RESEARCH ARTICLE

Influences of Nitrogen, Magnesium and Soil Moisture Contents and their Interactions on Yield Quality and Tolerance Indices of Rosemary (*Rosmarinus officinalis* L.)

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ABSTRACT

The present study was carried out in the glasshouse of the Department of Biology, College of Science, Salahaddin University-Erbil, and laboratories of Research Center in Erbil Polytechnic University, from April 21st, 2019 to July 26th, 2020, to determine the effects of foliar application of nitrogen (N1:100, N2:200, and N3:300 kg. h^{-1}) and magnesium (Mg1:0.0, Mg 2:30, and Mg3:60 kg. h^{-1}) applied under two different soil moisture contents (SM1:100% field capacity (FC) and SM2: 60% FC) on some physiological properties and yield quality of rosemary plants (*Rosmarinus officinalis* L.). A factorial experiment was laid out according to a completely randomized design with four replications. Two cuttings were taken from the rosemary shoots (in March, and July, 2020). Results showed that SM2 decreased phenolic compounds in cut 1 (cut 1), dry matter percent in leaves in cut 2 and relative nitrogen yield in cut 1, cut 2 & cut 1+2. N3 increased dry matter in leaves & shoots in cut2 significantly, proline, phenolic compounds in leaves, stress tolerance index (STI), modified stress tolerance index 1(MSTIK1), & modified stress tolerance index 2 (MSTIK2). The interaction treatment SM2Mg2 increased the proline content in dry leaves. The proline content was increased by the triple interactions SM2N3Mg2 and SM2N3Mg3.

Keywords: Rosemary, Water stress, Chemical fertilizers, Phenolic compounds, Carbohydrates.

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INTRODUCTION

Rosemary *(Rosmarinus officinalis* L.) is a common household medicinal, woody, perennial herb with fragrant, evergreen, needle-like leaves and white, pink, purple, or blue flowers; the plant belongs to the Lamiaceae family. Its essential oil (volatile oil) is used therapeutically and contains many important chemical compounds like borneol, bornyl acetate, camphene, cineol, pinene & camphor. Rosemary extracts contain carnosol, carnosic acid, and rosmarinic acid. The presence of these chemical constituents may differ between rosemary extracts according to the extraction procedures.

The name rosemary is derived from the Latin ros (roris) meaning dew, and marinus meaning sea. Being known as the "dew of the sea", the plant grows in many places on the planet (in dry soils or moderately humid soils), reaching a height of 1 to 2 meters. Rosemary plants do not tolerate anaerobic or very wet soils, but those with salinity half. Its flowering period is from May to June, and fruiting is from spring to summer.[1] Rosemary essential oil can increase the shelf life of food and personal care items due to its high antibacterial and antioxidant properties (Figure 1).[2]

Various medieval drug monographs and literature have described it as a medicinal plant and a wonder-drug.[3] Rosemary is used to treat some conditions or symptoms like depression,

Figure 1: Shoots and flowers of rosemary plant.

**Author for Correspondence: abdulghany.ismaeel@su.edu.krd* circulatory disorders, wounds, pain (neuralgia, muscle pain), mild spasms, rheumatism, digestive, and eczema.[4]

Drought stress in agriculture is described as a shortage of soil water in a given area due to below-average rainfall.[5] Temperature, dryness, light, salt, and chemical toxicity have all caused stress to agricultural fields throughout the world, and there is a need to control the use of water resources owing to the threat of climate change. Plants' morphological and physiological changes and gene regulation might respond to drought within the same acclimation period.[6] Under low nitrogen concentrations, plant roots must absorb more water to be able to take up the same quantity of nitrogen for metabolism from the soil, *vice-versa*, plant roots are unable to obtain adequate levels of nitrogen from soil under drought stress, which has severe impacts on plant development through disrupted physiological metabolisms.[7]

Nitrogen is one of the essential macro elements used in fertilization for good crop performance and to enhance biomass production. Since it is responsible for cell expansion, resulting in the development of the plant area while also exercising the functions of essential constituents of pigments and proteins, which influence physiological processes.[8] Nitrogen and water are the two main factors that play vital roles in turf grass growth and ornamental quality constraints. Only about half of the nitrogen fertilizer applied to plants is absorbed.[9]

Because metabolic activities may go on even when tissue water potential is low, efficient nitrogen feeding can help crops deal with water stress. Plants use a variety of acclimation processes to adjust their rate of development to the accessibility of resources. Designing appropriate management approaches that improve crop performance and increase resource use efficiency in resource-constrained situations requires understanding the key strategies and growth characteristics that describe how plants respond to maximum and minimum quantities of these resources.[10]

The main obstacles to plant growth and development are water restrictions and reduced nitrogen application, which have been widely documented to affect leaf water relations, chlorophyll fluorescence, and photosynthetic traits, leading to slower plant growth and earlier senescence, and lower crop productivity.[11]

Magnesium deficiency negatively affects on carbohydrates in plants.[12] The addition of magnesium has a major impact on oil, its properties, chlorophyll, and carbohydrate content compared with control trees.[13] According to some research, the absence of chlorophyll in magnesium leaves isn't caused by a deficiency in magnesium, which is necessary for the production of chlorophyll molecules, but rather by a barrier to protein synthesis. The content of two types of limiting amino acids, lysine and threonine, in cereal protein also increased when sufficient magnesium was provided, which could somewhat improve rice's nutritional quality. Brown rice's crude protein and total amino acid content also increased when sufficient magnesium was provided. Plant magnesium insufficiency has been a widespread phenomenon in recent years, and it now plays a significant role in limiting plant productivity and quality. Crops including sugar cane, flue-cured tobacco, bananas, eggplant vegetables, tea, peanuts, soybeans, citrus, early rice, late rice, astragals, corn, and millet all benefit greatly from magnesium's ability to increase output and quality.[14]

MATERIALS AND METHODS

A factorial experiment (with three factors) was conducted in a glasshouse and laboratories of the biology department, Salahaddin University-Erbil, Iraq, during the period 2019-2020 to determine the effects of soil moisture content (SM1: 100% field capacity (FC) and SM2:60% FC), nitrogen fertilization (N1:100, N2:200, and N3:300 kg/ha), magnesium (Mg1: 0.0, Mg2: 30, and Mg3:60 kg/ha), and their interactions on yield quality and tolerance indices of rosemary (*R. officinalis* L.). The experiment was applied according to CRD with four replications.

A sample of the soil used in the experiment was prepared after air drying, then grind and passed through a sieve with holes 2 mm in diameter, the soil sample was analyzed in the central laboratory of the College of Agriculture, University of Mosul, Iraq to determine some chemical and physical properties of the soil as shown in Table 1. While soil minerals were estimated using X-ray Fluorescence (XRF) apparatus according to.[15] Nitrogen was estimated by Kjeldahl method,[16] potassium was estimated by the spectrophotometer method, and Mg and total phosphorus were mentioned by.[16] The field capacity of the soil was estimated using the method described by[17] which was 35%. Soil texture was evaluated using the pipette method, the organic matter was estimated in dry burning method, pH was calculated using a pH meter and the soil's electrical conductivity (EC) was measured using an EC meter.

Brown plastic pots with 25 and 17 cm diameters for the top and bottom base, respectively, 20 cm height, with holes in the bottom to drain out the excess water were prepared. Every pot was filled with five kilograms air-dried soil.

Table 1: Some physical and chemical properties of the soil used in the study

	Parameters	*value*
Physical properites	Soil Texture	Sandy loam
	Soil Structure	Sand:70.80% Clay:7.95% Silt:21.25%
Chemical properites	PH	7
	EC	1.00 (mL s cm^{-1})
	N	0.35%
	P	4.29 ppm
	K	4743.445 ppm
	Ca	101.892 (g kg^{-1})
	Mg	15 ppm
	Mn	740.379 ppm
	Fe	34560.802 ppm
	Zn	58.220 ppm

Rosemary plants were obtained from one of the nurseries in Erbil, Iraq, authenticated by the herbarium of Biology Department, College of Education, Salahaddin University-Erbil, Iraq. In mid-April, cuttings were prepared for planting by selecting healthy rosemary plants (at least one year old) with a lot of young new growing branches on them.[18] Cuttings of 7.5 cm were obtained from young shoots just below the leaf joints by using a sharp knife, then leaves were removed from the bottom 4 cm using fingers, and the cuttings were soaked in Indole-3-butiric acid solution (1000 ppm) diluted in distilled water for two minutes.[19] Rosemary cuttings were planted by inserting two cuttings in 4 cm deep in each pot, and thinning and replanting processes were done for all pots after two weeks from planting.

Nitrogen fertilizer from urea (46% N) in three doses (100, 200 and 300 $kg.ha^{-1}$) were prepared, and concentrations of 0.0, 30 and 60 $kg.ha^{-1}$ of magnesium was prepared from MgO (56% Mg). Solutions of 100 kg/ha for each of phosphorus from MAP (Mono ammonium phosphate) (NPK 12:61:0) (61% P_2O_5) and potassium from potassium humate (11% K) were prepared. All fertilizers were foliar applied on rosemary plant shoots once, except the nitrogen fertilizer which was applied in two half doses, the first half dose was done in the same time of spraying other fertilizers and the second one was applied before harvesting by one month.

Pots were irrigated by well water as needed according to soil moisture content treatments (field capacities of 100 and 60% FC during the study period. The amount of water lost was replenished in order to maintain the requested soil moisture content. Samples of an irrigation well water were taken and kept in sterile glass bottles for analyzing and determining physical and chemical characteristics at the laboratories of the Department of Environmental Sciences, College of Science, Salahaddin University-Erbil, Iraq. PH, EC, chloride, and sodium were estimated as described in (20), while total dissolved solid (TDS), nitrate, potassium (K), calcium, magnesium, turbidity, hardness, and sulfate (SO_4^{-2}) were estimated as described in[16] as shown in Table 2.

Table 2: chemical analysis of the irrigation water used in the study

Parameters	*Value*	*Units*	*Norms*
Turbidity	1.13	NTU	0-5
pH	7.89	-	6.5-8.5
EC	0.388	$mS.m^{-1}$	0.1-1.5
TDS	252	ppm	100-1000
Chloride	24.92	ppm	350
Sodium	8.7	ppm	200
Potassium	1.2	ppm	250
Calcium	56	ppm	150
Magnesium	14.58	ppm	100
Total Hardness	200	$mg.CaCO_3.l^{-1}$	100-500
Total Alkalinity	192	$mg.CaCO_3.l^{-1}$	30-200
Nitrate	16.78	ppm	50
Sulphate	29.79	ppm	400

Harvest (cutting) of Rosemary Plants

Rosemary plant shoots were harvested by cutting the shoots on April, 2020 (1st cutting (cut 1)) after twelve months of planting and cut 2 (2nd cutting) on July, 2020. In cut 1, the branches of rosemary plants were cut from about 15 cm above the ground, leaving the nodes below the cutting point to let the plants grow again after the harvesting process,[18] but in the second cutting, the shoot system was cut completely at the contact point of the stem with the roots. Shoots (aerial parts) were harvested using a sharp stainless steel scissor. The harvested samples were air-dried on a perfectly clean surface on paper bags (with holes) at room temperature in a shady place with fresh air (dust-free atmosphere) for at least 10 days. The root system of rosemary plants was carefully separated from adhering soil particles using tap water, roots were washed with water several times, and then air-dried on a clean surface in the shade at room temperature for 10 days.

EXPERIMENTAL PARAMETERS

Rosemary Plants Moisture% and dry Matter%

A sample was taken from the air-dried rosemary plants and weighed, and then the sample was dried in oven at 70°C until the weight became constant. The following equation was applied:

Moisture factor = weight of the air-dried sample (g)/weight of the oven-dried sample (g)[16]

Thereafter, air-dried samples were weighed, considering the moisture factor.

Moisture content% in leaves, stems and shoots

Moisture% = ((fresh weight- dry weight)/fresh weight) x 100

Dry matter content% in leaves, stems and shoots

Dry matter% = (dry weight/fresh weight) x 100, or

Dry matter% = 100- moisture%

Some Physiological Characteristics

Proline Determination

A sample of fresh rosemary leaves was prepared to determine the proline content[21] using spectrophotometer apparatus at 520 nm. Firstly, a ground 0.5 g leaf sample was homogenized in 10 mL of sulfosalicylic acid (3% w/v). The filtrates were filtered after 24 hours through filter paper, then 2 mL of the filter solution was mixed with 2 mL of acid ninhydrin solution (0.125 g ninhydrin +3 mL glacial acetic acid +2 mL of phosphoric acid (6M H_3PO_4) with 2 mL of glacial acetic acid (taking care that acid ninhydrin will remain stable only for 24 hours at 4°C). After one hour in a 100°C water bath, the reaction was stopped by transferring the mixture to an ice bath; 4 mL of toluene was added to the mixture, and test tubes were shaken vigorously by hand for 20 seconds. By using a separation funnel, the toluene phase (chromophore toluene) was separated and the absorbance was measured at 520 nm in a spectrophotometer (EMC 11 LAB GERMANY model) using pure toluene as a blank. The calibration curve was prepared using purified proline (Figure 2), the results were expressed as micromoles of proline per gram of dry material of leaves.

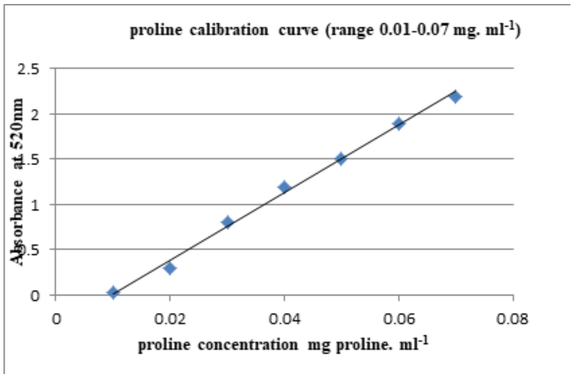

Figure 2: Calibration curve for evaluation of free proline concentration in leaves.

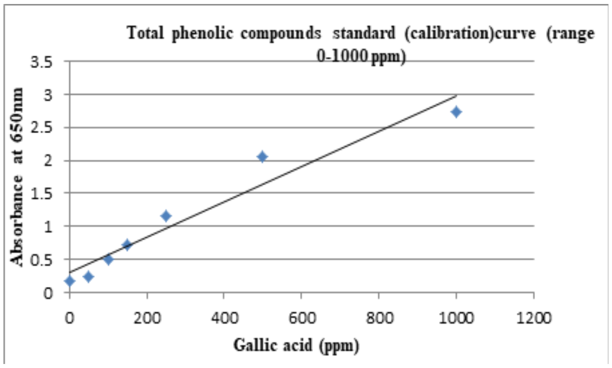

Figure 3: Calibration curve for evaluation of phenolic compounds concentrations

Total Phenolic Compounds in Rosemary Leaves

Rosemary leaf extract was prepared by the maceration method. 0.5 gms of powdered plant leaves were extracted using 15 mL of acidic methanol (one mL of HCl (0.1%) was added to 100 mL of methanol with (1:100 V: V). The extraction was carried out for 48 hours at room temperature, then filtered using filter paper. The plant extract's total phenolic content (TPC) was determined using the folin- iocalteu procedure.[22] Three mL of distilled water were added to 1-mL of methanolic extract, then 0.5 mL of folin-ciocalteau reagent was added and left for 3 minutes. Two mL of 20% Na2CO3 were added, the mixture was allowed to stand for two hours in the shade with intermittent shaking, and 25 mL of distilled water was added. The absorbance was measured at 650 nm (Figure 2). Total phenolic compounds in rosemary methanolic extracts were expressed as mg GAE/g dry leaf equivalent using the standard gallic acid curve.

Determination of Soluble Carbohydrates

Leaf samples were dried at 70°C for 48 hours, then crushed into a fine powder to determine the amount of soluble carbohydrates. Using the phenol-sulfuric acid technique to identify the soluble carbohydrates in rosemary leaves, a total carbohydrate percentage in the powder was calculated.[23] 5 mL of 95% ethanol were added to 0.5 g of rosemary leaf powder to extract the carbohydrates. One mL of the ethanol extract was combined with 1-mL of a 5% (w/v) aqueous phenol solution in a test tube (which was prepared immediately before the measurements). The mixture is then quickly added 5 cc of pure sulfuric acid. The test tubes are then allowed to stand for 10 minutes, vortexed for 30 seconds, and then placed in a water bath for 20 minutes at room temperature to develop color. Then, a spectrophotometer was used to measure the absorption of light at 490 nm. For the standard curve, several D-glucose concentrations were used (Figure 3). The quantity of soluble sugars in the samples is calculated using the standard curve.

Total Protein Content (mg g^{-1})

Rosemary leaf samples were put in an oven to dry at 70°C for 48 hours, then ground in an electric stainless steel mill and passed through a sieve of 2 mm. Before each grind process, the cup and blades of the grinding mill were cleaned well, the sample was put back in the oven till constant dry weight was obtained, and concentrated sulfuric acid (H_2SO_4) and hydrogen peroxide (30% H_2O_2) were used to digest the rosemary powder leaves,[16] total N was measured by the Kjeldahl method as described in,[16] then total protein was determined from total nitrogen determination, multiplying the results by 6.25 (protein factor)[24] according to the following formula (Figure 4):

Total Protein content (mg/g) = Total nitrogen content (mg/g) x 6.25

Relative yield (RY%) of fertilizer, relative efficiency (RE%) of fertilizer and the highest total yield (HTYN) of fertilizer and response to fertilizer (RF%):

The relative yield of fertilizer and Relative efficiency of fertilizer were calculated according to (25) as follows:

The relative yield of fertilizer (RY%):

RY% = (yield dry weight of control treatment/yield dry weight of fertilized treatment) x 100

Relative efficiency of fertilizer% (RE%):

RE% = ((dry weight of fertilized treatment-dry weight of control treatment)/dry weight of control treatment) x100.

The highest total yield of fertilizer (g) (HTYN)):

HTYN = yield dry weight of fertilized treatment-yield dry weight of fertilizer.

Response to fertilizer % in fresh or dry weight (RF%):

RF % = ((weight of fertilizer yield-weight of control yield)/ weight of fertilizer yield) x100

Tolerance indices:

Tolerance indices were calculated in dry weight of leaves (cut.1) using the following equations:

Mean productivity (MP):

$$MP = (Ypi + Ysi)/2$$

Where Ysi: Mean of grain yield under stressed condition and Ypi: Mean of grain yield under non stress conditions

Stress susceptibility index (SSI):

$$SSI = (1-(Ysi/Ypi))/SI$$

Where SI = 1−(Ys/Yp) and, Ys: represents the yield in stress status, Yp: Yield under non-stress conditions

Stress tolerance index (TOL):

$$TOL = (Ypi-Ysi)$$

Geometric Mean Productivity (GMP):

$$GMP = (Ypi \times Ysi)^{0.5}$$

Table 3: Effects of soil moisture, nitrogen, magnesium and their interactions on moisture% and dry matter % (DM%) in leaves; and moisture% and DM% in shoots of rosemary plants (cut.2).

Treatments	*L. moisture %*		*L.DM%*		*Sh. moisture %*		*Sh. DM%*	
SM1(100%)FC	35.150	b	54.851	a	33.060	a	56.940	a
SM2(60%)FC	37.094	a	52.907	b	34.839	a	55.161	a
N1(100 kg/ha)	37.275	a	52.734	b	36.344	a	53.656	b
N2(200 kg/ha)	39.450	a	50.543	b	35.600	a	54.400	b
N3(300 kg/ha)	31.642	b	58.360	a	29.904	b	60.096	a
Mg1(0.0 kg/ha)	34.504	a	55.496	a	33.729	a	56.271	a
Mg2(30 kg/ha)	35.538	a	54.462	a	33.562	a	56.438	a
Mg3(60 kg/ha)	38.325	a	51.680	a	34.557	a	55.443	a
SM1N1	38.633	ab	51.376	bc	37.438	a	52.562	b
SM1N2	37.592	ab	52.397	bc	33.279	ab	56.721	ab
SM1N3	29.225	c	60.780	a	28.462	b	61.538	a
SM2N1	35.917	ab	54.093	bc	35.250	a	54.750	b
SM2N2	41.308	a	48.690	c	37.920	a	52.080	b
SM2N3	34.058	bc	55.940	ab	31.346	ab	58.654	ab
SM1Mg1	30.700	b	59.301	a	31.789	a	58.211	a
SM1Mg2	37.333	a	52.661	b	33.710	a	56.290	a
SM1Mg3	37.417	a	52.591	b	33.680	a	56.320	a
SM2Mg1	38.308	a	51.690	b	35.669	a	54.331	a
SM2Mg2	33.742	ab	56.264	ab	33.413	a	56.587	a
SM2Mg3	39.233	a	50.769	b	35.434	a	54.566	a
N1Mg1	37.588	ab	52.419	bc	35.605	ab	54.395	ab
N1Mg2	33.963	bc	56.053	b	35.105	ab	54.895	ab
N1Mg3	40.275	ab	49.732	bc	38.323	a	51.677	b
N2Mg1	39.688	ab	50.306	bc	35.759	a	54.241	b
N2Mg2	36.275	ab	53.710	bc	32.984	ab	57.016	ab
N2Mg3	42.388	a	47.615	c	38.056	a	51.944	b
N3Mg1	26.238	c	63.762	a	29.824	ab	60.177	ab
N3Mg2	36.375	ab	53.625	bc	32.596	ab	57.404	ab
N3Mg3	32.313	bc	57.693	ab	27.292	b	62.708	a
SM1 N1 Mg1	38.300	ab	51.713	bc	36.897	abc	53.103	abc
SM1 N1 Mg2	39.725	ab	50.285	bc	37.093	abc	52.907	abc
SM1 N1 Mg3	37.875	ab	52.129	bc	38.325	abc	51.676	abc
SM1 N2 Mg1	35.575	ab	54.420	bc	31.798	abc	58.202	abc
SM1 N2 Mg2	35.275	ab	54.696	bc	31.158	abc	58.842	abc
SM1 N2 Mg3	41.925	a	48.076	c	36.882	abc	53.118	abc
SM1 N3 Mg1	18.225	c	71.770	a	26.672	bc	63.328	ab
SM1 N3 Mg2	37.000	ab	53.002	bc	32.880	abc	57.120	abc
SM1 N3 Mg3	32.450	ab	57.568	bc	25.833	c	64.167	a
SM2 N1 Mg1	36.875	ab	53.124	bc	34.313	abc	55.688	abc
SM2 N1 Mg2	28.200	bc	61.820	ab	33.117	abc	56.883	abc
SM2 N1 Mg3	42.675	a	47.335	c	38.321	abc	51.679	abc
SM2 N2 Mg1	43.800	a	46.191	c	39.721	a	50.280	c
SM2 N2 Mg2	37.275	ab	52.724	bc	34.810	abc	55.190	abc
SM2 N2 Mg3	42.850	a	47.154	c	39.229	ab	50.771	bc
SM2 N3 Mg1	34.250	ab	55.754	bc	32.975	abc	57.025	abc
SM2 N3 Mg2	35.750	ab	54.248	bc	32.312	abc	57.688	abc
SM2 N3 Mg3	32.175	ab	57.817	bc	28.752	abc	61.248	abc

The Means in each category of column followed by the same letters are not significantly different at $p \leq 0.05$ according to duncan's multiple range test.

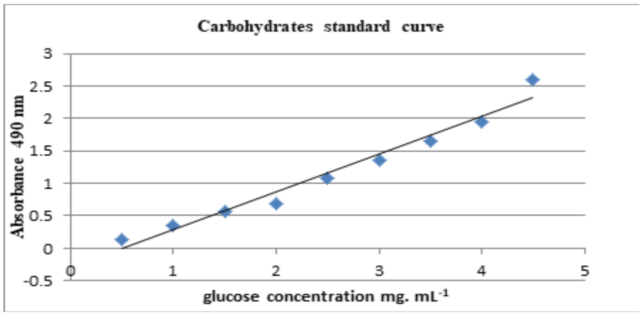

Figure 4: Calibration curve for evaluation of soluble carbohydrates concentrations.

Relative efficiency index (REI):

$$REI = (Ysi/Ys) \times (Ypi/Yp)$$

Stress Tolerance Index (STI):

$$STI = (Ysi \times Ypi)/(Yp^{2})$$

Modified Stress Tolerance Index 1(MSTIk1):

$$MSTIk1 = (Ypi\ 2/Yp\ 2) \times STI$$

Modified Stress Tolerance Index 2(MSTIk2):

$$MSTIk2 = (Ysi\ 2/Ys\ 2) \times STI$$

Relative decrease in yield (RDY):

$$RDY = 100-((Ysi/100) \times Ypi)$$ [26-30]

Statistical Analysis

Data was analyzed statistically according to the statistical package for the social sciences (SPSS) program, Version 24 and the means were compared using Duncan multiple range test at a probability 0.05 of significance.

RESULTS AND DISCUSSION

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Moisture% in Rosemary Leaves cut 2

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Moisture% in Leaves cut 2 (LM%)

Table 3 showed that soil water deficiency (SM2) caused significant increases in LM content (37.1%) compared to SM1 (35.2%). N3 decreased LM% significantly to 31.6% compared to N1 (37.3%). Interaction treatment SM1N3 reduced LM% significantly to 29.2% compared to SM2N2 (41.3%), SM1Mg1 also decreased LM % significantly to 30.7% compared to SM2Mg3 (39.2%) and N3Mg1 decreased LM % significantly to 26.2% compared to N2Mg3 (42.4%). Triple interaction treatment SM1N3Mg1 reduced LM% significantly to 18.2% compared to SM1N2Mg3, SM2N1Mg3, SM2N2Mg1 and SM2N2Mg3 which registered 41.9, 42.7, 43.8 and 42.9%, respectively.

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Dry Matter% in Leaves cut2 (LDM%)

Soil water deficiency (SM2) caused a significant decrease in LDM% and registered 52.9% compared to 54.9% for normal soil moisture content (SM1). Ribas-Carbo et al.reported that net photosynthesis decreased in soybean leaves by 40 and 70% under mild and severe water stress, respectively.[31] N3 increased LDM% significantly (58.4%) compared to N1 and N2 which registered 52.7 and 50.5%, respectively (Table 3). Interaction treatment SM1N3 increased LDM % significantly to 60.78% compared to SM2N2 (48.69%). SM1Mg1 increased LDM% significantly (59.3%) compared to other SMMg interaction treatments. N3Mg1 caused a significant rise in LDM (63.76%) compared to N2Mg3 (47.6%). Triple interaction treatment SM1N3Mg1 caused a significant increase in LDM (71.77%) compared to SM1N2Mg3, SM2N1Mg3, SM2N2Mg1 and SM2N2Mg3 which registered 48.1, 47.3, 46.2 and 47.2% respectively (Table 3).

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Moisture% of Shoots (Sh. M%) cut 2

N3 reduced Sh. M% significantly to 29.9 compared to 36.3% for N1. Interaction treatment SM1N3 reduced Sh. M to 28.5 compared to 34.4% for SM1N1and the interaction treatment N3Mg3 reduced Sh. M to 27.3 compared to 38% for N1Mg3 and N2Mg3. Triple interaction treatment SM1N3Mg3 reduced Sh. M% significantly to 25.8 compared to 39.7% for SM2N2Mg1.

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on DM% Shoots (Sh. DM%) cut 2

N3 increased the Sh.DM% significantly to 60 compared to 53.7% for N1. Interaction treatments SM1N1, SM2N1 and SM2N2 reduced Sh.DM % significantly to 52.6, 54.8 and 52.1%, respectively compared to 56.7, 61.5 and 58.7 for SM1N2, SM1N3 and SM2N3. Interaction treatments N1Mg3, N2Mg1, N2Mg3 reduced Sh.DM% to 51.7, 54.2 and 51.9%, respectively, compared to other NMg interaction treatments. Triple interaction treatment SM2N2Mg1 reduced Sh.DM % significantly to 50.3 compared to 64.2% for SM1N3Mg3.

Effects of Soil Moisture, Nitrogen and Magnesium Application and Their Interactions on Some Physiological Characteristics

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Proline (μmol proline. g^{-1} dry weight) in Leaves cut 1

SM2 increased proline content (μmol.g^{-1}) in leaves significantly to 20.2 μmol.g^{-1} compared to SM1 (18.2), results were in agreement with results[32,33] agreement with[34] which found that proline was increased significantly in water deficit treatments. N3 increased proline significantly to 20.7 μmol.g^{-1} compared to N1 (18.3 μmol.g$^{-1)}$. Interaction treatment SM2N3 showed a significant increase in proline (22.7 μmol.g^{-1}) compared to other SMN interaction treatments. SM2Mg2 increased proline significantly to 21 μmol.g^{-1} compared to SM1Mg2 and SM1Mg3 which decreased proline statistically to 17 μmol.g^{-1}. N3Mg1 registered a significant increase in proline compared to N1Mg3 (16.6 μmol.g^{-1}). The triple interactions SM2N1Mg2, SM2N3Mg2 and SM2N3Mg3 also increased

Table 4: Effects of Soil Moisture, Nitrogen, Magnesium and their interactions on some chemical constituents of rosemary plant leaves DW (cut.1)

Treatments	*Proline micromoles proline.g^{-1}*		*Phenolic compounds mg.g^{-1}*		*Total carbohydrates %*		*Protein mg.g^{-1}*	
SM1(100%)FC	18.163	b	36.443	a	29.555	b	78.389	a
SM2(60%)FC	20.202	a	31.577	b	30.279	a	78.681	a
N1(100 kg/ha)	18.254	b	30.595	b	30.100	a	77.292	a
N2(200 kg/ha)	18.586	ab	29.073	b	30.287	a	75.917	a
N3(300 kg/ha)	20.707	a	42.361	a	29.363	a	82.396	a
Mg1(0.0 kg/ha)	19.784	a	34.363	a	29.786	a	79.927	a
Mg2(30 kg/ha)	19.120	a	35.050	a	30.325	a	78.906	a
Mg3(60 kg/ha)	18.644	a	32.617	a	29.640	a	76.771	a
SM1N1	16.595	b	33.275	b	29.017	ab	81.458	a
SM1N2	19.134	b	29.569	b	31.264	a	70.271	a
SM1N3	18.759	b	46.484	a	28.384	b	83.438	a
SM2N1	19.913	ab	27.915	b	31.184	a	73.125	a
SM2N2	18.038	b	28.577	b	29.310	ab	81.563	a
SM2N3	22.655	a	38.239	ab	30.343	ab	81.354	a
SM1Mg1	20.087	ab	34.379	a	29.499	a	82.563	a
SM1Mg2	17.345	b	38.685	a	29.879	a	82.500	a
SM1Mg3	17.056	b	36.264	a	29.286	a	70.104	a
SM2Mg1	19.481	ab	34.346	a	30.073	a	77.292	a
SM2Mg2	20.895	a	31.414	a	30.770	a	75.313	a
SM2Mg3	20.231	ab	28.970	a	29.994	a	83.438	a
N1Mg1	18.831	ab	31.380	abc	29.531	a	71.719	a
N1Mg2	19.351	ab	31.933	abc	30.554	a	91.563	a
N1Mg3	16.580	b	28.473	bc	30.215	a	68.594	a
N2Mg1	18.442	ab	27.738	c	29.877	a	82.594	a
N2Mg2	17.965	ab	33.474	abc	31.149	a	70.313	a
N2Mg3	19.351	ab	26.006	c	29.835	a	74.844	a
N3Mg1	22.078	a	43.970	a	29.950	a	85.469	a
N3Mg2	20.043	ab	39.742	abc	29.270	a	74.844	a
N3Mg3	20.000	ab	43.371	ab	28.869	a	86.875	a
SM1 N1 Mg1	18.961	abc	35.959	ab	27.403	ab	79.375	a
SM1 N1 Mg2	15.931	bc	34.484	ab	29.416	ab	100.938	a
SM1 N1 Mg3	14.892	c	29.384	b	30.231	ab	64.063	a
SM1 N2 Mg1	19.307	abc	22.297	b	30.536	ab	79.563	a
SM1 N2 Mg2	18.788	abc	40.460	ab	32.472	a	73.438	a
SM1 N2 Mg3	19.307	abc	25.949	b	30.784	ab	57.813	a
SM1 N3 Mg1	21.991	ab	44.882	ab	30.559	ab	88.750	a
SM1 N3 Mg2	17.316	abc	41.111	ab	27.749	ab	73.125	a
SM1 N3 Mg3	16.970	abc	53.458	a	26.843	b	88.438	a
SM2 N1 Mg1	18.701	abc	26.801	b	31.660	ab	64.063	a
SM2 N1 Mg2	22.771	a	29.383	b	31.692	ab	82.188	a
SM2 N1 Mg3	18.268	abc	27.562	b	30.199	ab	73.125	a
SM2 N2 Mg1	17.576	abc	33.179	ab	29.218	ab	85.625	a
SM2 N2 Mg2	17.143	abc	26.488	b	29.827	ab	67.188	a
SM2 N2 Mg3	19.394	abc	26.063	b	28.887	ab	91.875	a
SM2 N3 Mg1	22.165	ab	43.058	ab	29.341	ab	82.188	a
SM2 N3 Mg2	22.771	a	38.372	ab	30.792	ab	76.563	a
SM2 N3 Mg3	23.030	a	33.285	ab	30.896	ab	85.313	a

The Means in each category of column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

Table 5: Effects of soil moisture, nitrogen, magnesium and their interactions on rosemary tolerance indices in leaves DW (cut.1)

Treatments	*MP*		*SSI*		*TOL*		*STI*		*MSTIk1*		*MSTIk2*		*RDY*	
N1(100 kg/ha)	6.860	b	1.138	a	1.379	a	0.673	b	0.654	b	0.585	b	99.552	a
N2(200 kg/ha)	7.313	b	-3.570	a	-1.092	a	0.788	b	0.623	b	0.942	b	99.475	a
N3(300 kg/ha)	9.489	a	0.644	a	1.358	a	1.324	a	2.437	a	1.883	a	99.118	b
Mg1(0.0 kg/ha)	7.696	a	-1.367	a	0.182	a	0.882	a	1.124	a	1.149	a	99.413	a
Mg2(30 kg/ha)	8.046	a	1.130	a	1.235	a	0.953	a	1.247	a	1.078	a	99.366	a
Mg3(60 kg/ha)	7.920	a	-1.551	a	0.229	a	0.950	a	1.343	a	1.183	a	99.367	a
N1 Mg1	6.509	b	4.726	a	2.673	a	0.591	c	0.522	c	0.520	bc	99.606	a
N1 Mg2	6.994	b	4.149	a	2.848	a	0.695	c	0.914	bc	0.378	c	99.537	a
N1 Mg3	7.076	b	-5.461	a	-1.383	a	0.734	c	0.526	c	0.858	abc	99.511	a
N2 Mg1	7.001	b	-6.105	a	-2.128	a	0.734	c	0.485	c	0.908	abc	99.511	a
N2 Mg2	7.888	ab	-1.563	a	-0.100	a	0.891	bc	0.858	bc	1.149	abc	99.407	ab
N2 Mg3	7.051	b	-3.043	a	-1.048	a	0.738	c	0.525	c	0.769	abc	99.508	a
N3 Mg1	9.578	a	-2.722	a	0.000	a	1.321	ab	2.366	ab	2.018	a	99.120	bc
N3 Mg2	9.256	a	0.805	a	0.958	a	1.272	ab	1.968	abc	1.708	ab	99.153	bc
N3 Mg3	9.634	a	3.850	a	3.118	a	1.378	a	2.976	a	1.922	a	99.082	c

SM1 (100%): used as control, MP: Mean productivity, SSI: Stress susceptibility index, TOL: Tolerance index, STI: Stress Tolerance Index, MSTIk 1: Modified Stress Tolerance Index 1, MSTIk2: Modified Stress Tolerance Index 2, RDY: Relative decrease in yield. The Means in each category of column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

proline significantly compared to SM1N1Mg3 (15 µmol.g^{-1}), Table 4.

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Phenolic Compounds mg Per Plant in Leaves Dry Weight cut 1

SM2 showed a significant decrease in phenolic compounds (31.6 mg) compared to SM1 (36.4 mg), this result did not agreed with[35] results who reported that total phenol concentration was increased in soybean seeds taken from water-stressed plants. N3 caused significant increase in phenolic compounds (42 mg) compared to N1 (30.6mg). Interaction treatment SM1N3 showed significant increase in phenolic compounds (46.5 mg) compared to other SMN interaction treatments. N2Mg1 and N$_2$Mg$_3$ showed negative effects and reduced the weight of phenols in dry leaves statistically (27.7 and 26 mg, respectively) compared to N3Mg1 (44 mg). Triple interaction SM1N$_3$Mg$_3$ increased phenol contents significantly (53.5 mg) compared to 36 mg for SM1N1Mg1.

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Total Carbohydrates % (TC %) in Dry Weight cut 1

SM2 caused a significant increase in TC% in dry leaves (30%), the results agreed with (32 and 36) findings. SM2N1 and SM1N2 showed significant increase in TC% (31%), while SM1N3 decreased the TC% significantly to 28%. Triple interaction treatment SM1N2Mg2 recorded a significant increase to 32% compared to SM1N3Mg3 (27%).

Effects of Soil Moisture, Nitrogen and Magnesium Application and their Interactions on Protein mg/g DW cut 1

Table 4 shows that the data did not show any significant differences between treatments in their effects on protein content. These results did not agree with results obtained by.[32]

Effects of Soil Moisture, Nitrogen and Magnesium Application and Their Interactions on Tolerance Indices In Leaves Dry Weight Cut1

Mean Productivity (MP)

N3 caused significant increase in MP to 9.5 compared to N1 and N2 6.9 and 7.3, respectively. The interaction treatments N3Mg1, N3Mg2, and N3Mg3 showed significant increases in MP 9.6, 9.3 and 9.6, respectively) compared to N1Mg1.

Stress Susceptibility Index (SSI) and Tolerance Index (TOL)

There was no difference between treatments and their interactions in their effects on SSI and TOL (Table 5).

Stress tolerance Index (STI) and Modified Stress Tolerance Index1 (MSTIK1)

N3 caused significant increase in STI (1.34) compared to N1 and N2. Interaction treatment N3Mg3 also increased STI significantly to 1.378 compared to N1Mg1.N3 caused significant increase in MSTIK1 too 0.623 compared to N1 and N2. Interaction treatment N3Mg3 also increased MSTIK1 significantly to 2.476 compared to N1Mg3 (0.526).

Modified Stress Tolerance Index2 (MSTIK2)

N3 caused significant increase in MSTIK2 to 1.881 compared to N2 (0.585). Interaction treatment N3Mg1 and N3Mg3 also increased MSTIK2 significantly to 2.976 compared to other interaction treatments.

Relative Decrease in Yield (RDY)

A significant decrease in RDY was registered in N3 (99.1%) compared to N1 and N2. Interaction treatment N3Mg3 also decreased RDY significantly to 99.082 compared to other interaction treatments between N and MG.

Table 6: Effects of soil moisture, nitrogen, magnesium and their interactions on Relative yield of nitrogen fertilizer (RYN) in Shoots dry weight

Treatments	*RYN DW cut1*		*RYN DW cut2*		*RYN DW cut1+2*	
SM1(100%)FC	100.181	a	97.285	a	109.207	a
SM2(60%)FC	78.713	b	90.313	b	81.458	b
Mg1(0.0 kg/ha)	87.884	a	92.762	a	90.475	a
Mg2(30 kg/ha)	85.430	a	96.637	a	84.479	a
Mg3(60 kg/ha)	95.028	a	91.999	a	111.044	a
SM1N2	119.998	a	101.610	a	103.667	a
SM1N3	80.364	b	92.960	ab	114.747	a
SM2N2	81.292	b	93.524	ab	84.325	a
SM2N3	76.135	b	87.103	b	78.591	a
SM1Mg1	115.738	a	94.339	a	96.721	ab
SM1Mg2	100.750	abc	103.904	a	101.751	ab
SM1Mg3	84.055	abc	93.611	a	129.149	a
SM2Mg1	60.029	c	91.185	a	84.228	ab
SM2Mg2	70.110	bc	89.369	a	67.208	b
SM2Mg3	106.001	ab	90.387	a	92.938	ab
N2Mg1	100.417	a	97.629	a	96.963	a
N2Mg2	94.833	a	98.680	a	87.224	a
N2Mg3	106.685	a	96.391	a	97.800	a
N3Mg1	75.350	a	87.895	a	83.986	a
N3Mg2	76.026	a	94.593	a	81.735	a
N3Mg3	83.371	a	87.607	a	124.287	a
SM1 N2 Mg1	138.773	a	100.435	a	105.867	ab
SM1 N2 Mg2	114.656	ab	103.942	a	104.189	ab
SM1 N2 Mg3	106.565	ab	100.453	a	100.944	ab
SM1 N3 Mg1	92.703	ab	88.244	a	87.575	ab
SM1 N3 Mg2	86.844	ab	103.867	a	99.312	ab
SM1 N3 Mg3	61.545	b	86.770	a	157.355	a
SM2 N2 Mg1	62.061	b	94.823	a	88.059	ab
SM2 N2 Mg2	75.010	b	93.419	a	70.259	b
SM2 N2 Mg3	106.805	ab	92.329	a	94.657	ab
SM2 N3 Mg1	57.998	b	87.547	a	80.398	ab
SM2 N3 Mg2	65.209	b	85.319	a	64.157	b
SM2 N3 Mg3	105.197	ab	88.444	a	91.219	ab

The Means in each category of column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

Table 7: Effects of soil moisture, nitrogen, magnesium and their interactions on relative efficiency of nitrogen fertilizer (REN) in shoots dry weight.

Treatments	*REN DW cut1*		*REN DW cut2*		*REN DW cut1+2*	
SM1(100%)FC	31.638	b	-0.057	a	7.003	b
SM2(60%)FC	63.809	a	12.896	a	17.078	a
Mg1(0.0 kg/ha)	68.598	a	9.247	a	13.977	a
Mg2(30 kg/ha)	32.830	a	5.235	a	8.655	a
Mg3(60 kg/ha)	41.742	a	4.777	a	13.488	a
SM1N2	1.385	b	0.703	a	-0.793	b
SM1N3	61.891	ab	-0.817	a	14.799	ab
SM2N2	48.970	ab	9.045	a	12.377	ab
SM2N3	78.647	a	16.747	a	21.778	a
SM1Mg1	2.083	b	7.043	a	5.840	ab
SM1Mg2	15.581	b	-3.492	a	-1.438	b
SM1Mg3	77.250	ab	-3.722	a	16.607	ab
SM2Mg1	135.113	a	11.451	a	22.115	a
SM2Mg2	50.080	ab	13.961	a	18.748	ab
SM2Mg3	6.234	b	13.277	a	10.370	ab
N2Mg1	40.787	a	3.091	a	4.826	a
N2Mg2	21.307	a	2.822	a	5.081	a
N2Mg3	13.438	a	8.709	a	7.469	a
N3Mg1	96.409	a	15.403	a	23.129	a
N3Mg2	44.354	a	7.647	a	12.230	a
N3Mg3	70.046	a	0.846	a	19.507	a
SM1 N2 Mg1	-24.677	c	0.081	a	-5.104	b
SM1 N2 Mg2	4.401	bc	-3.399	a	-3.731	ab
SM1 N2 Mg3	24.429	bc	5.426	a	6.457	ab
SM1 N3 Mg1	28.842	bc	14.005	a	16.783	ab
SM1 N3 Mg2	26.761	bc	-3.585	a	0.856	ab
SM1 N3 Mg3	130.072	ab	-12.870	a	26.757	ab
SM2 N2 Mg1	106.250	abc	6.100	a	14.757	ab
SM2 N2 Mg2	38.213	abc	9.043	a	13.893	ab
SM2 N2 Mg3	2.448	bc	11.991	a	8.482	ab
SM2 N3 Mg1	163.975	a	16.801	a	29.474	a
SM2 N3 Mg2	61.946	abc	18.879	a	23.604	ab
SM2 N3 Mg3	10.021	bc	14.562	a	12.258	ab

The Means in each category of column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

Relative Yield of Nitrogen Fertilizer (RYN) in Dry Weight of Shoots (cut1, cut2, and cut1+2)

Cut1

SM2 caused significant decrease in RYN of shoots of rosemary DW cut1 to 79 compared to 100% in SM1. Interaction treatment SM1N2 showed a significant increase of RYN compared to other SMN interactions, but SM2Mg1 decreased RYN to 60% compared to SM1Mg1 which registered 116%l. Triple interaction SM1N3Mg1 showed significant decrease in RYN at 62.545% compared to SM1N2Mg1 which was recorded 139% (Table 6).

Cut2

SM2 recorded a significant decrease in RYN% (90%) compared to SM1 (97.3%), SM2N3 showed a significant decrease in RYN% (87%) compared to SM1N2 (102%), Table 6.

Cut1+2

SM2 caused significant decrease in RYN% of accumulative yield (cut1+2) to 81% compared to SM1 (109%). Interaction treatment SM2Mg2 decreased RYN% significantly to 67%, compared to SM1Mg3 (129%). Triple interaction treatment SM1N3Mg3 recorded a significant increase (157%) compared to other SMNMg interaction treatments.

Effect of Soil Moisture, Nitrogen, Magnesium and Their Interactions on Relative Efficiency of Nitrogen Fertilizer (REN) in Dry Weight of Shoots (Sh. DW)

Cut1

Table (7) showed that SM2 recorded a significant increase in REN % in cut1 64 compared to 32% in SM1. SM2N3 caused a significant increase to 79 compared to SM1N2 which recorded 1%. The interaction treatment SM2Mg1 recorded a significant increase 135 compared to SM1Mg1 2%. Triple interaction treatment (SM2N3Mg1) caused a significant increase in REN% in cut1 164 compared to -24.7% for SM1N2Mg1.

Cut2

No differences between all treatments in their effects on REN% in Sh. DW of in second cutting.

Cut1+2

SM2 increased REN significantly by 17% compared to SM1 which registered 7%. SM1N2 decreased REN significantly to -0.8 compared to 22% in SM2N3. Interaction treatment SM1Mg2 also reduced significant decrease in REN to -1.4 compared to 22% for SM2Mg1. Triple interaction treatment SM1N2Mg1 reduced REN significantly to -5 compared to 29% for SM2N3Mg1, as shown in Table 7.

Effect of Soil Moisture, Nitrogen, Magnesium and Their Interactions on the Highest Total Yield of N Fertilizer (HTYN) in Shoots Dry Weight

Cut1

Table 8 shows that SM2 decreased HTYN significantly to 2.5 g compared to SM1 which registered 1.2 g. The interaction treatment SM1N2 registered a significant decrease in HTYN by -0.9 g compared to 3.3 and 3.0 g for SM1N3 and SM2N3, respectively. Triple interaction treatments SM1N3Mg3 and SM2N3Mg1 increased the HTYN significantly to 5.7 and 5.2 g, respectively. They were superior compared to other triple interaction treatments, especially compared to SM1N2Mg1 by -2.2 g.

Cut2

SM2 increased HTYN significantly to 6.4 g compared to SM1 which registered (-0.4 g). The treatments N1Mg2, and N1Mg3 decreased HTYN significantly compared to N2 Mg2 by 11.6 g. Triple interaction treatment SM2N3Mg2 increased HTYN significantly to 12.9 g compared to -5.7 g for SM1N3Mg3 (Table 8).

Cut1+2

Table 8 showed that SM2 also increased HTYN significantly to 6.3 compared to SM1 which registered 2.5 g. The interaction SM1N3 and SM2N3 were superior and registered the 5.9 and 8.0 g, respectively compared to SM1N2 (-1 g). SM2Mg1 increased HTYN significantly 8 compared to -0.7 g for SM1Mg2.

Table 8: Effects of soil moisture, nitrogen, magnesium and their interactions on the highest total yield of nitrogen fertilizer (HTYN) in shoots dry weight.

Treatments	*Cut1*		*Cut2*		*Cut1+2*	
SM1(100%)F.C.	1.218	b	-0.428	b	2.469	b
SM2(60%)F.C.	2.489	a	6.392	a	6.270	a
Mg1(0.0 kg/ha)	2.221	a	2.984	a	5.205	a
Mg2(30 kg/ha)	1.909	a	5.142	a	3.135	a
Mg3(60 kg/ha)	1.430	a	0.821	a	4.769	a
SM1N2	-0.857	b	-0.108	a	-0.964	b
SM1N3	3.293	a	-0.748	a	5.903	a
SM2N2	1.957	ab	5.237	a	4.583	ab
SM2N3	3.021	a	7.548	a	7.958	a
SM1Mg1	0.104	a	2.406	ab	2.510	ab
SM1Mg2	0.630	a	-1.361	b	-0.731	b
SM1Mg3	2.921	a	-2.328	b	5.630	ab
SM2Mg1	4.339	a	3.561	ab	7.900	a
SM2Mg2	3.189	a	11.645	a	7.002	ab
SM2Mg3	-0.061	a	3.970	ab	3.909	ab
N2Mg1	0.648	a	0.943	a	1.590	a
N2Mg2	1.104	a	4.505	a	1.693	a
N2Mg3	-0.101	a	2.246	a	2.145	a
N3Mg1	3.795	a	5.025	a	8.820	a
N3Mg2	2.715	a	5.779	a	4.578	a
N3Mg3	2.961	a	-0.604	a	7.393	a
SM1 N2 Mg1	-2.208	b	-0.037	ab	-2.245	b
SM1 N2 Mg2	-0.483	ab	-1.343	ab	-1.825	ab
SM1 N2 Mg3	0.120	ab	1.058	ab	1.178	ab
SM1 N3 Mg1	2.415	ab	4.850	ab	7.265	ab
SM1 N3 Mg2	1.743	ab	-1.380	ab	0.363	ab
SM1 N3 Mg3	5.723	a	-5.713	b	10.082	ab
SM2 N2 Mg1	3.503	ab	1.923	ab	5.425	ab
SM2 N2 Mg2	2.690	ab	10.353	ab	5.211	ab
SM2 N2 Mg3	-0.323	ab	3.435	ab	3.113	ab
SM2 N3 Mg1	5.175	a	5.200	ab	10.375	a
SM2 N3 Mg2	3.688	ab	12.938	a	8.793	ab
SM2 N3 Mg3	0.200	ab	4.505	ab	4.705	ab

The Means in each category of column followed by the same letters are not significantly different at $p \leq 0.05$ according to Duncan's multiple range test.

The triple interaction treatment SM2N3Mg1 caused significant increase in HTYN by 10 compared to SM1N2Mg1 -2.2 g.

Effect of Soil Moisture, Nitrogen, Magnesium and Their Interactions on Response% to Nitrogen Fertilizer (RN%) in Shoots Fresh and Dry Weight

Cut1

- Fresh weight

SM2 recorded a significant increase in RN% (23) in cut1 compared to 3% in SM1. SM2Mg1 caused a significant increase in RN% (40%) compared to SM1Mg1 (-10.5%), but SM1N2 showed a significant decrease in RN% (-17%) compared to

Table 9: Effects of soil moisture, nitrogen, magnesium and their interactions on the response of nitrogen fertilizer (RN) in shoots fresh and dry weight.

Treatments	*FW Cut1*		*DW Cut1*		*FW Cut2*		*DW Cut2*		*FW Cut1+2*		*DW Cut1+2*	
SM1(100%)FC	3.002	b	-2.341	a	-15.014	b	2.172	b	-6.600	b	3.517	b
SM2(60%)FC	23.298	a	-1.676	a	8.064	a	9.143	a	14.409	a	12.586	a
Mg1(0.0 kg/ha)	14.771	a	1.876	a	0.143	a	7.238	a	6.232	a	9.525	a
Mg2(30 kg/ha)	17.452	a	-4.430	a	-4.639	a	2.548	a	4.440	a	6.587	a
Mg3(60 kg/ha)	7.227	a	-3.472	a	-5.928	a	7.187	a	1.042	a	8.042	a
SM1N2	-16.764	b	-8.049	a	-13.903	b	-1.610	b	-13.287	b	-3.667	b
SM1N3	22.768	a	3.366	a	-16.125	b	5.955	ab	0.087	ab	10.700	a
SM2N2	20.452	a	12.467	a	12.252	a	6.259	ab	15.800	a	9.693	a
SM2N3	26.144	a	-15.819	a	3.876	a	12.028	a	13.018	a	15.480	a
SM1Mg1	-10.500	c	1.378	a	-13.551	b	5.661	a	-10.615	c	3.279	ab
SM1Mg2	2.676	abc	-22.244	a	-18.194	b	-3.904	a	-9.570	c	-1.751	b
SM1Mg3	16.831	abc	13.842	a	-13.298	b	4.761	a	0.385	bc	9.022	ab
SM2Mg1	40.042	a	2.375	a	13.836	a	8.815	a	23.079	a	15.772	a
SM2Mg2	32.229	ab	13.383	a	8.915	a	9.001	a	18.450	ab	14.926	a
SM2Mg3	-2.377	bc	-20.786	a	1.441	ab	9.613	a	1.698	bc	7.062	ab
N2Mg1	2.928	a	6.050	a	0.466	a	2.371	a	1.776	a	3.037	a
N2Mg2	7.575	a	-2.962	a	-5.712	a	0.993	a	0.469	a	3.803	a
N2Mg3	-4.970	a	3.539	a	2.770	a	3.609	a	1.523	a	2.200	a
N3Mg1	26.614	a	-2.297	a	-0.181	a	12.105	a	10.687	a	16.014	a
N3Mg2	27.330	a	-5.899	a	-3.566	a	4.104	a	8.411	a	9.372	a
N3Mg3	19.423	a	-10.482	a	-14.627	a	10.766	a	0.560	a	13.884	a
SM1 N2 Mg1	-32.203	b	-1.527	ab	-16.052	b	-0.435	a	-19.869	c	18.988	a
SM1 N2 Mg2	-12.257	ab	-41.874	b	-19.718	b	-3.942	a	-15.306	bc	-4.189	ab
SM1 N2 Mg3	-5.830	ab	19.253	ab	-5.937	ab	-0.453	a	-4.687	abc	-0.944	ab
SM1 N3 Mg1	11.203	ab	4.282	ab	-11.049	ab	11.756	a	-1.360	abc	12.425	ab
SM1 N3 Mg2	17.609	ab	-2.614	ab	-16.669	b	-3.867	a	-3.835	abc	0.688	ab
SM1 N3 Mg3	39.491	a	8.431	ab	-20.658	b	9.975	a	5.457	abc	-5.867	b
SM2 N2 Mg1	38.059	a	13.627	ab	16.984	a	5.177	a	23.422	a	11.941	ab
SM2 N2 Mg2	27.406	a	35.951	a	8.294	ab	5.928	a	16.244	ab	11.795	ab
SM2 N2 Mg3	-4.109	ab	-12.175	ab	11.478	ab	7.671	a	7.733	abc	5.343	ab
SM2 N3 Mg1	42.025	a	-8.877	ab	10.687	ab	12.453	a	22.735	a	19.602	a
SM2 N3 Mg2	37.052	a	-9.184	ab	9.536	ab	12.074	a	20.656	a	18.056	ab
SM2 N3 Mg3	-0.646	ab	-29.396	ab	-8.596	ab	11.556	a	-4.336	abc	8.781	ab

The Means in each category of column followed by the same letters are not significantly different at P≤ 0.05 according to Duncan's multiple range test.

other treatments. Triple interaction SM1N2Mg1 decreased RN% -32% compared to -24.7% in SM1N2Mg1 (Table 9).

- Dry weight

Triple interaction SM2N2Mg2 showed a significant increase in RN% (36%), while SM1N2Mg2 significantly decreased RN% to -42%.

Cut2

- Fresh weight

SM2 increased RN% significantly (8%) compared to SM1 which registered (-15%). The interactions SM2N2 and SM2N3 increased RN% significantly to12% and 4% respectively compared to -14% in SM1N2. SM2Mg1 and SM2Mg2 increased significantly RN% to 14 and 9% respectively. Triple interaction treatments SM2N2Mg1 increased RN% significantly to 17% compared to other treatments (Table.9)

- Dry weight

Table 9 shows that SM2 increased RN% significantly (9%) compared to SM1 which registered 2.2%. Interaction treatment SM2N3 increased RN% significantly to 12 compared to -1.6% in SM1N2 as control.

Cut1+2

- Fresh weight

Table 9 shows that SM2 increased RN% significantly 14% compared to SM1 which registered -6.6%. Interaction treatments SM2N2 and SM2N3 increased RN% significantly to 16 and 13%, respectively compared to -13% for SM1N2. SM2Mg1 showed a significant increase in RN% compared to other treatments. Triple interaction treatments SM2N2Mg1, SM2N3Mg1 and SM2N3Mg2 increased RN% significantly to 23.422, 22.735 and 20.656%, respectively compared to SM1N2Mg1 (-20%).

- Dry weight

SM2 caused significant increase in RN% (12.6%) compared to SM1 (3.5%). SM1N2 showed significant decrease of RN% to -3.7% compared to other SMN interaction treatments. SM1Mg2 reduced RN% to -1.8% compared to the SM1Mg1 as control. Triple interaction treatment SM1N3Mg3 caused significant reduction in RN% (-5.9%) compared to SM1N2Mg1 (19%).

CONCLUSION

According to the results of this study we can conclude that, water adequate (SM1 100% FC) affected positively and recorded the significant increases in all rosemary plant characteristics such as dry matter%, phenolic compounds, and relative yield of nitrogen in shoots (cut1, cut2, and 1+2). Water stress (SM260% FC) increased plant tissue moisture%, proline, carbohydrates, relative efficiency of nitrogen in shoots (cut1, and 1+2), total highest yield in shoots (cut1, cut2, and 1+2), and response to fertilizer in fresh and dry shoots. Nitrogen application at 300 kg.ha^{-1} increased growth characteristics such as DM% in leaves and shoots, proline, and phenolic compounds. Interaction treatment SM2N3 increased proline, relative efficiency of N in shoots (cut1 and cut1+2), and response to N in shoots DW. SM2Mg1 increased moisture%, proline, relative efficiency of nitrogen in shoots (cut1, and 1+2), total highest yield in shoots cut1+2, and response to fertilizer in fresh and dry shoots in rosemary plants. N3Mg1 increased DM%, proline, and carbohydrates. Triple interaction treatment SM1N3Mg3 increased DM% in shoots, phenolic compounds, relative yield of nitrogen in shoots (cut1+2), and total highest yield in shoots cut1 and SM1N2Mg1 decreased most of the study parameters except relative yield cut1, and response % to N in DW cut1+2.

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