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Research Article

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The Effect of Fertilizing with Different N and P Sources on the Growth of *Swietenia mahagoni* (L.) Jacq. Seedlings Under Water Stress

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KEY-WORDS

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ABSTRACT

Drought is a worldwide threat that affects many countries by reducing agricultural production and increasing water scarcity. *Swietenia mahagoni* (L.) Jacq. (mahogany) is a threatened Endangered tree; it has an important value in world markets as its heartwood is highly resistant to rot and insect damage, surpassing all other global mahogany varieties. It has several ecological services (fuel, timber, medicine, shade, and shelter). This study aims to enhance its growth by using various nitrogen (N) and phosphorus (P) fertilizer sources; and by studying their effect on the growth and drought tolerance of mahogany seedlings to obtain their highest growth using the lowest available water resources. During the two growth seasons (2022-2023) and (2023-2024), a field experiment was conducted at Gemmeiza Agricultural Research Station. Three sources of P fertilizers (single and triple superphosphate and phosphoric acid "H_3PO_4") and three N fertilizers (urea, ammonium sulfate $(NH_4)_2SO_4$ and ammonium nitrate (NH_4NO_3) were applied under the influence of three levels of water regime [100, 75, and 50 % field capacity (FC)]. Results showed that drought stress greatly declined shoot length, leaf area, the total fresh and dry weights of the plant, relative water content, total chlorophyll (a, b), and N, P contents in leaves. Still, they sharply increased root length, water use efficiency, proline, and carbohydrate contents in leaves. All different combinations of N and P fertilizer sources significantly improved the above-mentioned parameters compared to the control. The supply of a combination of $(NH_4)_2SO_4$ and H_3PO_4 significantly produced the highest growth.

Introduction

Egypt has been affected by water scarcity, which challenges water security, particularly with the continual expansion in population **(Elkholy, 2021)**. In addition, Egypt might be affected by water scarcity, especially with rising temperatures, and the Grand Ethiopian Renaissance Dam built on the Nile could hurt the water supply **(Nakashima *et al.*, 2014)**. **Ghazi *et al.* (2023)** reported that agricultural Egyptian scientists offer practical solutions to environmental challenges by introducing nutrients that increase plant tolerance to water deficit. An increasing or decreasing in water consumption negatively impacts plant production **(Kang *et al.*, 2024)**. Drought can have a negative impact not only on the morphological features, but also on the physiological, biochemical, and molecular features **(Fathi and Tari 2016)**. Water is essential for germination, dividing cells and expansion, metabolic activities, and other functions **(da Silva *et al.*, 2013)**. Both nutrients and water are two of the most critical components influencing tree growth, and they interact with one another. A lack of soil moisture can produce nutritional shortages even within the soil supplied with fertilizer **(da Silva *et al.*, 2011)**. Drought has an impact on the mobility and loss of both nitrogen and phosphorus nutrients **(Homyak *et al.*, 2017)**. Phosphorus is important for the growth of plants. However, the difficult availability of P in soil constitutes the greatest challenge for crop output, especially after plants suffer from drought **(Khan *et al.*, 2023).**

In Egyptian soil conditions, P availability is regarded as one of the important growth-limiting variables for plants due to its quick complexation and precipitation with cations in alkaline soil **(Dawa *et al.*, 2007; Ikhajiagbe, 2020).** Alkaline soils are the most deficient in nitrogen (N) and phosphorus (P), leading to a decline in plant production (**Adnan *et al.*, 2018**). Most soils in Egypt are alkaline, with pH values ranging from 7 to 9 (**El-Ramady *et al.*, 2019**).

In Egypt, superphosphates have traditionally been the main source of phosphate fertilizers for agricultural production. However, recently, alternative options have become available, such as phosphoric acid, which is commonly applied directly through irrigation water, particularly in alkaline and calcareous soil conditions (**Akhtar, *et al.* 2016**). Single superphosphate (SSP) and triple superphosphate (TSP) are utilized to produce these phosphatic fertilizers **(Marschner, 1995; Rosen *et al.*, 2014).**

Gelaw *et al.*, (2023) found that N and P can help plants adapt to a lack of water by increasing the activity of the photosynthetic system and antioxidant enzymes. Phosphorous is the second most important macronutrient after nitrogen for plant growth and development **(Kochian, 2012)**.

Phosphorus is an important component of nucleic acids, phospholipids, high-energy phosphate bond complexes, and many coenzymes **(Wyngaard *et al.*, 2016).** It is necessary for glucose and nitrogen metabolism, and the mutual conversion of protein and carbohydrate metabolism **(Yao *et al.*, 2012)**. It is an important component of ATP, the chemical that provides energy to the plant for nutrition translocation, nutrient uptake, and respiration. Also, a result, P is required for cell division and the development of new plant tissues. It enhances crop quality, promotes early maturity, and increases disease resistance.

In plants, nitrogen is found in proteins, enzymes, nucleic acids, amino acids, chlorophyll, adenosine triphosphate (ATP), and other essential compounds. As a result, nitrogen plays an important role in plant development and growth, including cell division, photosynthesis, and energy transmission. Nutritional combinations are more effective than individual nutrients, and interactions can be helpful or toxic **(Khan *et al.*, 2014)**. According to **Metwaly (2018)**, the most common chemical nitrogen forms used as commercial fertilizers in Egypt are ammonium nitrate (NH_4NO_3), urea ($CO (NH_2)_2$), and ammonium sulfate $(NH_4)_2SO_4$. These three types of chemical nitrogen fertilizers promote plant growth and productivity because they are readily available to plants and simple availability for plants.

Swietenia mahagoni (L.) Jacq. belongs to the family Meliaceae and holds significant commercial and pharmacological value **(Divya *et al.*, 2012)**. A mature tree can be 15 to 25 m high on average **(Orwa *et al.*, 2009).** Spanish, Cuban, Small-leaved, and West Indian mahoganies are some of their common names **(Gilman and Watson 2011)**. It is a big semi-evergreen wood tree native to South Florida, the Bahamas, and the western Caribbean. It is a strong, rapidly growing tree with powerful wood. It is highly resistant to wind damage and serves well as a shade tree or road tree. Additionally, it has a fantastic canopy structure, making it a great ornamental landscape tree. Its wood is used for high-quality furniture, joinery, musical instruments, etc. It is very expensive for its timber quality, color, firmness and durability. Also, it is a medicinal plant as a source of vitamins and iron **(Hossain, 2015)**. An antidiabetic to decline blood glucose **(Ervina, 2020)** and gestational diabetes mellitus (**Khotimah *et al.*, 2024**). Our present research aimed to study the impact of water regime on the growth and some metabolic activities of *Swietenia mahagoni* (L.) Jacq. seedlings to decrease the amount of water consumed and obtain the highest growth features of their seedlings to overcome drought conditions by using different nitrogen and phosphorus fertilizer sources.

Materials and methods

Experimental design

The present investigation was conducted in an open location of the research farm of Gemmeiza Agricultural Research Station, in the Middle of the Nile Delta, Egypt (Lat. 30.97 N, and Long. 30.97 E), during the two growth seasons (2022-2023) and (2023-2024). In this experiment, timber seedlings of Spanish mahogany (*S. mahagoni* L. Jacq.) were used. Its seedlings with 11-13 leaves and 35-40 cm height were obtained from the nursery of the Timber Trees and Forestry Research Department, Horticulture Research Institute, and Agricultural Research Center, Egypt. On the 1st of May, seedlings were cultivated in natural environmental conditions, transferred at the age of about one year and uniform seedlings were transplanted individually (one seedling per bag) in black plastic bags (diameter of 18 cm and a depth of 45 cm) filled with a mixture of 9.5 kg air dried soil as clay**:** sand at 3**:**1 ratio. Chemical and physical analysis of agricultural soil was analyzed according to **Jackson (1973)**.

The layout of this experiment was a split-plot design. The main plot factor included three forms of drought stress, while a combination of three fertilizer sources, both nitrogen and phosphorous, was assigned to the sub-plots (with an unfertilized control). The plastic bags were distributed in a completely randomized plot design consisting of three replications; each replicate included 90 seedlings and 30 treatments. Recommended levels of nitrogen and phosphorus rate were applied in the form of chemical fertilizers.

At the beginning of the experiment, the gravimetric technique was employed to determine the moisture content of the soil, as described by Reynolds (1970). The water stress treatments were carried out by weighting the bags every 3 days and adding the depleted amount of water through the entire period of the experiment to derive the percentage of moisture content to each treatment. The irrigation rates expressed as a percentage of field capacity (FC) were: 100 (control), 75 and 50 % FC. On July 1st of both growing seasons, three levels of water stress were applied using tap water for the irrigation of seedlings. Chemical analysis of irrigation tap water according to **Jackson (1973)**.

Fertilizer treatments

Three sources of phosphorous (P) fertilizer were used in this study; single superphosphate, triple superphosphate, and phosphoric acid. These fertilizers were applied once as a basal dose before planting. Additionally, phosphoric acid (H_3PO_4) was applied once with irrigation water one month after the planting at a rate equivalent to 2.6 g of P_2O_5. The applied amounts were as follows: single superphosphate (12.5%) = 20.8g (P1), triple superphosphate (46%) = 5.65g (P2), and phosphoric acid (H_3PO_4, 55.33 %), which contains 40.05% P_2O_5, w/w) and has a density of 1.596 g/cm^3 = 41cm/L (P3). Also, three nitrogen (N) fertilizer sources (urea, $(NH_4)_2SO_4$ and NH_4NO_3) were applied in three split doses during July, August, and September at a rate of 2g of N as urea (46 %) = 4.3g (N1), NH_4NO_3 (33.5 %) = 6g (N2), and $(NH_4)_2SO_4$ (20.2%) = 9,6g (N3) and without N, P fertilizers source as control. Until the water stress study started, all transplanted plants were irrigated regularly, and the study was finished after one year in each season.

Growth parameters

After the study's end, growth features (shoot and root length (cm), leaf area, and total fresh and dry weights of plants (root, stem, and leaves (g) were determined. Total leaf area (cm^2) was calculated mathematically employing leaf area-leaf weight relationship from leaf disks generated by a cork borer according to **Reddy *et al.*, (1989).**

The samples of the whole fresh plant were air-dried and oven-dried at 70°C until a constant weight was achieved. The dry weight of the entire fresh plant was then recorded. Relative water content (RWC) was estimated by taking 15 leaf discs (2 cm^2) from leaf numbers (7 and 8) from the top of the plant and weighting its fresh (FW), placed in distilled water at room temperature for 24 hours, and then the saturation weight was measured (SW). Leaf discs were dried at 70°C till a steady weight, then the dry weight was measured (DW) and RWC was calculated as a percentage according to **Smart and Bingham (1974)**.

RWC % = (FW- DW) / (SW- DW) × 100.

Water use efficiency (WUE) was determined according to **Bacon (2009)** using the formula:

WUE = Total biomass (g) / Water consumption (L).

Where the total biomass of seedlings is equal to the total fresh weight of their roots, stem, and leaves at the end. Water quantities supplied were estimated by calculating the total amounts of irrigation water provided to seedlings at different irrigation levels (field capacity) throughout the growing season.

Plant analysis

The total chlorophyll (a and b) contents were estimated by using 0.1 g from mature fresh leaf number 7 from the top of the plant, immersed for 24 h The total phosphorus content was estimated using the molybdate-blue colorimetric method, as outlined by Kitson and Melon in 1944.at 4°C in 20 ml methanol (96%) and was measured by using a spectrophotometer at a wavelength of 666 and 653 nm. The data were expressed as mg g^{-1} fresh weight as follows (after **Dere *et al.*, 1998**): Chl. a = $(15.65A_{666} - 7.34A_{653})$; Chl. b = $(27.05A_{653} – 11.21A_{666})$; Total chlorophyll = chlorophyll (a) + chlorophyll (b)

Proline was estimated from the dry biomass of adult leaves 7 and 8 at the apex of the plant. Proline content (mg $100g^{-1}$ dry weight) was measured calorimetrically in the extract of dry leaf tissues using ninhydrin reagent and measured at 520 nm (after **Bates *et al.*, 1973**).

Carbohydrate concentrations (%) were determined from the dry weight of the mature leaves number 7 and 8 at the stem top according to **Dubois *et al.*, (1956)**. The estimation of N and P contents in leaves, the samples of fresh leaves were taken, washed with tap and distilled water, dried at 80°C, milled, and subsequently digested with concentrated H_2SO_4 and H_2O_2. N% were estimated using the micro-Kjeldahl method **(Liang and MacKenzie 1994)**. The total P content was estimated by using the molybdate-blue colorimetric method as outlined by **Kitson and Melon in 1944**.

Statistical analyses

The main plot factor included three forms of drought stress, while a combination of three fertilizer sources of both nitrogen and phosphorous were assigned to sub-plots (including unfertilized as control) and the plastic bags were distributed in a completely randomized plot design with three replications; each replicate included 90 seedlings and 30 treatments. Recommended levels of nitrogen and phosphorus rate were applied in the form of chemical fertilizers.

The normality and variance homogeneity between data was checked. One-way analysis of variance (ANOVA), and Duncan's test at 5% probability was used to assess the significance of differences in plant measurements between different treatments by applying the CO- STAT Statistical Software **(Stern, 1991).**

Results

Impact of water stress

The data summarized in Table (1) indicate that drought stress levels significantly negatively affected the plants, resulting in a decline in shoot length, leaf area, and total fresh weight. The highest values were recorded in plants irrigated at 100% field capacity, with measurements of 98.50 cm for shoot length, 201.88 cm² for leaf area, and 188.39 g for total fresh weight in the first season. In the second season, these measurements were 98.65 cm for shoot length, 201.55 cm² for leaf area, and 190.15 g for total fresh weight. However, it had a positive impact and significantly increased root length, with a maximum of 50 % field capacity of 40.08 and 40.89 cm in the first and second seasons, respectively.

The results in Table (2) indicate that by increasing degrees of water regime, total dry weight, relative water content (RWC), and total chlorophyll greatly detracted as the lowest value was obtained from 50 % FC (104.90 g, 53.55, and 26.17 mg g^{-1} FW) in the first season and (107.54 g, 52.30 and 24.82 mg g^{-1} FW) in the second season, respectively. In contrast, after use efficiency (WUE) has the opposite trend. The maximum value was obtained at 50 % FC (5.33 and 5.40) in the 1st and 2nd seasons, respectively.

The results presented in Table (3) reveal that decreasing soil water moisture leads to a significant reduction in nitrogen (N) and phosphorus (P) content in leaves. The highest levels of N and P were observed at 100% field capacity (FC), with values of 3.70% and 0.32%, respectively, in the first season, and 2.83% and 0.28% in the second season. In contrast, proline and total carbohydrates have the reverse trend as the largest value was generated at 50%FC (32.37mg $100g^{-1}$ DW and 22.37%) in the first season and (33.21mg $100g^{-1}$ DW and 23.35%) in the second season.

Impact of different nitrogen and phosphorus combination sources

Results in Table (1) revealed that all combinations of N and P sources had a positive effect and increased measurements of shoot and root length, leaf area, and the weights of total fresh weight compared to the control. There are significant differences among the various combinations of nitrogen (N) and phosphorus (P) fertilizer sources. The combination of (N3P3) proved to be the most effective, yielding the best results for several traits. In the first season, this combination resulted in measurements of 106.07 cm, 45.63 cm, 208.74 cm^2, and 209.81 g. In the second season, the measurements were slightly improved at 106.86 cm, 46.84 cm, 208.41 cm^2, and 212.47 g. The results interactions had a significant impact, as the highest value from (N3P3) at 100% FC (111.28cm, 210.82 $cm^{2,}$ and 223.34g) and (112 cm, 210.49 cm^2, 226.25g) in the first and the second season respectively, and the lowest from control at 50 % FC, except root length with the largest value by using (N3P3) at 50% FC and (the 50.94 cm and 49.12 cm) and the smallest from control at 100% FC (25.73cm and 24.5cm) in both seasons respectively.

According to the results in Table (2), all diversity combinations of N and P sources significantly increased total dry weight RWC, WUE, and total chlorophyll compared to the control. Also, there are significant variations among the combinations of N and P fertilizer sources. A combination of (N3P3) supply significantly generated the best measurements (152.81 g, 59.96%, 4.97 and 33.33 mg g^{-1} FW) in first season and (156.65 g, 58.71%, 5.03 and 31.98 mg g^{-1} FW) in 2nd season respectively. The interactions results had a significant effect, as the greatest from (N3P3) at 100 % FC (166.34 g, 60.99% and 35.53 mg g^{-1} FW) in the first season and (169.89 g, 59.74% and 34.18 mg g^{-1} FW) in the second season, respectively, and the lowest from control at 50% FC, with the exception of WUE, as the largest by using (N3P3) at 50% FC (6.47 and 6.58) and the smallest value was generated from control at 100% FC (2.37 and 2.31) in 1st and 2nd seasons respectively.

Table (1): Different growth characters of *Swietenia mahagoni* seedlings as impacted by various combinations of N and P fertilizer sources under water deficit.

	First Season				**Second Season**			
Drought	**100 %FC**	**75 %FC**	**50 % FC**	**Mean**	**100 % FC**	**75 %FC**	**50 % FC**	**Mean**
Fertilizers	**Shoot length (cm)**							
Control	82.65 ^{qr}	79.06 st	70.48 ^{u}	**77.40** ^{j}	80.27 ^{mn}	78.60 ^{n}	68.11 ^{o}	**75.66** ^{i}
N1P1	95.19 ^{hij}	90.96 ^{klm}	82.86 ^{qr}	**89.67** ^{g}	96.00 ^{g}	92.37 ^{hi}	84.45 ^{l}	**90.94** ^{f}
N1P2	97.14 ^{fgh}	93.48 ^{ijk}	85.16 ^{pq}	**91.93** ^{f}	96.83 ^{fg}	93.10 ^{h}	85.57 ^{l}	**91.83** ^{f}
N1P3	108.20 ^{b}	103.94 ^{c}	98.67 ^{efg}	**103.60** ^{b}	108.80 ^{b}	104.80 ^{c}	99.98 ^{de}	**104.53** ^{b}
N2P1	90.13 ^{lmn}	86.40 ^{op}	78.21 ^{t}	**84.91** ^{i}	91.03 ^{hij}	87.90 ^{k}	78.90 ^{n}	**85.94** ^{h}
N2P2	93.53 ^{ijk}	88.84 ^{mno}	81.67 ^{rs}	**88.01** ^{h}	93.23 ^{h}	89.07 ^{jk}	81.82 ^{m}	**88.04** ^{g}
N2P3	104.10 ^{c}	100.52 ^{de}	92.61 ^{jkl}	**99.08** ^{c}	105.70 ^{c}	101.61 ^{d}	93.22 ^{h}	**100.17** ^{c}
N3P1	100.30 ^{de}	96.12 ^{ghi}	87.90 ^{nop}	**94.77** ^{e}	100.87 ^{d}	97.18 ^{fg}	88.88 ^{jk}	**95.64** ^{e}
N3P2	102.47 ^{cd}	98.48 ^{efg}	90.27 ^{lmn}	**97.07** ^{d}	101.80 ^{d}	98.55 ^{ef}	90.41 ^{ij}	**96.92** ^{d}
N3P3	111.28 ^{a}	107.22 ^{b}	99.73 ^{def}	**106.07** ^{a}	112.00 ^{a}	108.37 ^{b}	100.22 ^{de}	**106.86** ^{a}
Mean	**98.50** ^{a}	**94.50** ^{b}	**86.76** ^{c}		**98.65a**	**95.15b**	**87.16c**	
	Root length (cm)							
Control	25.73 ^{q}	27.20 ^{pq}	30.25 ^{op}	**27.73** ^{h}	24.50 ^{q}	26.60 ^{p}	29.63 ^{o}	**26.91** ^{j}
N1P1	32.37 ^{no}	34.43 ^{lmn}	37.62 ^{ijkl}	**34.81** ^{e}	33.25 ^{m}	35.33 ^{k}	38.69 ^{i}	**35.76** ^{g}
N1P2	34. 11 ^{mn}	36.53 ^{jklm}	38.99 ^{ghij}	**36.54** ^{e}	34.70 ^{kl}	36.77 ^{j}	39.43 ^{hi}	**37.00** ^{f}
N1P3	42.33 ^{defg}	44.63 ^{bcde}	46.92 ^{ab}	**44.63** ^{a}	43.28 ^{e}	45.70 ^{d}	48.80 ^{b}	**45.93** ^{b}
N2P1	28.30 ^{pq}	30. 10 ^{op}	32.98 ^{no}	**30.46** ^{g}	29.60 ^{o}	31.07 ^{n}	33.93 ^{lm}	**31.54** ^{i}
N2P2	30.53 ^{op}	32. 17 ^{no}	35.39 ^{klmn}	**32.70** ^{f}	30.93 ^{n}	32.93 ^{m}	35.33 ^{k}	**33.07** ^{h}
N2P3	40.66 ^{fghi}	42.16 ^{defg}	45.14 ^{bcd}	**42.65** ^{b}	41.47 ^{fg}	43.24 ^{e}	46.03 ^{cd}	**43.58** ^{c}
N3P1	36.43 ^{jklm}	38.25 ^{hijk}	41. 19 ^{efgh}	**38.63** ^{d}	37.33 ^{j}	39.42 ^{hi}	42.41 ^{ef}	**39.72** ^{e}
N3P2	38.23 ^{hijk}	40.34 ^{fghi}	43.23 ^{cdef}	**40.60** ^{c}	38.77 ^{i}	40.67 ^{gh}	43.67 ^{e}	**41.03** ^{d}
N3P3	41.77 ^{defg}	46.01 ^{abc}	49.12 ^{a}	**45.63** ^{a}	42.35 ^{ef}	47.23 ^{c}	50.94 ^{a}	**46.84** ^{a}
Mean	**35.05** ^{c}	**37.18** ^{b}	**40.08** ^{a}		**35.62** ^{c}	**37.90** ^{b}	**40.89** ^{a}	
	Leaf area (cm^2)							
Control	192.17 ^{lmn}	190.05 ^{mno}	187.16 ^{o}	**189.79** ^{i}	191.83 ^{klm}	189.72 ^{lmn}	186.83 ^{n}	**189.46** ^{h}
N1P1	197.23 ^{ijk}	195.20 ^{jkl}	192.00 ^{lmn}	**194.80** ^{g}	196.90 ^{hij}	194.87 ^{ijk}	191.63 ^{klm}	**194.47** ^{f}
N1P2	202.74 ^{def}	201.47 ^{efg}	198.22 ^{ghij}	**200.81** ^{e}	202.41 ^{def}	201.13 ^{efg}	197.88 ^{ghi}	**200.48** ^{d}
N1P3	209.57 ^{ab}	207.37 ^{bc}	204.10 ^{cde}	**207.01** ^{b}	209.23 ^{ab}	207.03 ^{bc}	203.77 ^{cde}	**206.68** ^{a}
N2P1	195.33 ^{jkl}	193.30 ^{lm}	189.90 ^{no}	**192.84** ^{h}	195.00 ^{ijk}	192.97 ^{kl}	189.57 ^{mn}	**192.51** ^{g}
N2P2	200.67 ^{fgh}	197.57 ^{hijk}	194.73 ^{kl}	**197.66** ^{f}	200.33 ^{fgh}	197.24 ^{hi}	194.40 ^{ijk}	**197.32** ^{e}
N2P3	207.00 ^{bc}	204.87 ^{cd}	201.93 ^{def}	**204.59** ^{c}	206.63 ^{bc}	204.53 ^{cde}	201.60 ^{def}	**204.26** ^{b}
N3P1	198.13 ^{hij}	198.00 ^{hijk}	193.90 ^{l}	**196.67** ^{f}	197.80 ^{ghi}	197.63 ^{hi}	193.57 ^{jk}	**196.33** ^{e}
N3P2	205.17 ^{cd}	202.75 ^{def}	200.23 ^{fghi}	**202.72** ^{d}	204.83 ^{cd}	202.42 ^{def}	199.90 ^{fgh}	**202.38** ^{c}
N3P3	210.82 ^{a}	208.93 ^{ab}	206.47 ^{bc}	**208.74** ^{a}	210.49 ^{a}	208.60 ^{ab}	206.13 ^{bc}	**208.41** ^{a}
Mean	**201.88** ^{a}	**199.95** ^{b}	**196.86** ^{c}		**201.55** ^{a}	**199.61** ^{b}	**196.53** ^{c}	
	Total fresh weight (g $plant^{-1}$)							
Control	142.37 ^{o}	132.25 ^{p}	113.59 ^{q}	**129.41** ^{j}	138.80 ^{o}	128.38 ^{p}	109.06 ^{q}	**125.41** ^{j}
N1P1	178.64 ^{i}	165.28 ^{k}	150.99 ^{mn}	**164.97** ^{g}	181.14 ^{i}	168.84 ^{k}	153.75 ^{m}	**167.91** ^{g}
N1P2	185.98 ^{fg}	171.10 ^{j}	156.36 ^{lm}	**171.15** ^{f}	186.38 ^{h}	173.59 ^{j}	157.85 ^{l}	**172.61** ^{f}
N1P3	215.27 ^{b}	200.30 ^{d}	187.34 ^{fg}	**200.97** ^{b}	217.43 ^{b}	202.51 ^{e}	189.71 ^{g}	**203.22** ^{b}
N2P1	164.44 ^{k}	150.32 ^{n}	136.21 ^{p}	**150.32** ^{i}	169.44 ^{k}	153.78 ^{m}	139.63 ^{o}	**154.28** ^{i}
N2P2	171.92 ^{j}	157.78 ^{l}	142.63 ^{o}	**157.44** ^{h}	173.54 ^{j}	158.59 ^{l}	145.32 ^{n}	**159.15** ^{h}
N2P3	207.23 ^{c}	191.90 ^{ef}	179.57 ^{hi}	**192.90** ^{c}	208.95 ^{d}	194.78 ^{f}	182.74 ^{i}	**195.49** ^{c}
N3P1	194.52 ^{de}	179.23 ^{hi}	164.96 ^{k}	**179.57** ^{e}	197.66 ^{f}	183.33 ^{i}	168.69 ^{k}	**183.23** ^{e}
N3P2	200.22 ^{d}	184.98 ^{gh}	172.09 ^{j}	**185.77** ^{d}	201.87 ^{e}	186.77 ^{gh}	174.44 ^{j}	**187.69** ^{d}
N3P3	223.34 ^{a}	211.88 ^{bc}	194.22 ^{de}	**209.81** ^{a}	226.25 ^{a}	213.63 ^{c}	197.54 ^{f}	**212.47** ^{a}
Mean	**188.39** ^{a}	**174.50** ^{b}	**159.80** ^{c}		**190.15** ^{a}	**176.42** ^{b}	**161.87** ^{c}	

Means followed by the same letter (s) are not significantly different at 5% according to Duncan's test. Urea = N1, Ammonium nitrate = N2, Ammonium sulfate = N3, Single superphosphate = P1, Triple superphosphate = P2, Phosphoric acid = P3, and FC = field capacity.

Table (2): Different characters of *Swietenia mahagoni* seedlings as impacted by different combinations of N and P fertilizer sources under water deficit.

	First Season				**Second Season**			
Drought	**100 %FC**	**75 %FC**	**50 % FC**	**Mean**	**100 % FC**	**75 %FC**	**50 % FC**	**Mean**
Fertilizers	**Total dry weight (g plant^{-1})**							
Control	89.37 ^{o}	79.25 ^{q}	60.59 ^{r}	**76.41 ^{j}**	84.82 ^{o}	76.25 ^{p}	62.18 ^{q}	**74.42 ^{j}**
N1P1	123.64 ^{i}	110.28 ^{k}	95.99 ^{mn}	**109.97 ^{g}**	126.67 ^{i}	114.54 ^{k}	100.15 ^{m}	**113.79 ^{g}**
N1P2	130.98 ^{g}	116.10 ^{j}	101.36 ^{lm}	**116.15 ^{f}**	132.95 ^{h}	118.47 ^{j}	103.50 ^{l}	**118.31^{f}**
N1P3	160.27 ^{b}	145.30 ^{d}	132.34 ^{fg}	**145.97 ^{b}**	163.51 ^{b}	148.72 ^{e}	134.61^{h}	**148.95 ^{b}**
N2P1	109.44 ^{k}	95.32 ^{n}	82.21 ^{pq}	**95.66 ^{i}**	112.63 ^{k}	99.65 ^{m}	84.92 ^{o}	**99.07 ^{i}**
N2P2	116.92 ^{j}	102.78 ^{l}	87.63 ^{op}	**102.44 ^{h}**	118.35 ^{j}	105.00 ^{l}	89.03 ^{n}	**104.13 ^{h}**
N2P3	152.23 ^{c}	136.90 ^{ef}	124.57 ^{hi}	**137.90 ^{c}**	154.69 ^{d}	140.48 ^{g}	127.54 ^{i}	**140.90 ^{c}**
N3P1	139.52 ^{de}	124.23 ^{hi}	109.96 ^{k}	**124.57 ^{e}**	143.19 ^{f}	128.05 ^{i}	113.96 ^{k}	**128.40 ^{e}**
N3P2	145.22 ^{d}	129.98 ^{gh}	117.09 ^{j}	**130.77 ^{d}**	147.00 ^{e}	132.32 ^{h}	117.94 ^{j}	**132.42 ^{d}**
N3P3	166.34 ^{a}	154.88 ^{bc}	137.22 ^{ef}	**152.81 ^{a}**	169.89 ^{a}	158.46 ^{c}	141.60 ^{fg}	**156.65 ^{a}**
Mean	**133.39 ^{a}**	**119.50 ^{b}**	**104.90 ^{c}**		**135.37 ^{a}**	**122.19 ^{b}**	**107.54 ^{c}**	
	Relative water content (%)							
Control	52.62 ^{ijk}	50.83 ^{l}	48.97 ^{m}	**50.81 ^{j}**	51.37 $^{i jk}$	49.58 ^{l}	47.72 ^{m}	**49.56 ^{j}**
N1P1	53.87 ^{h}	53.33^{hi}	50.80 ^{l}	**52.67^{h}**	52.62 ^{h}	52.08 ^{hi}	49.55 ^{l}	**51.42 ^{h}**
N1P2	57. 15 ^{e}	56.09 ^{f}	53.87 ^{h}	**55.70 ^{e}**	55.90 ^{e}	54.84 ^{f}	52.62 ^{h}	**54.42 ^{e}**
N1P3	59.78^{b}	59.03 ^{c}	57.07 ^{e}	**58.63^{b}**	58.53 ^{b}	57.78 ^{c}	55.82 ^{e}	**57.38 ^{b}**
N2P1	52.88 ^{ij}	51.98^{k}	50.50 ^{l}	**51.79 ^{i}**	51.63 ^{ij}	50.73 ^{k}	49.25 ^{l}	**50.54 ^{i}**
N2P2	56.07 ^{f}	55. 10 ^{g}	53.00 ^{i}	**54.72 ^{f}**	54.82 ^{f}	53.85 ^{g}	51.75 ^{i}	**53.47 ^{f}**
N2P3	58.97 ^{c}	57.96 ^{d}	55.90 ^{f}	**57.61 ^{c}**	57.72 ^{c}	56.71^{d}	54.65 ^{f}	**56.36 ^{c}**
N3P1	54.96^{g}	53.96 ^{h}	52. 17 ^{jk}	**53.70 ^{g}**	53.71 ^{g}	52.71 ^{h}	50.92 ^{jk}	**52.45 ^{g}**
N3P2	57.92 ^{d}	57.05 ^{e}	55.07 ^{g}	**56.68 ^{d}**	56.67^{d}	55.80 ^{e}	53.82 ^{g}	**55.43 ^{d}**
N3P3	60.99 ^{a}	60.70 ^{a}	58.20 ^{d}	**59.96 ^{a}**	59.74 ^{a}	59.45 ^{a}	56.95 ^{d}	**58.71 ^{a}**
Mean	**56.52 ^{a}**	**55.60 ^{b}**	**53.55 ^{c}**		**55.27 ^{a}**	**54.35 ^{b}**	**52.30 ^{c}**	
	Water use efficiency (WUE)							
Control	2.37 ^{t}	2.94 ^{r}	3.79 ^{l}	**3.03 ^{j}**	2.31 ^{y}	2.85 ^{x}	3.64 ^{q}	**2.93 ^{j}**
N1P1	2.98 ^{qr}	3.67 ^{lm}	5.03 ^{g}	**3.90 ^{g}**	3.02 ^{w}	3.75 ^{p}	5.12 ^{g}	**3.97 ^{g}**
N1P2	3.10 ^{q}	3.80 ^{l}	5.21 ^{f}	**4.04 ^{f}**	3.11 ^{v}	3.86 ^{o}	5.26 ^{f}	**4.07 ^{f}**
N1P3	3.59 ^{mn}	4.45 ^{i}	6.25 ^{b}	**4.76 ^{b}**	3.63 ^{q}	4.50 ^{k}	6.32 ^{b}	**4.82 ^{b}**
N2P1	2.74 ^{s}	3.34 ^{op}	4.54 ^{i}	**3.54 ^{i}**	2.82 ^{x}	3.42 st	4.65 ^{j}	**3.63 ^{i}**
N2P2	2.86 ^{rs}	3.50 ^{n}	4.75 ^{h}	**3.71 ^{h}**	2.89 ^{x}	3.52 ^{r}	4.85 ^{h}	**3.75 ^{h}**
N2P3	3.45 ^{no}	4.26 ^{j}	5.99 ^{c}	**4.57 ^{c}**	3.48 ^{rs}	4.33 ^{l}	6.09 ^{c}	**4.64 ^{c}**
N3P1	3.24 ^{p}	3.98 ^{k}	5.50 ^{e}	**4.24 ^{e}**	3.30 ^{u}	4.07 ^{n}	5.62 ^{e}	**4.33 ^{e}**
N3P2	3.34 ^{op}	4.11 ^{k}	5.73 ^{d}	**4.39 ^{d}**	3.37 ^{t}	4.15 ^{m}	5.82 ^{d}	**4.45 ^{d}**
N3P3	3.72 ^{lm}	4.71 ^{h}	6.47 ^{a}	**4.97 ^{a}**	3.77 ^{p}	4.75 ^{i}	6.58 ^{a}	**5.03 ^{a}**
Mean	**3.14 ^{c}**	**3.88 ^{b}**	**5.33 ^{a}**		**3.17 ^{c}**	**3.92 ^{b}**	**5.40 ^{a}**	
	Total chlorophyll (mg g^{-1} FW)							
Control	22.31^{m}	19.46 ^{n}	18.03 ^{n}	**19.91 ^{i}**	20.99 ^{m}	18.11 ^{n}	16.68 ^{n}	**18.58 ^{i}**
N1P1	29.23 ^{efgh}	26.98 ^{hij}	24.94 ^{jkl}	**27.05 ^{fg}**	27.88 ^{efgh}	25.63 ^{hij}	23.59 ^{jkl}	**25.70 ^{fg}**
N1P2	30.43 ^{defg}	28.24 ^{fghi}	26. 10 ^{ijk}	**28.26 ^{ef}**	29.08 ^{defg}	26.89 ^{fghi}	24.75 ^{ijk}	**26.91^{ef}**
N1P3	34.40 ^{ab}	31.97 ^{bcd}	30. 11 ^{defg}	**32. 16 ^{ab}**	33.05 ^{ab}	30.62 ^{bcd}	28.76 ^{defg}	**30.81 ^{ab}**
N2P1	27. 12 ^{hij}	25. 10 ^{jkl}	23.00 ^{lm}	**25.07 ^{h}**	25.77 ^{hij}	23.75 ^{jkl}	21.65 ^{lm}	**23.72 ^{h}**
N2P2	28. 13 ^{ghi}	26.25 ^{ijk}	24.28 ^{klm}	**26.22 ^{gh}**	26.78 ^{ghi}	24.90 ^{ijk}	22.93 ^{klm}	**24.87 ^{gh}**
N2P3	33.47 ^{abc}	30.99 ^{cde}	29.00 ^{efgh}	**31. 15 ^{bc}**	32.12 ^{abc}	29.64 ^{cde}	27.65 ^{efgh}	**29.80 ^{bc}**
N3P1	30.89 ^{cdef}	29. 13 ^{efgh}	27.03 ^{hij}	**29.02 ^{de}**	29.54 ^{cdef}	27.78 ^{efgh}	25.68 ^{hij}	**27.67 ^{de}**
N3P2	32.03 ^{bcd}	30.60 ^{defg}	28.07 ^{ghi}	**30.23 ^{cd}**	30.68 ^{bcd}	29.25 ^{defg}	26.72 ^{ghi}	**28.88 ^{cd}**
N3P3	35.53 ^{a}	33.30 ^{abc}	31. 17 ^{cde}	**33.33 ^{a}**	34.18 ^{a}	31.95 ^{abc}	29.82 ^{cde}	**31.98 ^{a}**
Mean	**30.35 ^{a}**	**28.20 ^{b}**	**26.17 ^{c}**		**29.00 ^{a}**	**26.85 ^{b}**	**24.82 ^{c}**	

Means followed by the same letter (s) are not significantly different at 5% according to Duncan's test. Urea = N1, Ammonium nitrate = N2, Ammonium sulfate = N3, Single superphosphate = P1, Triple superphosphate = P2, Phosphoric acid = P3, and FC = field capacity.

Table (3): Different characters of *Swietenia mahagoni* seedlings as impacted by different combinations of N and P fertilizer sources under water deficit.

First Season					**Second Season**			
Drought	**100 %FC**	**75 %FC**	**50 % FC**	**Mean**	**100 % FC**	**75 %FC**	**50 % FC**	**Mean**
Fertilizers	**Total Carbohydrates (%)**							
Control	12.60^{l}	13.93^{l}	16.23^{k}	**14,26**^{g}	13.58^{l}	14.91^{l}	17.21^{k}	**15.24**^{g}
N1P1	19. 10^{hij}	19.97^{ghi}	21.20^{efg}	**20.09**^{e}	20.08^{hij}	20.95^{ghi}	22.18^{efg}	**21.07**^{e}
N1P2	19.91^{ghi}	21. 15$^{efg h}$	22. 15^{def}	**21.07**^{e}	20.89^{ghi}	22.13^{efgh}	23.13^{def}	**22.05**^{e}
N1P3	24.05^{bcd}	25. 10^{abc}	25.92^{ab}	**25.02**^{ab}	25.03^{bcd}	26.08^{abc}	26.90^{ab}	**26.00**^{ab}
N2P1	17.23^{jk}	17.98^{ijk}	19. 13^{ghij}	**18. 11**^{f}	18.21^{jk}	18.96^{ijk}	20.11^{ghij}	**19.09**^{f}
N2P2	17.88^{jk}	19. 18^{ghij}	20.00^{ghi}	**19.02**^{f}	18.86^{jk}	20.16^{ghij}	20.98^{ghi}	**20.00**^{f}
N2P3	23. 10^{cde}	24. 12^{bcd}	24.93^{abc}	**24.05**^{bc}	24.08^{cde}	25.10^{bcd}	25.91^{abc}	**25.03**^{bc}
N3P1	20.92$^{fg h}$	22.22^{def}	23.20^{cde}	**22. 11**^{d}	21.90$^{fg h}$	23.20^{def}	24.18^{cde}	**23.09**^{d}
N3P2	22.17^{def}	23. 11^{cde}	24.03^{bcd}	**23. 10**^{cd}	23.15^{def}	24.09^{cde}	25.01^{bcd}	**24.08**^{cd}
N3P3	25.17^{abc}	25.83^{ab}	26.87^{a}	**25.96**^{a}	26.15^{abc}	26.81^{ab}	27.85^{a}	**26.94**^{a}
Mean	**20.21**^{c}	**21.26**^{b}	**22.37**^{a}		**21.19**^{c}	**22.24**^{b}	**23.35**^{a}	
10-) Proline (mg 100g $^{-1}$ DW)								
Control	22.60^{l}	23.93^{l}	26.23^{k}	**24.26**^{g}	23.44^{l}	24.77^{l}	27.07^{k}	**25.10**^{g}
N1P1	29. 10^{hij}	29.97^{ghi}	31.20^{efg}	**30.09**^{e}	29.94^{hij}	30.81^{ghi}	32.04^{efg}	**30.93**^{e}
N1P2	29.91^{ghi}	31. 15^{efg}	32. 15^{def}	**31.07**^{e}	30.75^{ghi}	31.99^{efgh}	32.99^{def}	**31.91**^{e}
N1P3	34.05^{bcd}	35. 10^{abc}	35.92^{ab}	**35.02**^{ab}	34.89^{bcd}	35.94^{abc}	36.76^{ab}	**35.86**^{ab}
N2P1	27.23^{jk}	27.98^{ijk}	29. 13^{ghij}	**28.** 11^{f}	28.07^{jk}	28.82^{ijk}	29.97^{ghij}	**28.95**^{f}
N2P2	27.88^{jk}	29. 18^{ghij}	٣٠.٠٠^{ghi}	**29.02**^{f}	28.72^{jk}	30.02^{ghij}	30.84^{ghi}	**29.86**^{f}
N2P3	33. 10^{cde}	34. 12^{bcd}	٣٤.٩٣^{abc}	**34.05**^{bc}	33.94^{cde}	34.96^{bcd}	35.77^{abc}	**34.89**^{bc}
N3P1	30.92^{fgh}	32.22^{def}	٣٣.٢٠^{cde}	**32. 11**^{d}	31.76^{fgh}	33.06^{def}	34.04^{cde}	**32.95**^{d}
N3P2	32. 17^{def}	33. 11^{cde}	٣٤.٠٣^{bcd}	**33. 10**^{cd}	33.01^{def}	33.95^{cde}	34.87^{bcd}	**33.94**^{cd}
N3P3	35. 17^{abc}	35.83^{ab}	٣٦.87^{a}	**35.96**^{a}	36.01^{abc}	36.67^{ab}	37.71^{a}	**36.80**^{a}
Mean	**30.21**^{c}	**31.26**^{b}	**32.37**^{a}		**31.05**^{c}	**32.10**^{b}	**33.21**^{a}	
Nitrogen (%)								
Control	2.98^{r}	2.89^{s}	2.78^{t}	**2.88**^{j}	2.11^{r}	2.02^{s}	1.91^{t}	**2.01**^{j}
N1P1	3.69^{i}	3.63^{j}	3.38^{n}	**3.57**^{g}	2.82^{i}	2.76^{j}	2.51^{n}	**2.70**^{g}
N1P2	3.75^{h}	3.70^{i}	3.46^{m}	**3.64**^{f}	2.88^{h}	2.83^{i}	2.59^{m}	**2.77**^{f}
N1P3	4.03^{b}	3.94^{d}	3.71^{i}	**3.89**^{b}	3.16^{b}	3.07^{d}	2.84^{i}	**3.02**^{b}
N2P1	3.11^{p}	3.06^{q}	2.99^{r}	**3.05**^{i}	2.24^{p}	2.19^{q}	2.12^{r}	**2.18**^{i}
N2P2	3.62^{j}	3.55^{k}	3.30^{o}	**3.49**^{h}	2.75^{j}	2.68^{k}	2.43^{o}	**2.62**^{h}
N2P3	3.96^{d}	3.90^{e}	3.61^{j}	**3.82**^{c}	3.09^{d}	3.03^{e}	2.74^{j}	**2.95**^{c}
N3P1	3.83^{f}	3.77^{h}	3.50^{l}	**3.70**^{e}	2.96^{f}	2.90^{h}	2.63^{l}	**2.83**^{e}
N3P2	3.91^{e}	3.81^{fg}	3.55^{k}	**3.76**^{d}	3.04^{e}	2.94^{fg}	2.68^{k}	**2.89**^{d}
N3P3	4.11^{a}	3.99^{c}	3.80^{g}	**3.97**^{a}	3.24^{a}	3.12^{c}	2.93^{g}	**3.10**^{a}
Mean	**3.70**^{a}	**3.62**^{b}	**3.41**^{c}		**2.83**^{a}	**2.75**^{b}	**2.54**^{c}	
Phosphorus (%)								
Control	0.20^{o}	0.18^{p}	0.16^{q}	**0.18**^{j}	0.16^{o}	0.14^{p}	0.12^{q}	**0.14**^{j}
N1P1	0.29^{i}	0.27^{jk}	0.25^{lm}	**0.27**^{g}	0.25^{i}	0.23^{jk}	0.21^{lm}	**0.23**^{g}
N1P2	0.32^{gh}	0.31^{h}	0.27^{jk}	**0.30**^{f}	0.28^{gh}	0.27^{h}	0.23^{jk}	**0.26**^{f}
N1P3	0.38^{ab}	0.36^{cd}	0.32^{gh}	**0.35**^{b}	0.34^{ab}	0.32^{cd}	0.28^{gh}	**0.31**^{b}
N2P1	0.27^{jk}	0.25^{lm}	0.23^{n}	**0.25**^{i}	0.23^{jk}	0.21^{lm}	0.19^{n}	**0.21**^{i}
N2P2	0.28^{ij}	0.26^{kl}	0.24^{mn}	**0.26**^{h}	0.24^{ij}	0.22^{kl}	0.20^{mn}	**0.22**^{h}
N2P3	0.37^{bc}	0.35^{de}	0.31^{h}	**0.34**^{c}	0.33^{bc}	0.31^{de}	0.27^{h}	**0.30**^{c}
N3P1	0.34^{ef}	0.32^{gh}	0.28^{ij}	**0.31**^{e}	0.30^{ef}	0.28^{gh}	0.24^{ij}	**0.27**^{e}
N3P2	0.35^{de}	0.33^{fg}	0.29^{i}	**0.32**^{d}	0.31^{de}	0.29^{fg}	0.25^{i}	**0.28**^{d}
N3P3	0.39^{a}	0.37^{bc}	0.35^{de}	**0.37**^{a}	0.35^{a}	0.33^{bc}	0.31^{de}	**0.33**^{a}
Mean	**0.32**^{a}	**0.30**^{b}	**0.27**^{c}		**0.28**^{a}	**0.26**^{b}	**0.23**^{c}	

Means followed by the same letter (s) are not significantly different at 5% according to Duncan's test. Urea = N1, Ammonium nitrate = N2, Ammonium sulfate = N3, Single superphosphate = P1, Triple superphosphate = P2, Phosphoric acid = P3, and FC = field capacity.

Application of different combinations of N and P sources significantly increased proline, total carbohydrates, N and P contents in leaves more than the control Table (3). Additionally, there are significant differences among the combinations of N and P fertilizer sources. A combination of (N3P3) supply significantly produced the best characteristics (35.96 mg $100g^{-1}$ DW, 25.96%, 3.97% and 0.37%) in 1st season and (36.80 mg $100g^{-1}$ DW, 26.94%, 3.10%, and 0.33%) in 2nd season, respectively. The interactions results had a significant impact, as the greatest N and P contents were gained from (N3P3) at 100% FC (4.11 and 0.39%) in 1st season and (3.24 and 0.35%) in 2nd season respectively, and the lowest value was created from control at 50% FC (3.80 and 0.35%) in 1st season and (2.93 and 0.31%) in the second season, respectively, except proline and total carbohydrates, as the largest value by using (N3P3) at 50% FC (36.87 mg $100g^{-1}$ DW and 26.87%) in the first season and (37.71 mg $100g^{-1}$ DW and 27.85%) in the second season, respectively. However, the smallest result was obtained from control at 100% FC (22.60 mg $100g^{-1}$ DW and 12.60%) in the first season and (24.77 mg $100g^{-1}$ DW and 14.91%) in the second season, respectively (Table 3).

Discussion

Impact of water stress

In the present research, all growth traits of *S. mahagoni* seedlings were affected to varying degrees by different levels of drought stress. Specifically, drought stress resulted in significant reductions in shoot and root length, leaf area, and the total weights of both fresh and dry matter of the plant organs. The lowest values for these traits were observed under the 50% field capacity (FC) treatment. The threat of drought causes morphological and physiological changes in higher plants **(Ghorbani *et al.*, 2019).**

These results of seedling vegetative growth and biochemical features of *S. mahagoni* seedlings were in harmony with the findings of the studies by **Gullap *et al.* (2024)** when applied three levels of drought stress (100, 75, and 50% FC) were on soybean (*Glycine max* L.) seedlings, and the study of **Wang et al., (2023)**, on Mongolian oak (*Quercus mongolica* Fisch. ex Ledeb.) tree seedlings under three of soil moisture conditions [75%, 50% and 23% of soil moisture FC], their results revealed that the values of all studied growth traits (plant's height, total fresh and dry weights and total chlorophyll (a, b)) reduced by increasing water stress, while proline and carbohydrate contents in leaves were greatly positively impacted by rising degrees of water stress.

Drought induces the plant's stem to expand slowly, the plant stays dwarfed, and its leaf growth diminishes, also, water stress could be caused by a hormonal imbalance between abscisic acid and cytokinin, which affects plant growth by altering cell wall elongation forms **(Ahmad *et al.*, 2019)**. Reductions in fresh and dry weight of the plant may also be due to a decrease in plant growth forms, chlorophyll, photosynthesis, and canopy structure during drought conditions or due to the decline in the cell enlargement and more leaf senescence resulting from minimized turgor pressure **(Zhao, 2020).**

Drought causes chlorophyll content degradation due to the formation of an excessive reactive oxygen species (ROS) which causes lipid peroxidation and breakdown of chlorophyll **(Karimpour, 2019)**. Chloroplast destruction occurs due to the presence of reactive oxygen species (ROS) (**Mafakheri *et al.*, 2010**). Plants must produce osmolytes (proline and carbohydrate) under stress conditions to preserve the photosynthetic apparatus, retain cell turgor, and avoid a hydraulic collapse **(Gurrieri *et al.*, 2020)**. Additionally, plants accumulate osmolytes and antioxidant enzymes to detract cytoplasmic osmotic capacity and eliminate excess reactive oxygen species **(Rane *et al.*, 2021)**.

Regarding the obtained result, root length has improved positively with rising degrees of drought stress. Our observation in the same trend obtained by **El-Sayed *et al.* (2022)**, who reported that after applying three styles of irrigation intervals (5, 7, and 9 days) on the seedlings of *S. mahagoni*, they found that stressed seedlings gave the longest roots. Concerning the significance of root length, **Wasaya *et al.* (2018)** displayed that, field soil moisture contents rise with soil depth; hence, an extended root system could reach a greater soil volume to collect available water. Furthermore, because roots are the sole organ that receives water from the soil, they are the primary organs that respond to perceive and keep up plant growth under drought stress.

As described in our results, relative water content (RWC) was markedly reduced by lowering soil water content. These data are similar to those recorded by **Jibo and Barker (2019)**, who confirmed that RWC declined via decreasing soil moisture capacities due to the application of three degrees of water stress on *Acacia senegal* seedlings. RWC is one of the most significant characteristics connected to drought stress and diminishes in response to the lack of moisture. Rising RWC means that the plant has its need for water to complete the various plant physiological processes **(Sarkar *et al.*, 2015)**. The reduction in

RWC of leaves could be related to a shortage of water in the soil, with root systems failing to compensate for water loss through transpiration due to a decline in the absorbing surface **(Bolat *et al.*, 2014)**.

Water use efficiency (WUE) was enhanced positively with rising drought levels, as the highest values were obtained at 50 % FC. These findings were confirmed by a previous study by **Abd-Elrahman *et al.* (2022)**, who subjected Eggplant (*Solanum melongena* L.) to three irrigation modes. In the opinion of **Esmaeilpour *et al.* (2016)**, WUE is the capacity of a plant to create dry matter per unit of water, and it is an important indicator of a plant's resistance to drought stress. Increasing WUE gives plants an advantage for fitness in water-limited ecosystems. Drought-tolerant plants achieve greater water use efficiency by minimizing water loss. This can occur through the closure of their stomata when water is scarce, as indicated by **Farooq *et al*. (2009)**.

As described in the results, N and P were considerably decreased by derogating soil water content; it became apparent that the highest values of previous parameters were achieved in the case of 100% FC practice; this conclusion is consistent with previous experimental studies on *Eucalyptus citriodora* Hook seedlings by **Abdel-Magied *et al.*, (2022)**, when seedlings were placed under three irrigation intervals, (2, 5, and 7 days), irrigation intervals at 7 days reduced the values of N and P elements in leaves more than 2 and 5 days. Reduction in N and P content in leaves minimizes the absorption of important nutrients during a drought **(Nohong and Nompo, 2015)**. Soil water scarcity inhibits micro-organisms' mineralization for organic matter, which ultimately hurts N and P availability, uptake, and transportation, affecting the utilization of nutrients by plant roots **(Wasaya *et al.*, 2018)**. Moreover, drought impacts the mobility of nutrients and limits the transfer of nutrients between roots and aerial organs, thereby reducing the uptake of nitrogen and phosphorus. **(Suriyagoda *et al.*, 2014).**

Impact of N and P fertilizer sources

Both nutrients and water are two of the most important factors determining tree growth and they interact **(Yin *et al.*, 2009)**. Nutrient combinations perform better than individual nutrients **(Khan *et al.*, 2014)**. Interactions can be advantageous (synergistic) or destructive (antagonistic). Applying nitrogen fertilizer promotes phosphorus absorption **(Onasanya *et al.*, 2009)**.

In this study, all treatments involving various combinations of nitrogen (N) and phosphorus (P) fertilizers resulted in significantly higher vegetative growth and biochemical traits compared to the control group. Our findings showed that the combination of (N3P3) or (N2P3) notably improved vegetative growth indicators, such as shoot length and chlorophyll content, as well as nitrogen and phosphorus levels in the leaves. These results align with the findings of **Abd-Elrahman *et al*. (2022)**, who also observed beneficial effects from applying (N3P3) or (N2P3) on eggplant under three different irrigation conditions (50%, 75%, and 100% field capacity).

By application of a combination of (N1P3), fertilizers increased the output of seedling growth (shoot length, leaf area, total chlorophyll content and proline). The findings of this study were also confirmed by **Gelaw *et al.* (2023)** who found that N and P can help plants adapt to a lack of water by increasing the activity of the photosynthetic system and antioxidant enzymes and by the application of (N1P3) on four maize seedlings that were exposed to four drought treatments. The combination of (N1P1) significantly improved total chlorophyll and P content in leaves, with our results in agreement with those created by **Alhassan *et al.* (2022)**. They applied (N1P1) on *Vigna radiata* (L.) under water stress. A combination of (N1P1), significantly improved total biomass, root length, water use efficiency, relative water content, total chlorophyll, and P content in leaves. Thus, our results agree with those obtained by **Abo-Alhassan *et al.* (2022)** when employed (N1P1) on *Vicia faba* L. plants under two irrigation regimes, fertilizers significantly enhanced the previous measurements.

Concerning a combining (N1P2), our observation showed that this combination markedly accelerated seedling vegetative growth, root development, and dry biomass. A similar trend was noticed by **Li *et al.* (2022)** on Maize (*Zea mays* L.), by using (N1P2) under two deficit irrigation levels. The plants that received a combination of (N2P2) fertilizers noticeably increased shoot length. These results followed those of **Kizilgeci (2018)** when supplied (N2P2) on wheat (*Triticum aestivum* L.) under dryland conditions. A combination of (N3P1), with the improved shoot length, is in the same line as those obtained by **Ibrahim and El-Kassas (2016)**, through using (N3P1) on *Vigna unguiculata* L. under three water field capacities (50, 75, and 100%). A combination of (N3P2), fertilizers strictly raised shoot length, canopy fresh and dry weight of seedlings. These results correspond with those of **Farrag *et al.* (2016)** by employing (N3P2) on potato (*Solanum tuberosum* L.) cultivar under 50, 75 and 100 % FC.

Concerning N and P sources, a

combination of (N3P3) is the best application according to **Ezzat *et al.* (2011)**, who stated that among the forms of N-fertilizers, the application of N3 was more successful than other forms. The better effect of N3 can be linked to the acidic component's involvement in lowering soil pH and facilitating nutrient absorption by plant roots, resulting in large increases in N and P elements uptake and faster plant growth. Especially, the majority of Egypt's soils are alkaline with a pH of 7 to 9 **(El-Ramady *et al.*, 2019)**. Based on the results of **Sardans *et al.*, (2004)**, high soil pH (pH: 8-9) inhibits P mobility and diffusion, which causes less accessible P to plants. pH range of 6.5 to 7.0 is the ideal pH for P availability in soils **(Penn and Camberato 2019)**. N3 lowers soil alkalinity three times more than N1 or N2 **(Chien *et al.*, 2010)**.

The superiority of N3 over N1 is most likely due to the presence of sulphur (S 24%), which is a component of succinyl Co-A, a component of chlorophyll in leaves, accelerated photosynthesis, which forced vegetative growth **(Ralsool *et al.*, 2013)**. Sulfur is an essential component of amino acids **(Patra *et al.*, 2013)**. Because N3 has an acidifying effect on soil, its continued usage may be beneficial in alkaline soils **(Amanullah *et al.*, 2016)**. Since nitrates are not held by the soil complex, they can be significantly leached away (Wang et al., 2015). Urea may enhance growth by improving macro and micronutrient uptake in both shoots and roots (**Sabir *et al.*, 2013**).

The synergism between NH_4^+ and P in mahogany creates the advantageous effect of NH_4^+ supply for mahogany cultivation. In contrast, antagonism between nitrate and phosphate uptake represents a disadvantage of nitrate supply for mahogany cultivation **(Cardoso *et al.*, 2015).** P3 has a primary role in lowering soil pH, which may enhance the availability of mineral elements (macro and micronutrients) by making them more soluble and available for absorption by plants, thereby increasing vegetative growth **(Mohamed, 2021).** As noted by **Holloway *et al.* (2001)**, (P3) might be less reactive to soil components due to the dilute solution that contains the P ion in the soil around the fluid stream than around the granule (P1 and P2). So, this trial concluded that when (P3) was combined with each of the three N sources, N and P elements concentration increased considerably. P1 is 90% water soluble and essentially plant available. However, due to its low P breakdown, it is not commonly used. So (P2), is also known as concentrated superphosphate **(Marschner, 1995)**.

Applying P3 directly benefits wheat

plants in alkaline and calcareous soils. Previous research found that a half-dose of P3 gave the same maize yield as a full dose of P1 **(Akhtar, *et al.* 2016)**. N and P had considerable interacting effects on plant development, with P addition increasing soil N absorption in seedlings of *Eucalyptus grandis*. Applying P in conjunction with ammonium increases the availability of both nutrients **(Graciano *et al.*, 2006).**

The increase in plant growth with nitrogen (N) fertilizer is likely due to nitrogen being an essential element in the formation of the amino acid tryptophan. Tryptophan is important for the synthesis of auxin, which plays a critical role in plant elongation and activates meristem cells. As a result, cell division increases, leading to a larger leaf area. **(Al-Taher *et al.*, 2005)**. Nitrogen enhances the formation of chloroplasts during leaf growth, also N is the most important elemental factor in chlorophyll biosynthesis **(Filho *et al.*, 2011)**.

Conclusion

The results showed that drought stress greatly declined shoot length, leaf area, the total fresh and dry weight, relative water content, total chlorophyll (a, b) and N, P contents in leaves. However, it sharply raised root length, water use efficiency, proline and carbohydrate contents in leaves. All different combinations of N and P fertilizer sources significantly improved the above parameters compared to the control. A combination of ammonium sulfate and phosphoric acid produced the highest value, while a combination of ammonium nitrate and single superphosphate significantly generated the lowest value. It was found that applying different combinations of N and P fertilizer sources mitigated drought stress by increasing the estimated vegetative growth and biochemical characteristics of *S. mahagoni* (L.) Jacq.

Authors recommended that further studies must be conducted to increase the wood production of the valuable tree *S. mahagoni* which means money at the end fill gaps in wood market in Egypt.

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تأثير التسميد بمصادر مختلفة من النيتروجين والفوسفور على نمو شتلات الماهوجني الأسباني تحت الإجهاد المائي

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الجفاف هو خطر عالمي تواجهه العديد من الدول مما يؤدي إلي نقص في الإنتاج الزراعي وزيادة ندرة المياه. شجرة الماهوجني الاسباني هي شجرة مهددة بالانقراض؛ ولها قيمة مهمة في الأسواق العالمية حيث أن خشب جذعها مقاوم للتعفن والتلف الحشري متفوقًا على جميع أصناف الماهوجني العالمية الأخرى. ولها العديد من الخدمات البيئية (الوقود والخشب والدواء والظل والمأوى). تهدف هذه الدراسة إلى تعزيز نموها باستخدام مصادر مختلفة من الأسمدة النيتروجينية (N) والفوسفورية (P)؛ ودراسة تأثيرها على نمو وتحمل الجفاف لشتلات الماهوجني للحصول على أعلى نمو لها باستخدام أقل موارد المياه المتاحة. خلال موسمي النمو (٢٠٢٢-٢٠٢٣) و(٢٠٢٣-٢٠٢٤) أجريت تجربة حقلية بمحطة البحوث الزراعية بالجميزة. تم تطبيق ثلاثة مصادر للأسمدة الفسفورية (سوبر فوسفات أحادي وثلاثي وحمض الفوسفوريك) وثلاثة أسمدة نيتروجينية (يوريا وكبريتات ونترات الأمونيوم) تحت تأثير ثلاثة مستويات من الإجهاد المائي [١٠٠ و٧٥ و٥٠٪ من السعة الحقلية]. أظهرت النتائج أن الإجهاد الناتج عن الجفاف أدى إلى انخفاض كبير في طول الساق ومساحة الأوراق وأوزان الوزن الطازج والجاف الكلي للنبات ومحتوى الماء النسبي والكلوروفيل الكلي (أ، ب) ومحتوى النيتروجين والفوسفور في الأوراق، ولكنه أدى إلى زيادة معنوية في طول الجذر وكفاءة استخدام المياه ومحتوى البرولين والكربوهيدرات في الأوراق. أدت جميع التركيبات المختلفة من مصادر الأسمدة النيتروجينية والفوسفورية إلى تحسين المعايير المذكورة أعلاه بشكل ملحوظ مقارنة بالغير معاملة. أعطت المعاملة بمزيج من سلفات الامونيوم وحمض الفوسفوريك أعلى نمو.