.27 ve 0.23 g/100 g (%), potasyum için sırasıyla 1.23 ve 1.31 g/100 g (%), kalsiyum için sırasıyla 1.19 ve 1.23 g/100 g (%). ile P, K ve Ca'nın en yüksek değerleri kaydetmiştir. Sözü edilen elementlerin en yüksek değerleri, mısır bitkilerine fosfor ve kalsiyum konsantrasyonları için birinci yılda N1M3 ve ikinci yılda N1M3 ve N3M1, potasyum konsantrasyonu için ise birinci yılda N1M3 ve ikinci yılda N3M1 uygulamalarından tespit edilmiştir.

Mısır magnezyum ve demir konsantrasyonları için Çizelge 4.10'da sunulan veriler, nano demir Fe₃O₄'ün mısıra yapraktan uygulanmasının her iki yılda da bitkilerde Mg ve Fe içerikleri üzerinde olumlu bir etki kaydettiğini göstermiştir. N2 uygulaması, alkali toprak koşullarında mısırın hamur olum döneminde (ekimden sonra 117. gün) en yüksek değerleri kaydetti. Ayrıca, kuru maya yapraktan uygulamaları ile kontrol bitkileri arasında istatistiksel olarak önemli bir fark olduğu belirtilmelidir. Mısırdaki en yüksek magnezyum ve demir konsantrasyonları her iki yılda da M3:10 g.L⁻¹ maya dozu uygulamasından tespit edilmiştir. Nano demir ve aktif kuru mayanın birlikte kullanımı ile, kontrole kıyasla 2019 ve 2020 yıllarında daha yüksek magnezyum ve demir konsantrasyonları belirlendi. En yüksek Mg bitki içerikleri ilk yılda N1M3, ikinci yılda N1M3 ve N3M1 kullanıldığında tespit edilmiştir. Mısırdaki en yüksek Fe konsantrasyonu her iki yılda da hamur olum döneminde N1M3 uygulamasından kaydedilmiştir. En düşük magnezyum ve demir g/100 g (%) alkali topraklar altında kontrolden elde edilmiştir.

Manganez, molibden ve selenyum konsantrasyonları (mg.kg⁻¹), maya dozlarına ve kontrol uygulamalarına göre 2019 ve 2020 yıllarında önemli farklılıklar göstermiştir (Çizelge 4.11). Mısır bitkilerine nano demir Fe₃O₄ özellikle N2 ve N3 püskürtüldüğünde, kontrol uygulamasına kıyasla selenyum konsantrasyonu önemli ölçüde arttı. Diğer yandan, nano Fe₃O₄'ün mısır üzerine yapraktan uygulanması, molibden ve manganez konsantrasyonları üzerinde olumsuz bir etki kaydetmiştir, burada en yüksek molibden ve manganez konsantrasyonu kontrolden tespit edilmiştir ve konsantrasyonlar, artan nano Fe₃O₄ doz artışlarıyla birlikte azalmıştır. Mısır bitkilerinde aktif kuru mayanın yaprağa uygulanmasıyla ilgili olarak, Çizelge 4.11'deki veriler, aktif kuru maya dozlarının M1:5'ten M3:10 g.L⁻¹'ye

kademeli olarak artırılmasıyla selenyum konsantrasyonunun önemli ölçüde arttığını göstermektedir. 2019 ve 2020 yıllarında kontrole göre M3'te en yüksek Se değeri tespit edilmiştir. Çizelge 4.11'de görüldüğü gibi 2019 ve 2020 yıllarında silaj amaçlı yetiştirilen mısır bitkilerine kuru maya uygulama dozlarının artırılmasıyla mg.kg^{-1} olarak molibden ve manganez konsantrasyonları önemli ölçüde azaltmıştır.

Bu çalışmada, silaj amaçlı nano demir ve kuru mayanın birlikte kullanılması ile her iki yılda mısır bitkisi, selenyum konsantrasyonunda kontrole ve tekli kullanıma göre daha fazla artış göstermiştir. N1M3 dozunun 2019 ve 2020 yıllarında en yüksek değerlere ulaşıldığı tespit edilmiştir (Çizelge 4.11).

Çizelge 4.12'deki veriler, hem 2019 hem de 2020 yıllarında çinko ve bakır konsantrasyonlarının (mg.kg^{-1}), mısır bitkilerine nano demir Fe_3O_4 ve aktif kuru maya uygulamalarından önemli ölçüde etkilendiğini göstermektedir. Nano demir uygulanması, mısır bitkisindeki çinko konsantrasyonunu olumlu şekilde iyileştirdi. Kontrol en yüksek Zn konsantrasyonu değerini kaydetse de, 2019 ve 2020 yıllarında tüm nano demir dozları ile kontrol muamelesi arasında önemli bir fark bulunmamıştır. Mısırın en yüksek bakır içeriği, ilk yıl N2: $0,6 \text{ g.L}^{-1}$ ve N3: $0,8 \text{ g.L}^{-1}$ dozlarından kaydedilmiştir (Çizelge 4.12). Aktif kuru maya konsantrasyonunun 0'dan (kontrol) 10 g.L^{-1} 'ye yükseltilmesi çinko konsantrasyonlarını ilk yıl önemli ölçüde artırırken, 2020 yılında çinko konsantrasyonlarının azaldığı belirlenmiştir. Çizelge 4.12'den mısır bitkilerine aktif kuru maya kullanımının bakır içeriğini arttırdığı görülmektedir. Mısırdaki en yüksek bakır konsantrasyonu her iki yılda da M3: 10 g.L^{-1} maya uygulaması ile bulunurken, ikinci yıl M2: $7,5$ ve M3: 10 g.L^{-1} aktif kuru maya arasında önemli bir fark görülmedi. Nano demir Fe_3O_4 ve aktif kuru mayanın birlikte kullanımında, Çizelge 4.12'de sunulan veriler, mg.kg^{-1} olarak en yüksek çinko konsantrasyonu değerinin 2019 yılında N3M2'de 161.30 ile kaydedildiğini göstermiştir. İkinci yıl, N1M2 dozu, $93,11 \text{ mg.kg}^{-1}$ ile en yüksek Zn konsantrasyonunu vermiştir.

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