Effect of Magnesium Salts on Growth and Production of Garlic (*Allium sativum* L.)

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***Abstract*—A Randomized Complete Block Design (R.C.B.D.) experiment with three replicates was conducted to investigate the effect of foliar application of magnesium salts on growth, yield components and some inorganic minerals of leaves of garlic (*Allium sativum* L.) local variety. The salts ($MgSO_4.7H_2O$, $Mg(NO_3)_2.6H_2O$ and $MgCl_2.6H_2O$) addition to untreated plants as control. The concentration of Mg were used was constant (1.97 g Mg. L_{-1} which comes from 2% $MgSO_4.7H_2O$). The results revealed that vegetative growth of garlic was affected significantly by magnesium salts. Highest number of leaves was found in plants treated with $MgCl_2$, the treatment which gave the lowest plant height, each of $MgSO_4$ and $Mg(NO_3)_2$ had the highest shoot dry weight. Foliar spraying with $Mg(NO_3)_2$ produced highest shoot dry matter percent and highest percent of leaves Phosphorus leaves content, significantly compared to other treatments. The results showed that spraying plants with $Mg(NO_3)_2$ and $MgSO_4$ improved yield components where head diameter , head weight, cloves number per head and bulbs yield were increased. Foliar spray with $MgSO_4$ had a significant effects on head scale thickness, whereas there were non- significant effects between different Magnesium salts spraying on each of clove dry matter and percent of TSS content. This study concluded that spraying plants with $MgSO_4$ or $Mg(NO_3)_2$ twice (45 days after planting and a month later) increased garlic yield and yield quality.**

***Index Terms*— Foliar, garlic, magnesium salts, yield.**

I. INTRODUCTION

Garlic (*Allium sativum* L.) belongs to Alliaceae family and is the second most widely used cultivated bulb crop after onions (Hasan, 2000). Garlic is used as a spice, seasonings and flavoring for foodstuff involving both green tops and bulbs, garlic is also cultivated for its medicinal properties (Mayeux, et al., 1998; Sterlin and Eagling, 2001). Plant growth and productivity is adversely affected by various biotic and abiotic factors, nutrients are one of the major abiotic factors, which adversely affects crop growth and yield. It is well known that the use of fertilizer helps in production and is a somewhat quick method for achieving maximum yields (Naruka, 2000). The trend toward higher yields also increases the requirements for nutrients including magnesium which can be applied either to the soil or as a foliar spray at the form of deferent kinds of salts like sulfate, nitrate and chloride. Recovery from Mg deficiency by application to soil require at least two years therefore, using foliar spray is one effective method for fast recovery and uptake (Lachover and Arnon, 1966).

Plant roots uptakes inorganic ions in different rates, monovalent ions like NO_3^-, K^+ and Cl^- mobile faster than divalent ions ($SO_4^=$ and Ca^{+2}), that means plants uptake cations and anions in unequal amounts from growing medium. New barley root put in K_2SO_4 and $CaCl_2$ solutions, uptakes K^+ faster than SO_4^{-2}, therefore cations uptake was faster than anions (Hiatt, 1967). Antagonism and synergism phenomena appear clearly between deferent ions in plant nutrition, nitrate reduction in the upper part of the plant would enhance cations uptake, therefore organic anions accumulates balancing the cation charges which combined with the nitrate ions (Kirkby and Knight, 1977).

Magnesium has unique roles in plant physiology, including a key role as the central atom in the chlorophyll molecule, consequently magnesium affects plant chlorophyll content and the production and use of carbohydrates, it is also important in the activity of a large number of enzyme systems in plants, particularly in the metabolism of carbohydrates. Magnesium is activator of several phosphorylases and carboxylases, it is serves as a link between enzyme and the substrate (Ibrahim, 2010 and Srivastava, 2010). Magnesium is intimately associated with the phosphorus metabolism and is particularly essential for the enzymes involved in the phosphate transfer reaction (Verma, 2008).

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Sulphur is an essential plant nutrient, its role in balanced fertilization and consequently in crop production is being recently realized, it performs many physiological functions like synthesis of sulphur containing amino acids (methionine and cysteine), proteins, and sulpho-lipids, some other biologically important sulfur containing compounds are; glutathione (a redox agent), biotine, thiamine (both vitamins) and coenzyme A. Sulfur is also a constituent of glycosides, which impart characteristic odors and flavours to mustard, onion and garlic. It also participates in forming and stabilizing three dimensional structure of proteins as disulfide (S-S) bonds (Verma, 2008; Abdallah, et al., 2010).

Availability of nitrogen is of prime importance for growing plants as it is a major source of protein and nucleic acid molecules. It is also an integral part of chlorophyll molecules, which are responsible for photosynthesis (Naruka, 2000). Mudziwa (2010) found that each of calcium nitrate and ammonium sulphate fertilizers increased neck and bulb circumference, bulb mass, bulb cloves and marketable yield of *Allium sativum* to 45.75 mm, 196.20 mm, 128.80 g, 34.58 cloves.bulb^{-1} and 24.56 ton.hectar^{-1} for calcium nitrate and 43.75 mm, 196.80 mm, 105.20 g, 33.54 cloves.bulb^{-1} and 27.23 ton.hectar^{-1} compare to control which gives 30.75 mm, 123.50 mm, 43.70 b, 19.08 cloves.bulb^{-1} and 19.40 ton.hectar^{-1}. In green tissues chloride uptake requires the presence of light because ATP produced in photophosphorylation is used as energy source for the active uptake of chloride (MacDonald et al. 1975). Chloride ion is a component or activator of enzymes involved in photosynthesis and cell division , and acts as an osmo-regulator (Kern and Chrispeels, 1978), and chloride with N have important role in photosystem II in photosynthesis, also Cl^- and NO_3^- increase plasma membrane turgidity therefore they positively affect N nutrition. Application of chloride-containing fertilizers has been reported to increase the availability of soil manganese, unlike other micronutrients chloride is highly mobile within the plant and easily translocated. Chloride is not toxic to plants at high concentrations; some of the non-biochemical roles of chloride in osmo-regulation may require these high concentrations (Fixen, 1993). Davenport and Bentley (2001) reported that potato percent marketable yield was lower with potassium chloride fertilizer than with potassium sulfate (84.0% and 86.3% respectively).

The aim of this study was to investigate the effect of Mg salts applied as foliar nutrition on garlic plants to determine the favorable salt for best growth and yield under the environmental conditions of the middle region of Iraq.

II. Materials and Methods

The experiment was carried out in a silty loam soil with a pH (7.70) and EC (4.20 ds.m^{-1}) in the field of the College of Agriculture, Abu-Ghraib, Baghdad-Iraq. Cloves of the local cultivar variety were planted on November 10, 2005, using Randomized Complete Block Design (R.C.B.D) with three replicates. The cloves were planted on both sides of a 2 m length furrows and 10 cm between cloves. Treatments were foliar sprayed by three magnesium salts as foliar nutrition, in addition to the untreated plants as control. The first spray was done 45 days after planting, and the second was done a month later. The 2% $MgSO_4.7H_2O$ was used as standard concentration, where Mg concentration in this salt was 1.97 g Mg.L^{-1} (Al-Sahaf, 1989), and a similar concentration of Mg, when the other salts were used, was obtained as shown in Table I. Sampling was done on 10 randomly selected plants for estimating the following parameters:

A. Growth Parameters

The plant leaf number and parameters of shoot (height, dry weight and dry matter) were recorded.

B. Leaves Chemical Component

Forth leaf from apical end were collected from plants (Lorenzo and Maynard, 1980), washed by distilled water and drying at 70 C˚ until the weight is fixed, 0.2 g of sample powder is taken and is digested with concentration H_2SO_4 acid and perchloric acid, then transferred to 50 ml volume flask and complete the volume by distilled water (Al-Sahaf , 1989). Nitrogen was determined with microkjheldahl (Jackson, 1958), while phosphorus were determined by using Ammonium molybdenum and vitamin c (John, 1970), each of potassium and magnesium were determined by using Flamephotometer as mentioned in Al-Sahaf (1989).

C. Yield Components

Each of neck and head diameter were determined by Vernier, head weight, cloves number.head^{-1}, bulbs yield were recorded.

D. Yield Quality

Scale thickness was determined by using micro-vernier, clove dry matter was determined too, and total soluble solid (TSS) was determined by using hand-refractometer (A.O.A.C., 1970). Data were subjected to analysis of variance (ANOVA) using the SAS program. Means were compared by the least significant difference (L.S.D.) test at the 0.05 probability (Reza, 2006).

TABLE I
MAGNESIUM SALTS USED FOR FOLIAR FERTILIZER

Material	Chemical formula	Typical composition (%)		Salt used (g. L^{-1})
		Mg	Other	
Magnesium sulfate	$MgSO_4.7H_2O$	9.86	13.01 S	20.0
Magnesium nitrate	$Mg(NO_3)_2.6H_2O$	9.48	10.93 N	20.77
Magnesium chloride	$Mg\ Cl_2.6H_2O$	11.96	34.87 Cl	15.74

III. Results and Discussion

A. Effect of Magnesium Salts on Vegetative Growth Parameters

The results in Table II reveal that the number of leaves per plant was affected significantly by magnesium salts. Highest number of leaves (8.00 leaves.plant^{-1}) was found in plants treated with $MgCl_2$ which differ significantly compared to $Mg(NO_3)_2$, and the same treatment $MgCl_2$ gave the lowest plant height (50.40 cm) while $MgSO_4$ produced the highest plant (60.27 cm). The different Mg salts had significant effect on shoot dry weight, each of $MgSO_4$ and $Mg(NO_3)_2$ had the highest shoot dry weight (6.71 and 6.49) g respectively, whereas control and $MgCl_2$ treatments gave the lowest shoot dry weight (4.53 and 4.89) g respectively. Results in Table II indicated that foliar spraying with $Mg(NO_3)_2$ produced highest shoot dry matter percent (21.53%) significantly compared to other treatments.

TABLE II
Effect of Foliar Application of Magnesium Salts on Vegetative Growth Parameters of Garlic

Treatments	Number of leaves.plant^{-1}	Plant height (cm)	Shoot dry weight (g.plant^{-1})	Shoot dry matter (%)
Control	7.27 ab	52.98 ab	4.53 b	19.83 b
$MgSO_4.7H_2O$	7.27 ab	60.27 a	6.71 a	18.79 b
$Mg(NO_3)_2.6H_2O$	6.80 b	58.72 ab	6.49 a	21.53 a
$Mg\ Cl_2.\ 6H_2O$	8.00 a	50.40 b	4.89 b	18.53 b

A same letter in the column indicates that there is no significant difference ($p<0.05$).

These results were expected since plants are very responsive to Mg fertilization because of Mg roles in chlorophyll synthesis (Ibrahim, 2010) and activation of a number of enzymes such as kinases, Ribulose 1, 5 biphosphate carboxylase (calvin cycle) and phosphoenol pyruvate carboxylase (C3-plants pathway of CO_2 fixation) (Bidwell, 1979). However, $MgCl_2$ gave the greatest number of leaves.plant-1, this may be due to the companion ion chloride as regarded an activator to photosynthetic enzymes, cell division, and osmoregulator (Kern and Chrispeels, 1978) so it expected to promote the growth of buds. Vigorous vegetative growth resulted from $MgSO_4$ salt may be attributed to companion ion S and its role in increasing chlorophyll concentration and growth throughout the season (Hu, Sparks and Evan, 1991). Shoot dry matter percent was the greatest in plants treated with $Mg(NO_3)_2$, nitrogen nutrition (as companion ion) may result in greater vegetative growth, increases in nitrogen concentration in sprays resulted in increase in biomass production with significant increase in shoot growth (Shiralipour, et al., 1981). Farooqui, et al. (2009) also found that application of 200 kg nitrogen ha^{-1} significantly increased the garlic plant height, number of leaves per plant, neck thickness, bulb diameter, number of cloves per bulb, fresh weight of 20 cloves, dry weight of 20 cloves , fresh weight of bulb, dry eight of bulb and bulb yield. Availability of nitrogen is of prime importance for growing plants as it is major and indispensable constituent of protein and nucleic acid molecules, it is an integral part of chlorophyll molecules, which are responsible for photosynthesis, an adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally leading to higher productivity. The findings of this investigation are in close conformity with those of Naruka and Dhaka (2001) and Yadav (2003).

B. Effect of Magnesium Salts on Leaves Chemical Component

Magnesium salts spray had only a significant effects on percent of phosphorus leaves content (Table III), where $Mg(NO_3)_2$ salt increased this percent significantly to 0.95% compared to other treatments. Whereas there were non-significant effects between different Magnesium salts spraying on each of N, K and Mg leaves content.

This result agree with the results of Romani and Maguire (2002) whom indicated that Mg has a role in increasing P uptake and its transport through plant, also it regulates plant hormones movement. This increase in P concentration may also due to increases in N concentration in this treatment (Shiralipour, et al., 1981) those researchers found that linear increase in shoot and root phosphorus content where observed when N concentration was increased.

TABLE III
Effect of Foliar Application of Magnesium Salts on Garlic Leaves Chemical Components

	Leaves content of			
Treatments	N (%)	P (%)	K (%)	Mg (%)
Control	1.20 a	0.64 b	3.07 a	1.06 a
$MgSO_4.7H_2O$	1.15 a	0.68 b	3.02 a	0.92 a
$Mg(NO_3)_2.6H_2O$	1.17 a	0.95 a	3.11 a	1.14 a
$Mg\ Cl_2.6H_2O$	1.11 a	0.70 b	3.31 a	0.98 a

A same letter in the column indicates that there is no significant difference ($p<0.05$).

C. Effect of Magnesium Salts on Yield and the Yield Components

The results in Table IV clearly showed that spraying plants with any source of Mg salt (except $MgCl_2$) improved both of neck diameter and yield components where head diameter, head weight, cloves number per head and bulbs yield were increased. Increasing bulb yields in $Mg(NO_3)_2$ and $MgSO_4$ treatments were coincided with increasing the head diameter, head weight and cloves number per head. This means that both Mg salts had significant effects on garlic plant yield.

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This results agreed with Farooqui, et al. (2009) whom found that application of 60 kg S.ha^{-1} significantly increased garlic yield attributes like neck thickness, bulb diameter , number of cloves per bulb, fresh weight of 20 cloves, dry weight of 20 cloves, fresh weight of bulb, dry weight of bulb and bulb yield in comparison to lower doses of sulphur. Overall increase in growth attributes may be due to sulphur increasing the root system of the plants which might have resulted in an increased uptake of nutrients and were used in photosynthesis, these results agree with the results presented by Randle and Bussard (1993), Sadarea, et al. (1997), Jaggi and Dixit (1999) and Jaggi (2004).

TABLE IV
EFFECT OF FOLIAR APPLICATION OF MAGNESIUM SALTS GARLIC YIELD AND YIELD COMPONENTS

Treatments	Neck diameter (cm)	Head diameter (cm)	Head weight (g)	Cloves number. head^{-1}	Bulbs yield (Ton.hec tare^{-1})
Control	11.10 b	56.60 ab	58.49 b	36.92 b	16.11 bc
$MgSO_4.7H_2O$	15.27 a	63.59 a	82.08 a	39.25 ab	21.53 a
$Mg(NO_3)_2.$ $6H_2O$	15.35 a	61.42 a	78.56 a	46.27 a	20.66 ab
Mg $Cl_2.$ $6H_2O$	12.01 b	52.13 b	49.97 c	34.87 b	12.92 c

A same letter in the column indicates that there is no significant difference ($p<0.05$).

D. Effect of Magnesium Salts on Yield Quality

Magnesium salts spray had only a significant effects on head scale thickness (Table V), where $MgSO_4$ salt increased this parameter significantly to 38 micron, while the lowest value recorded in plants sprayed with $Mg(NO_3)_2$ salt and control treatments. Thus increasing scale thickness mean increasing the head protectively especially from disease like *Fusarium* sp. (Holz and Knox-Davies, 1985). There were non-significant effects between different Magnesium salts spraying on each of clove dry matter and percent of cloves TSS content. This result certain the avoid of nitrogen applications after bubbling commences, as this can result in softer bulbs with shorter shelf life (Engeland, 1991).

TABLE V
EFFECT OF FOLIAR APPLICATION OF MAGNESIUM SALTS ON QUALITY CHARACTERISTIC OF GARLIC

Treatments	Scale thickness (micron)	Clove dry matter (%)	TSS (%)
Control	0.28 c	44.80 a	36.50 a
$MgSO_4.7H_2O$	0.38 a	45.65 a	37.28 a
$Mg(NO_3)_2.$ $6H_2O$	0.27 c	47.96 a	35.72 a
Mg $Cl_2.6H_2O$	0.33 b	43.96 a	36.67 a

A same letter in the column indicates that there is no significant difference ($p<0.05$).

IV. CONCLUSION

Conclusion could be made that spraying plants with $MgSO_4$ and $Mg(NO_3)_2$ twice (45 days after planting and other a month later) could increase yield, also Mg with its companion ion had great influence on growth and productivity of garlic.

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