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RESPONSE OF GARLIC PLANTS TO NITROGEN AND SULPHUR FERTILIZATION

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ABSTRACT: *Garlic (Allium sativum L.) is an important vegetable crop grown in the world. It is valued for its distinctive pungent flavor and is an essential ingredient of the cuisine in many regions of the world. Hence, the present studies were undertaken in a field experiments were conducted at Agricultural Research Station El-kasasin, Ismailia Governorate, Egypt, (30º 33 ′ ″31 N- 30° 56″7 ′ E, elev. 15.8 m) during two seasons of 2013/2014 and 2014/2015 to evaluate growth, yield and its components, as well as chemical constituents in cloves and bulb storability of garlic (Allium sativum L.) cv. Sids-40 under three levels of nitrogen (90, 120and 150 kg N/fed) and four levels of elemental sulphur (0, 50, 100 and 150 kg S fed^{-1}).The experiment was laid out in split plot design with three replications assigning nitrogen levels in the main plots and sulphur levels in sub-plots. The results of this study revealed that application of nitrogen and sulpher and their combinations had significant effects on most of the studied characters. The maximum plant height (80.91cm), leaf number (11.96), bulb diameter (6.40cm), and number of cloves per bulb (21.33) and bulb yield (8980 kg fed^{-1}) were observed with $N_{150}S_{150}$ treatment. While the minimum plant height (52.64cm), leaf number (7.91), weight of bulb (58.40g) and projected yield (6620 kg fed^{-1}) were observed under $N_1.S_0$ treatment. S at 150 kg fed^{-1} and nitrogen at 90 kg/fed recorded the minimum physiological loss in weight (%) for garlic during the storage period (6 monthes). However increasing nitrogen and decreasing sulphur level had adverse effect on storability of bulbs. Sulphur fertilization increased the Allicin concentration from 13.87mg g^{-1} in the control treatment to 26.59mg g^{-1} dry weight at 150 kg S fed^{-1} after 2 weeks of storage period. Allicin decreased gradually in the garlic cloves during the storage period (12 weeks).*

Key words: *Allium sativum*, *Allicin*, *Bulb contents, Garlic, Nitrogen fertilization, Storage life, Sulphur*

INTRODUCTION

Garlic (*Allium sativum* L.) occupies a prominent position among human foods, not only as a condiment, but also due to its therapeutic properties, attributed to the presence of bioactive compounds (Tepe *et al.* 2005). Garlic is a bulb from the Liliacerae family and is widely consumed all over the world. Its beneficial properties have been recognized for over 5000 years. It is indicated as an adjuvant agent in the therapy for prevention of various chronic infirmities such as heart diseases, infections, and atherosclerosis. Most of garlic's health benefits have been attributed to the antioxidant activity of organosulfurous compounds, predominantly allicin (Queiroz *et al.* 2009). Garlic is the food with the highest number of organosulfurous compounds. Thirty-three of these compounds have been identified, and the biological activity of several is known. On average, 1 g of fresh garlic contains 11 to 35 mg of total organosulfurous compounds, representing a level approximately four times greater (per gram of fresh weight) than that of other sources such as onions, broccoli, cauliflower, turnip, cabbage and other crucifers (Holub *et al.* 2002).

Nitrogen is an essential element for plant growth and maintenance, since it is considered as key nutrients in crops production. Many researchers studied the effect of different levels of N fertilizers on growth, nutrients uptake and yield of garlic to find out the economic N fertilizers level to produce the highest garlic productivity. Applied N significantly increased vegetative growth and yield parameters of garlic (Naruka *et al.* 2005). Nitrogen is a fertilizer in a balance and rational way to keep high and stable yield and is an important component of proteins, enzymes and vitamins in plant as well as a central part of the chlorophyll, the essential photosynthetic molecule.

Sulphur is essential for synthesis of proteins, vitamins and sulphur containing essential amino acids (cysteine, cystine and methionine) and is also associated with nitrogen metabolism. Sulphur has been recognized as an important nutrient for higher yield, quality as well as nutrient uptake of garlic. Sulphur not only increases the bulb yield but also improves its quality especially pungency and flavor. Sulphur containing compounds are not only of importance for nutritive value or flavors but also for resistance against pests and diseases (Ullah *et al*. 2008). Severe sulphur deficiency during bulb development has detrimental effects on yield and quality of garlic (Ajay and Singh, 1994). Insufficiency of sulphur is known to hamper N metabolism and synthesis of sulphur containing amino acids and thus exerts adverse effects on both yield and quality of the crop.

The present investigation was undertaken to find out the effect of nitrogen and sulphur on growth, yield, quality, nutrients uptake and storability of garlic.

MATERIALS AND METHODS

Two field experiments were carried out in El-kasasin, Farm (30º 33״31 ׳ N- 30° 56״7 ׳ E, elev. 15.8 m), Ismailia Governorate, Egypt during two growing seasons of 2013 / 2014 and 2014/ 2015, to study the effects of nitrogen and sulphur application on growth, yield and its components, as well as chemical constituents of cloves and bulb storability of garlic cv. (Sids-40) grown in a sandy loam soil. The experiment with three levels of nitrogen (90, 120 and 150 kg N/fed) and four levels of elemental sulphur (0, 50, 100 and 150 kg S /fed) was laid out in split plot design with three replications assigning nitrogen levels in main plots and elemental sulphur levels in sub plots. Randomized soil surface samples (0-30 cm) were taken from the experimental site before sowing and prepared to determine some physical and chemical properties according to Page *et al.* (1982) and Klute (1986) as shown in Table (1). In both seasons, big to medium size cloves were planted during middle of October, in 3.0 m x 3.5 m plots, at 20 x 15 cm spacing accommodating 350 plants per plot. The doses of fertilizers were adjusted with the application of ammonium nitrate (33.5% N), 200 kg of calcium superphosphate (15% P_2O_5) and 100Kg of potassium sulphate (50%K_2O). Different doses of nitrogen in the treatments were given in 3 split doses, one third applied with full dose of phosphate, potassium and elemental sulphur and the remaining two third at 40 and 60 days after planting in two equal splits. Harvesting was done during the end of March in both seasons.

Data recorded

Yield and its components:

At harvest time, all plants of each plot were cured, 15 days after harvest weighed in kg and recorded as total yield (ton/fed). A random sample (10 plants) was taken from each treatment to determine plant height, number of leaves/plant, bulb weight and diameter, as well as the number of cloves/bulb and clove weight.

Table 1: Physical and chemical properties of the experimental soil.

Property	Value
Particle size distribution (%)	
Sand	60.70
Silt	21.80
Clay	17.50
Texture grade	Sandy loam
pH (1:2.5 soil water suspension)	7.68
EC (dS/m, 1:5, soil: water extract.)	0.72
Soluble cations (meq/L)	
Ca^{++}	2.85
Mg^{++}	1.97
Na^{+}	1.85
K^{+}	0.50
Soluble anions (meq/L)	
$CO3^{--}$	0.00
$HCO3^{-}$	1.23
Cl^{-}	3.42
$SO4^{--}$	2.52
Organic matter (%)	0.60
Available nutrient (mg/kg)	
N	40.0
P	7.50
K	189.4
DTPA-extractable (mg/kg)	
Fe	3.80
Mn	2.55
Zn	0.85

Chemical analysis:

Concentrations of nutrients, namely, nitrogen, phosphorus and potassium were analyzed from matured bulbs. Five clean sample bulbs from each plot were collected randomly. The cloves were ground, and oven dried at 65°C for 48 h. The finely ground and dried tissues were wet digested as described by Wolf (1982). Total N was determined using the modified micro Kjeldhal method (Cottenie *et al.* 1982) and P by colorimetric method using spectrophotometer Ryan *et al.* (1996). Potassium content was measured using a flame photometer method as described by Chapman and Pratt (1982). Protein contents of garlic bulbs were determined in terms of the garlic bulbs nitrogen content multiplied by 6.25 (AOAC, 1994).

Determination of allicin

Ten bulbs per plot were stored after harvest for investigating changes in the allicin content during storage. Storage was performed for 12 weeks at a constant temperature of 20 °C in a dry and shaded room, which corresponds with common storage conditions in households.

Allicin extraction

The outer skin of the garlic cloves was peeled and crushed in a garlic press. The pressed garlic was then collected in a beaker and mixed thoroughly. 700-900 mg of the pressed mash was weighed and transferred to a 50 ml centrifuge tube. Using a volumetric pipette, 25 ml of cold water was delivered to the sample and immediately capped and shaken vigorously for 30 seconds. Heat transfer from hands was avoided by holding the tube cap while shaking. An additional 25 ml of cold water was added and shaken for 30 more seconds to dilute and mix the solution. Each sample is filtered through 0.45µm glass filter into High – performance liquid chromatography (HPLC) vial and capped for injection. Allicin content was extracted and determined according to (Hoppe *et al*.1996). The first sampling was carried out after 2 week of storage, then after 4, 6, 8, 10 and 12 weeks.

Weight loss during storage

The weight loss percentage of bulbs was calculated after 6 months of storage which is a factor of the differences between the initial and final weight divided by its initial weight multiplied by 100.

Data obtained during the two seasons of the study were statistically analyzed according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

I-Effect of different doses of nitrogen and sulphur on yield and yield contributing characters of garlic

The data presented in Table (2), showed that all the studied growth parameter and bulb yield were significantly increased by increasing the tested levels of both N and S fertilizers. The increasing trend of plant height was observed (from 64.16 to 71.53cm) with the increasing level of sulphur from zero to 150 kg fed^{-1} but in case of nitrogen, plant height increased from 57.90 to 77.92cm with the increasing level from 90 kg fed^{-1} to 150 fed^{-1}. The maximum plant height (80.91cm) was recorded by $N_{150}S_{150}$ followed by $N_{150}S_{100}$ (78.90cm) and $N_{150}S_{50}$ (77.03cm) as compared to $N_{90}S_0$ (52.64cm).

In respect of leaf number/plant, the significant variations due to N and/or S levels were also observed. The leaf number increased from 9.13 to 10.89 and 8.83 to 11.23with increasing S from S_0 to S_{150} and N from N_{90} to N_{150} respectively. In different combinations of sulphur and nitrogen the maximum leaf number (11.96) was noticed by $N_{150}S_{150}$ which was at par (11.84) with that of $N_{150}S_{100}$ followed by $N_{150}S_{50}$ (10.71).

In response of bulb diameter, significant variations were detected by N and/or application . The diameter increased from 5.34cm to 5.83cm with the increasing level of sulphur from zero to 150 kg fed^{-1} and from 4.97cm to 6.20cm when N level increased from 90 kg fed^{-1} to 150 fed^{-1} . Higher values were recorded with the combined higher levels of sulphur and nitrogen.

In case of bulb weight the significant variations were observed by both N and S applied individually or in combinations. The bulb weight increased from 70.37g to 78.82g with increasing level of sulphur (from 0 to 150 kg fed^{-1}) and increased from 63.20g to 86.12g with increasing N level from 90 kg

TABLE 2

fed^{-1} to 150 fed^{-1}. The interaction effects indicated that the maximum bulb weight was recorded in $N_{150}S_{150}$ (91.78 g) followed by $N_{150}S_{100}$ (85.55g) which was at par with $N_{150}S_{50}$ (85.18g).

The number of cloves per bulb varied significantly with individual effects only. The clove number increased from 16.59to 18.70 with increasing level of sulphur from zero to 150 kg fed^{-1}. Increasing level of nitrogen from 90 kg fed^{-1} to 150 fed^{-1}caused increase in number of cloves/plant from 15.16 to 20.03.

In case of individual effect of sulphur the clove weight increased from 3.24g to 3.69g with increasing S dose from zero to 150 kg fed^{-1}but for nitrogen the clove weight increased from 2.62g to 4.19g with increasing N rate from 90 kg fed^{-1} to 150 fed^{-1}. As for interaction, maximum clove weight was noticed with $N_{150}S_{150}$ (4.47g).

Perusal of data presented in Table (2), clearly demonstrated that bulb yield varied significantly by N and S levels applied alone or in combination. Increased trend in yield was recorded up to 150 kg N or S /fed. Yield increased from 7697kg fed^{-1} to 8390 kg fed^{-1} and from 6975kg fed^{-1} to 8825kg fed^{-1} with increasing level of sulphur from zero to 150 kg $fed^{-1}$and nitrogen from 90 kg N fed^{-1} to 150 kgN fed^{-1}. In interactions, maximum yield of 8980kg fed^{-1} was recorded in $N_{150}S_{150}$ combination followed by $N_{150}S_{100}$ (8810kg fed^{-1}) and $N_{150}S_{50}$ (8780 kg fed^{-1}). The minimum yield of 6620kg fed^{-1} was recorded in $N_{90}S_0$combination. The increase in bulb yield of garlic in sulphur applied plots might be due to higher production of metabolites and increase in meristematic activity. Besides, it could be attributed to improvement in nutritional environment in crop root zone and ultimately resulted in better vegetative growth and finally the bulb yield. Similar results were also reported by Channagoudra, (2004); Nasreen *et al.* (2007) and Channagouda *et al.* (2009). The increase in growth characters with the application of sulphur might be due to the favorable effect of sulphur on reducing soil pH, increasing soli particles, thereby improving soil structure and increasing the availability of certain plant nutrients in soil (Nagaich *et al.* 1999). The results are in conformity with those of Nasreen *et al.* (2007).

The findings of this investigation with N effect on garlic plant growth and yield are in close conformity with those of Naruka and Dhaka (2001), Yadav (2003) and Nasreen *et al.* (2007). Such increasing in morphological parameters of garlic plants as a result of increasing the level of nitrogen application may be attributed to the main role of nitrogen in increasing the merstematic activity, cell division and cell elongation as well as formation of proto-plasmic bulk which consequently affected growth of plants. Availability of nitrogen is prime importance for growing plants as it is major and indispensable constituent of protein and nucleic acid molecules. An adequate supply of nitrogen is associated with vigorous vegetative growth and more efficient use of available inputs finally leading to higher productivity.

II-Protein and nutrient uptake in garlic bulbs

**protein content and yield*

Crude protein content in garlic varied significantly with individual effects and in interactions (Table 3). Protein content increased from 11.79% to 13.13%with increasing level of sulphur from zero to 150 kg fed^{-1}. Increasing level of nitrogen from 90 kg fed^{-1} to 150 kg fed^{-1}caused an increase in protein content from 10.27% to 15.77%. In interactions, all possible combinations of N and S levels up to 150 kg/fed. for each increased protein content generally. The maximum protein content was noticed in

TABLE 3

$N_{150}S_{150}$ (16.81%) followed by $N_{150}S_{100}$ (15.94%) while the minimum protein content (9.94%) was noticed with $N_{90}S_{0.}$ More increases in crude protein content were detected by combined application of N and S thereby showing a synergistic relationship between N and S in garlic. The increase in growth, bulbs yield and crude protein might be attributed to increased photosynthetic and meristematic activities of plant and improvement in the synthesis of protein and amino acids in the presence of adequate available N supply.

Protein yield increased from 404kg fed^{-1} to 522 kg fed^{-1} and from 297 kg fed^{-1} to 658 kg fed^{-1} with increasing level of sulphur from zero to 150 kg fed^{-1}and nitrogen from 90 kg fed^{-1} to 150fed^{-1}. Maximum protein yield (739kg fed^{-1}) was recorded in $N_{150}S_{150}$ combination followed by $N_{150}S_{100}$ (665kg fed^{-1}) and $N_{150}S_{50}$ (637 kg fed^{-1}). The minimum yield of (255kg fed^{-1}) was recorded in $N_{90}S_0$ combination.

**Nutrient Uptake in garlic bulbs*

The value of nutrient uptake followed the pattern of yield obtained in different treatments (Table 3). The N uptake in cloves significantly increased from 47 kg /fed to 105.01 kg /fed with increasing nitrogen levels from 90 kg fed^{-1} to 150 fed^{-1} and from 64.21kg fed^{-1} to 83.47kg fed^{-1} with increasing sulphur levels from zero to 150 kg fed^{-1}. Maximum N uptake (118.27kg fed^{-1}) was recorded with $N_{150}S_{150}$ combination followed by $N_{150}S_{100}$ (106.46kg fed^{-1}) and $N_{150}S_{50}$ (101.88 kg fed^{-1}).

The uptake of P in cloves was significantly higher with all the treatments. Increasing levels of N fertilizers from 90 kg fed^{-1} to 150 fed^{-1} increased P uptake from 8.58 kg /fed to 21.23kg /fed and from 12.32kg fed^{-1} to 17.41kg fed^{-1} with increasing level of sulphur from zero to 150 kg fed^{-1} which may be due to better growth and dry matter production of plants and a deeper ramification of roots which causes higher uptake of phosphorus. In the interaction, effect show that maximum p uptake (24.58 kg fed^{-1}) was recorded in $N_{150}S_{150}$ combination which may be attributed to beneficial effect of this treatment on availability of P in soil (Singh *et al.* 1996) followed by $N_{150}S_{100}$ (22.00kg fed^{-1}) and $N_{150}S_{50}$ (20.66kg fed^{-1}). The minimum P-uptake of (7.16 kg fed^{-1}) was recorded in $N_{90}S_0$combination. These results may be due to that application of sulphur helps in the availability of other nutrients resulting in better growth and increased uptake of all the nutrients at higher levels of sulphur. Similar results have been reported by Dabhi *et al.* (2004); Jaggi (2005) and Nasreen *et al.* (2007). The positive effect of sulphur may be due to lowering soil pH factors that improved soil structure, soil chemical properties and increased the availability of certain plant nutrients such as P and better biochemical activity in the crop plants Singh and Singh (2005).

In case of potassium uptake the significant variations were observed with both individual and combination treatments. K-uptake increased from 16.38 kgfed^{-1} to 25.03 kgfed^{-1} with increasing level of sulphur from 0 to 150 kg fed^{-1} and increased from 11.84 kg fed^{-1} to 29.81 kg fed^{-1} with increasing N level from 90 kg Nfed^{-1} to 150 kgN fed^{-1}. Meanwhile, maximum K- uptake (36.23kg fed^{-1}) was recorded in $N_{150}S_{150}$ followed by $N_{150}S_{100}$ (32.65kg fed^{-1}) and $N_{150}S_{50}$ (27.03kg fed^{-1}). The minimum K-uptake of 9.06 kg fed^{-1} was recorded in $N_{90}S_0$ combination. This might be due to greater vegetative growth, translocation of stored material and cloves production. Similar findings were reported by Jaggi (2005). Sulphur fertilizer might have promoted the availability of native soil nutrients as reflected by their uptake. Similar opinion was reported by Nasreen *et al.* (2007).

III-Changes in Allicin Content during post- harvest storage in relation to N and S Fertilization

Intact garlic cells contain (+)-S-allyl- L-cysteine sulfoxide, an odorless compound known as alliin. When cell lysis occurs, the enzyme alliinase stored in vacuoles inside the cells is released, and when it comes in contact with alliin, it is converted into allicin (diallyl thiosulfinate) fig. (1 and 2). Allicin decomposes in the presence of air and water producing mainly diallyl disulfides (responsible for the characteristic odor of garlic). The same degradation process occurs in the body, and it is associated with the characteristic odor in breath after garlic ingestion (Ichikawa *et al.* 2006).

The amount of alliin is an important criterion for assessing the quality of the different commercial varieties of garlic since it is directly related to the state of freshness and appropriate conservation techniques. S fertilization was shown to increase a broad range of S-containing metabolites in plants such as cysteine, glutathione, and glucosinolates as well as cysteine sulfoxides in Allium species. Allicin increased from 13.87in control plots to 26.59 mg g^{-1} dry weight at the highest S rate in garlic cloves after 2 weeks of storage and from 3.23to 7.95 mg g-1 dry weight after 12 weeks of storage period with increasing level of sulphur from zero to 150 kg fed^{-1}. The control and lowest S application rate of 50 kg S fed^{-1} showed a reduced allicin concentration after 12 weeks of storage when compared to that of the plots which received either 100 or 150 kg S fed^{-1} (Table 4 and fig. 3). Allicin decreased gradually in the garlic cloves during the storage period up to 12 weeks however,it was increased by increasing S and/or N levels. Increasing level of nitrogen from ٩٠ kg fed^{-1} to ١٥0 fed^{-1}caused an increase in allicin content from 10.55 to 16.77 mg g^{-1} dry weight after 2weeks and from 2.52to 4.04 (mg g^{-1} dry weight) after 12 weeks of storage period (fig. 4). The interactions effect showed that the maximum allicin content was noticed in $N_{١٥0}$ S_{150} treatment (28.88mg g^{-1} dry weight) followed by $N_{١٥0}S_{100}$ treatment (26.62mg g^{-1} dry weight). In this regard (Bloem *et al.*2004) reported that an increase in S supply is

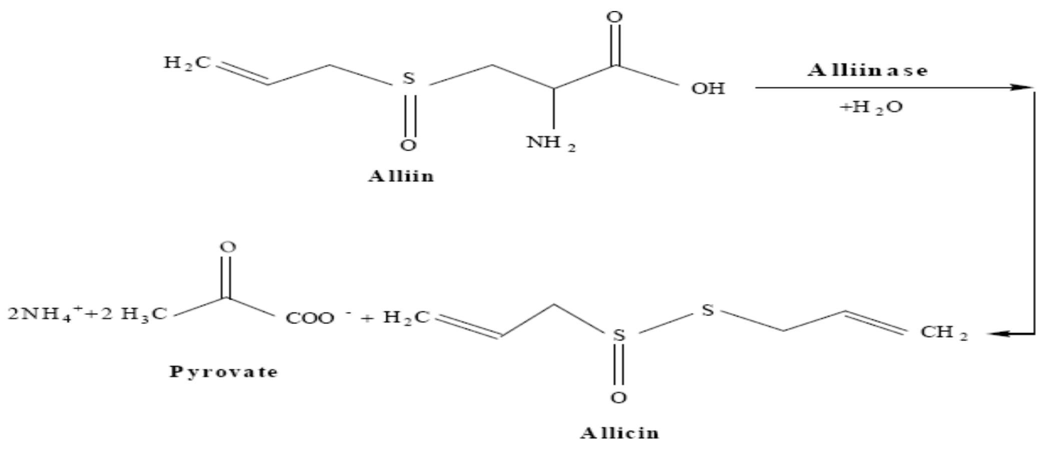

Fig. (1): The conversion of alliin into allicin during post-harvest storage.

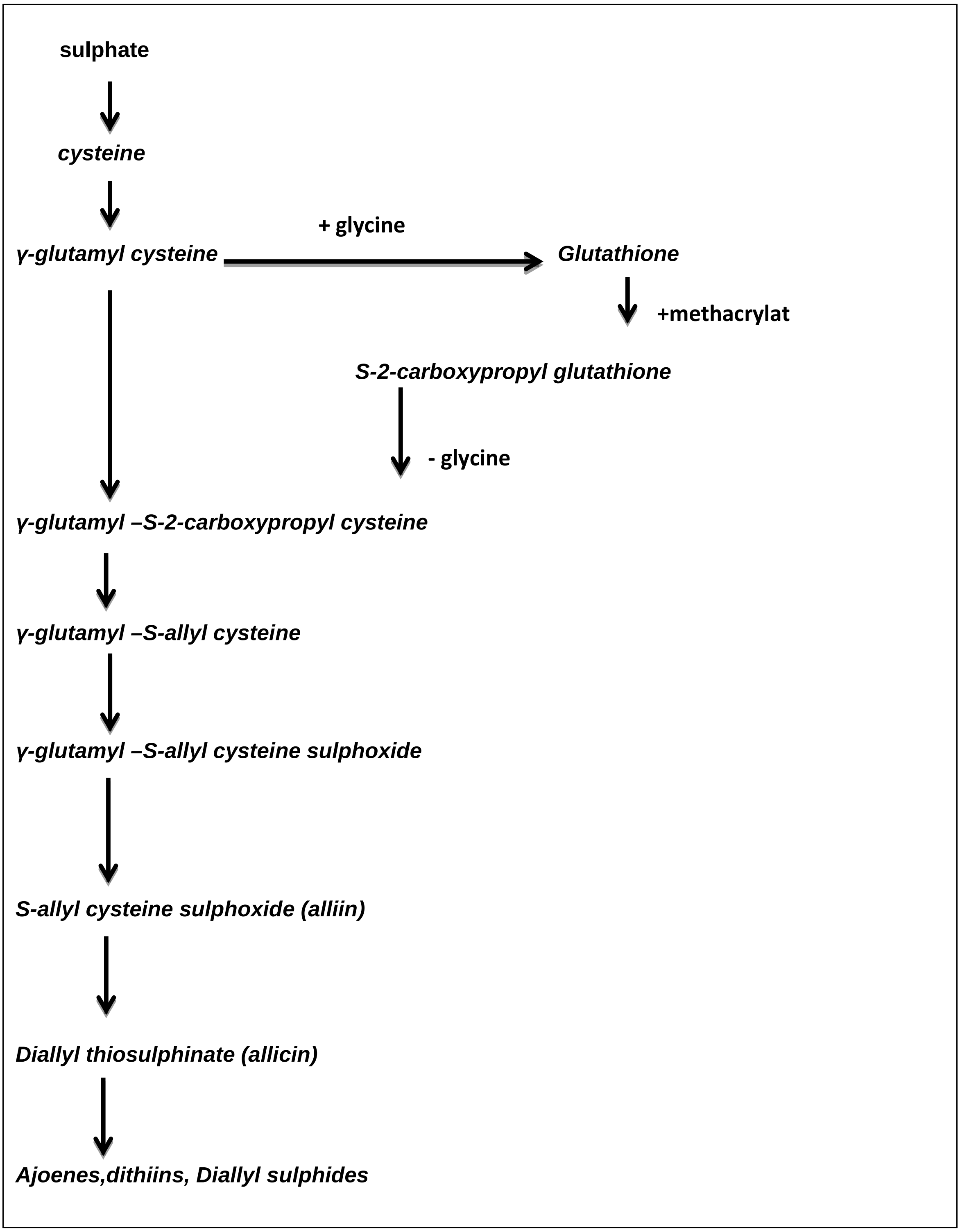

Fig (2): Biosynthetic pathway of the generation of sulphur-containing flavor compounds and their respective precursors in garlic, *Allium sativum* L.

Table 4

FIG 3

FIG 4

related to an increase in alliin content of leaves and bulbs of garlic crop, whereas nitrogen fertilization has only a minor influence on crop quality. They added that allicin content in bulbs could be doubled by S fertilization. Allicin translocate from leaves to bulbs so, time of harvest has a strong influence on the allicin content. At the beginning of plant development, high allicin contents were found in leaves, while with bulb development, they were translocate into this plant organ.

The results show that the potential health benefits of Allium species could be distinctly improved by S fertilization. This might be due to increased uptake of S by crop due to its application to soil resulting in the increased synthesis of volatile sulphur compounds and production of more pungency in garlic. `The combination of 150 kg N fed^{-1} with 150 kg S fed^{-1}recorded the highest allicin content in garlic during 12 weeks of storage period compared to other interactions due to greater supply of nitrogen and sulphur to the garlic crop. Sulphur metabolism is intimately related to nitrogen metabolism through the production of the amino acid cysteine as the first organic sulphur compound in sulphur assimilation. Nitrogen supply may, therefore, have an effect on sulphur uptake and formation of alk(en)yl cysteine sulphoxide flavor precursors (CSOs) Randle *et al*. (1993).

IV-Cumulative weight loss of garlic bulb during storage.

The results showed that physiological loss in weight (PLW) of garlic bulbs (Table 5) increased continuously with the increasing of storage period. Garlic bulbs grown with 150 kg N/fed (T9) recorded higher PLW loss and the highest loss (48.33%) was after 180 days of storage. On the contrary, garlic bulbs harvested from the plot received $N_{90}S_{150}$ combination recorded lower PLW loss (38.68 %) after 180 days of storage. An increased PLW for all the treatments could be due to rapid loss of moisture and drastic reduction in firmness for the active physiological processes like respiration, transpiration and ethylene production (Kumar *et al.* 2007). In periodical observation at 30 days interval, it was found that the stored bulbs of all treatments lost weight gradually and the maximum weight loss was recorded after 6 months of storage. Increasing levels of N fertilizer from 90 kg fed^{-1} to 150kgN fed^{-1} increased (PLW) during the studied storage period, while S fertilizations showed the opposite, since PLW was found to be reduced by increasing S fertilizer rate (Figure 5). Comparing the results of different treatments, it can be opined that application of elemental sulphur at 150kgSfed^{-1} should be made for quality crop with higher yield and better storability of garlic (Figure 6). In interactions, maximum weight loss after 6 months of storage 48.33%was recorded in $N_{150}S_0$ combination followed by $N_{150}S_{50}$ (46.64%) and $N_{120}S_0$ (46.31%). The minimum weight loss 38.68 % was recorded in $N_{90}S_{150}$combination.Loss in weight of bulb is usually known to be occurred due to rotting, dehydration transpiration, respiration, sprouting, etc. (Ullah *et al.* 2008). The increase in percentage of lost weight bulbs due to increased nitrogen rate could be attributed to the fact that higher rates of nitrogen enhanced plants to produce bulbs bulbs with soft succulent tissues which make them susceptible to the attack by a disease caused by microorganisms and leads to production of bulbs with large neck diameter which are difficult to dry (Gopalkrishnan and Srinivas 1990).. Each increase of N fertilizing dose, was followed by the significant increase of the quantity of rotten bulbs. Practically, the weight of rotten bulbs at the highest N fertilizer dose was more doubled compared to the least fertilizer dose experimental plots. The water content of garlic is an important quality parameter as

Table 5

Fig 5

Fig 6

only firm bulbs can be sold. It is known that high N application rates in the later stages of bulb development of garlic delay maturation and produce soft bulbs with shorter post-harvest shelf life. Water losses from intact bulbs are also affected by N or S fertilization (Bloem *et al.* 2004). Water losses from intact bulbs are distinctly higher than water losses from cloves. The reason is that the drying process starts from the outer hulls to the cloves. S fertilization had a more effect on the water content of cloves, though S fertilization significantly increased the S concentration in cloves. The water losses were by trend higher when S levels were low after 6 months of storage (Table 5). The comparison of the different fertilizer treatments shows that after 6 months of storage N fertilization had more significant effect on water losses from the plant tissue. In contrast, S fertilization resulted in lower water losses from cloves. This effect was significant and most pronounced when least N was applied. The data further reveal that a higher S content may prevent garlic bulbs from shriveling, while a high N supply may thwart this effect (Woldetsadik *et al.* 2003).

V -CONCLUSIONS

The present results demonstrate that garlic bulbs fertilized with a higher level of S have a higher potential to accumulate allicin after harvest, which is important to consider as garlic bulbs are usually stored before usage. A higher S fertilization in combination with lower N application resulted in high quality firm garlic bulbs, which are preferred by consumers. The result showed that nutrient combination of the garlic bulbs significantly influenced the physiological loss in weight (PLW) and organoleptic quality of garlic bulb and judicious selection of nutrient combination can extend the storage life and reduce the post-harvest deterioration of garlic bulb .The presented results are an important contribution for improving the quality and storage life of fresh garlic.

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إستجابة نباتات الثوم للتسميد بالنيتروجين والكبريت

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الملخص العربى

الثوم هو واحد من أهم محاصيل الخضر فى العالم ذو نكهة مميزة وهو عنصر اساسى من مكونات المطبخ فى العديد من مناطق العالم ولذا فقد اجريت الدراسات الحالية بهدف تقييم مستويات مختلفة من النيتروجين والكبريت على إنتاجية وجودة محصول الثوم حيث اقيمت تجربة حقلية فى محطة بحوت القصاصين بمحافظة الاسماعيلية –مصر خلال الموسم الشتوى ٢٠١٣/٢٠١٤و ٢٠١٤/ ٢٠١٥ لدراسة تأثير ثلاث مستويات من التسميدالنيتروجينى(٩٠، ١٢٠، ١٥٠ كجم نتروجين/فدان) واربعة مستويات من الكبريت(٠، ٥٠، ١٠٠ و ١٥٠ كجم كبريت/فدان) وايضا التفاعل بينهما على صفات النمو والمحصول والمحتوى الكيماوي للثوم (صنف سدس ٤٠) حيث استخدم التصميم الاحصائى للقطع المنشقة فى ثلاث مكررات. اوضحت النتائج المتحصل عليها ان جميع قياسات النمو والمحصول ومكوناتة زادت معنويا مع زيادة مستوى التسميد النيتروجينى والكبريت وكذلك التفاعل بينهما . أدى استخدام المعدل العالى من التسميد النيتروجينى والكبريت (S_{150} N_{150})فى تحقيق أعلى القيم فى جميع قياسات النمو المدروسة مقارنتة بالمعاملات الاخرى.

أظهرت النتائج أن هناك تأثيرات معنوية للتداخل بين التسميد النيتروجينى المعدنى والكبريت على صفات المحصول بالاضافة الى بعض المواد الحيوية ومحتوى العناصر المعدنية ولكن هذه الزيادة لم تصل لمستوى المعنوية فى حالة عدد الفصوص / نبات ووزن الفصوص . تبين أن المعاملة (٩٠ كجم ن/فدان + ١٥٠ كجم كبريت/فدان) أكثر المعاملات كفاءة فى تقليل الفقد فى الوزن الفسيولوجى خلال فترة التخزين ولكن مع زيادة معدل التسميد النيتروجينى ونقص معدل الكبريت كان له الاثر السيئ على القدرة التخزينية للابصال . أدى التسميد بالكبريت لإلى زيادة تركيز الاليسين من ١٣.٨٧ مج /جم مادة جافة للمقارنة إلى ٢٦.٥٩ مج/حم مادة جافة للتسميد ب ١٥٠ كجم كبريت /فدان بعد اسبوعين من التخزين، هذا وكان تركيز الاليسين غى الفصوص يقل بالتدريج أثناء فترة التخزين (١٢ أسبوع) . و أظهرت النتائج أيضا أن إضافة أعلى معدل من التسميد النيتروجينى والكبريت (١٥٠ كجم نتروجين/فدان+١٥٠ كجم كبريت/فدان) أعطى أعلى القيم لجميع قياسات المكونات الكيميائية (النيتروجين – الفوسفور – البروتين ومحتوى الاليسين فى فصوص الثوم) .

Table 2. Influence of N and S Fertilization on yield and yield parameters in garlic .

Treatments		Plant height (cm)	Number of leaves/plant	Bulb diameter(cm)	Bulb fresh weight(g)	No. of cloves /plant	Clove weight(g)	Total yield (kg/fed)
N-levels	S-levels							
90kgN/fed	Control	52.64	7.91	4.63	58.40	14.10	2.47	6620
	50 kg S/fed	56.77	8.78	4.83	61.77	15.33	2.55	6740
	100 kg S/fed	60.30	9.04	5.17	64.50	15.43	2.67	7010
	150kg S/fed	61.91	9.59	5.23	68.13	15.77	2.81	7530
	Mean	57.90	8.83	4.97	63.20	15.16	2.62	6975
120kgN/fed	Control	64.99	9.07	5.36	70.75	17.00	3.25	7740
	50 kg S/fed	67.98	10.29	5.60	74.34	17.23	3.48	7960
	100 kg S/fed	69.40	9.76	5.80	74.61	17.57	3.72	8450
	150kg S/fed	71.79	11.12	5.87	76.54	19.00	3.78	8660
	Mean	68.54	10.06	5.66	74.06	17.70	3.56	8203
150kgN/fed	Control	74.85	10.42	6.03	81.97	18.67	4.00	8730
	50 kg S/fed	77.03	10.71	6.07	85.18	19.90	4.10	8780
	100 kg S/fed	78.90	11.84	6.30	85.55	20.23	4.17	8810
	150kg S/fed	80.91	11.96	6.40	91.78	21.33	4.47	8980
	Mean	77.92	11.23	6.20	86.12	20.03	4.19	8825
Mean	Control	64.16	9.13	5.34	70.37	16.59	3.24	7697
	50 kg S/fed	67.26	9.93	5.50	73.77	17.49	3.38	7827
	100 kg S/fed	69.53	10.21	5.76	74.89	17.74	3.52	8090
	150kg S/fed	71.53	10.89	5.83	78.82	18.70	3.69	8390
L.S.D. at 5%	N levels	1.29	1.10	0.23	3.68	0.66	0.12	423.63
	S levels	0.53	0.46	0.19	1.73	0.83	0.14	276.88
	Interaction	0.75	0.66	0.27	2.48	ns	ns	395.81

Table 3. Influence of N and S Fertilization on protein and uptake of nutrients in garlic bulbs(on dry weight basic).

Treatments		Crude protein content %	protein yield kg/fed	Nutrient uptake (kg/fed)		
N-levels	S-levels			N	P	K
90kgN/fed	Control	9.94	255	40.79	7.16	9.06
	50 kg S/fed	10.13	280	44.75	7.95	10.27
	100 kg S/fed	10.44	301	48.23	8.52	12.13
	150kg S/fed	10.56	350	56.03	10.68	15.91
	Mean	10.27	297	47.00	8.58	11.84
120kgN/fed	Control	10.63	365	58.40	12.13	16.76
	50 kg S/fed	11.06	396	63.36	14.07	18.11
	100 kg S/fed	11.54	446	71.95	16.02	19.81
	150kg S/fed	12.00	476	76.12	16.97	22.95
	Mean	11.31	421	67.46	14.79	19.41
١50kgN/fed	Control	14.81	592	93.43	17.68	23.32
	50 kg S/fed	15.50	637	101.88	20.66	27.03
	100 kg S/fed	15.94	665	106.46	22.00	32.65
	150kg S/fed	16.81	739	118.27	24.58	36.23
	Mean	15.77	658	105.01	21.23	29.81
Mean	Control	11.79	404	64.21	12.32	16.38
	50 kg S/fed	12.23	437	70.00	14.23	18.47
	100 kg S/fed	12.79	471	75.55	15.51	21.53
	150kg S/fed	13.13	522	83.47	17.41	25.03
L.S.D. at 5%	N levels	0.61	66.93	10.70	2.91	3.76
	S levels	0.34	35.89	5.74	1.52	1.88
	Interaction	0.48	51.30	8.21	2.17	2.69

Table 4. Influence of N and S Fertilization on Allicin content (mg g-1 of DW) in garlic cloves after different storage times.

Treatments		Allicin content (mg g^{-1} of DW) in garlic cloves					
N-levels	S-levels	2nd weeks	4th weeks	6th weeks	8th weeks	10th weeks	12th weeks
90kgN/fed	Control	10.55	10.25	8.09	7.36	5.85	2.52
	50 kg S/fed	21.64	17.83	13.10	11.32	8.09	4.36
	100 kg S/fed	22.96	18.93	15.32	12.09	8.77	5.85
	150kg S/fed	24.92	19.77	17.27	14.30	9.10	6.78
	Mean	20.02	16.70	13.44	11.27	7.95	4.88
120kgN/fed	Control	14.3	12.49	8.77	8.24	6.38	3.11
	50 kg S/fed	22.51	20.83	16.17	15.23	10.25	5.47
	100 kg S/fed	23.86	21.20	18.24	16.48	10.46	6.02
	150kg S/fed	25.96	21.97	19.49	17.77	10.72	8.24
	Mean	21.66	19.12	15.67	14.43	9.45	5.71
150kgN/fed	Control	16.77	15.23	9.85	8.82	6.78	4.04
	50 kg S/fed	24.92	24.07	17.05	15.37	11.61	6.38
	100 kg S/fed	26.62	24.50	18.54	16.77	12.29	7.89
	150kg S/fed	28.88	25.67	20.78	18.38	12.49	8.82
	Mean	24.30	22.37	16.56	14.84	10.79	6.78
Mean	Control	13.87	12.66	8.90	8.14	6.33	3.23
	50 kg S/fed	23.02	20.91	15.44	13.97	9.98	5.40
	100 kg S/fed	24.48	21.54	17.37	15.11	10.51	6.59
	150kg S/fed	26.59	22.47	19.18	16.82	10.77	7.95
L.S.D. at 5%	N levels	0.29	1.14	0.30	0.34	0.26	0.52
	S levels	0.11	1.23	0.21	0.41	0.29	0.44
	Interaction	0.16	n.s	0.31	0.58	0.41	0.63

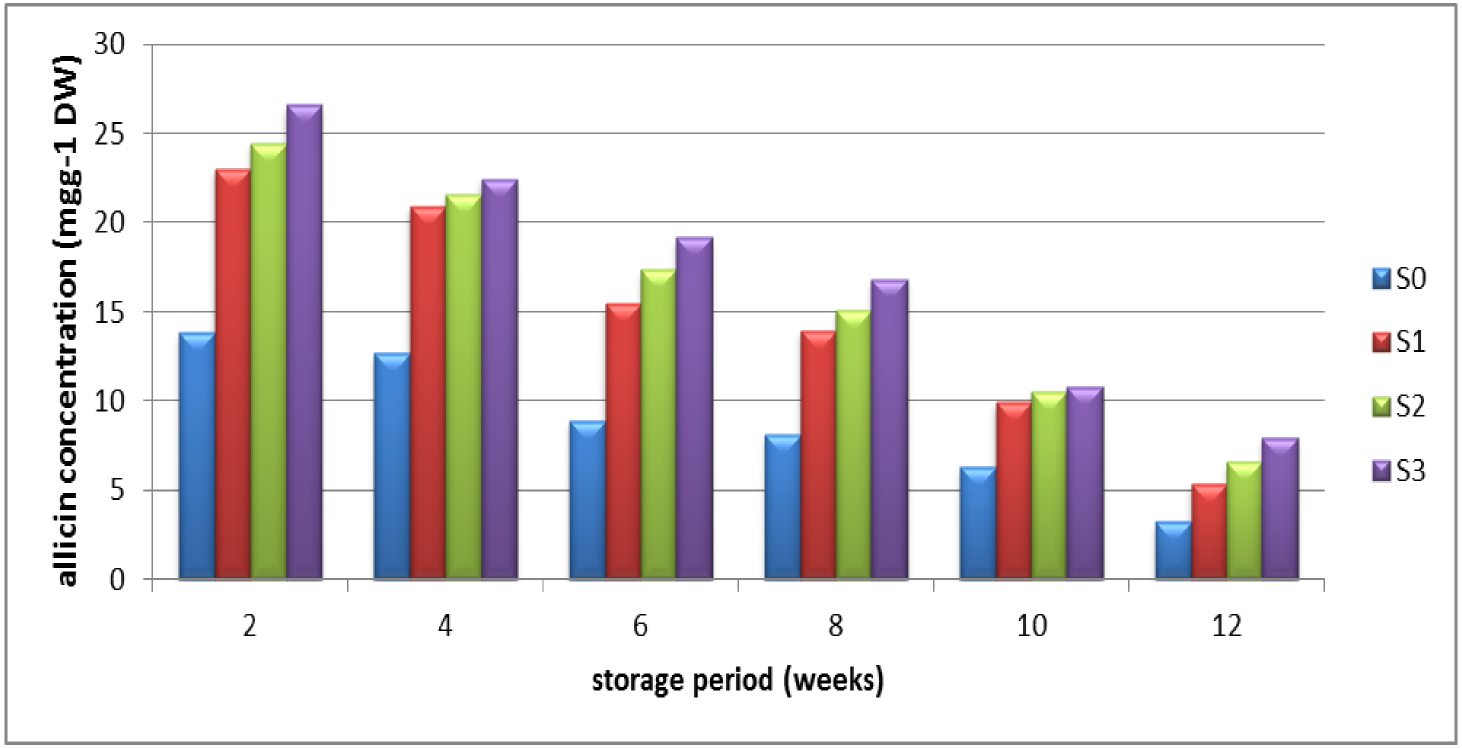

Figure 3. Effect of S fertilization on change in allicin concentration of garlic cloves with storage time

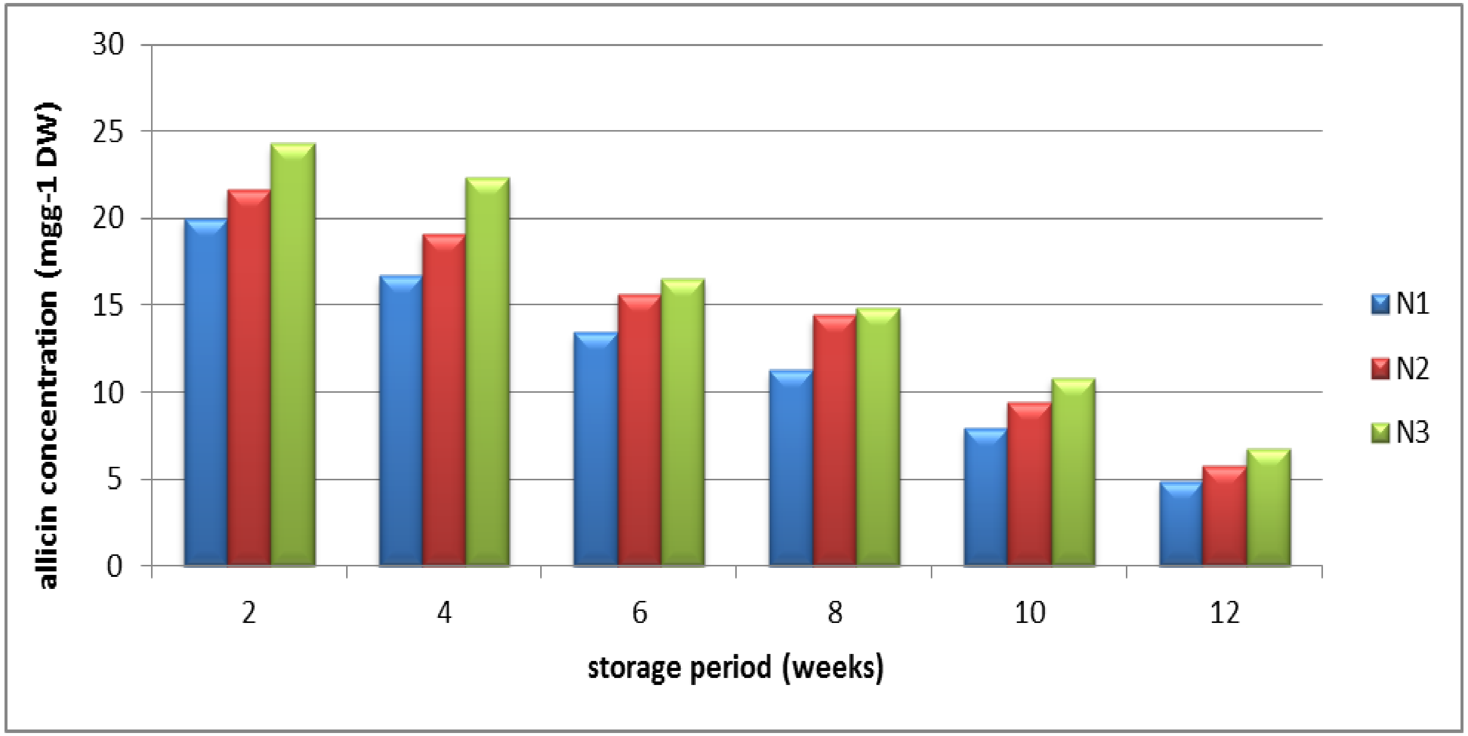

Figure 4. Effect of N fertilization on change in allicin concentration of garlic cloves with storage time

Table 5. Influence of N and S Fertilization on weight loss (%) of garlic during 6 months of storage.

Treatments		Cumulative bulb weight loss (%)					
N-levels	S-levels	30 days	60 days	90 days	120 days	150 days	180 days
90kgN/fed	Control	8.77	14.30	20.27	28.88	41.10	44.73
	50 kg S/fed	8.44	11.76	18.24	26.62	37.71	43.43
	100 kg S/fed	7.75	10.99	17.27	24.92	36.53	40.94
	150kg S/fed	7.30	10.55	15.32	22.96	35.97	38.68
	Mean	8.07	11.90	17.78	25.85	37.83	41.95
120kgN/fed	Control	10.65	17.77	22.82	31.79	42.80	46.31
	50 kg S/fed	10.36	16.48	21.24	29.55	40.90	43.80
	100 kg S/fed	10.25	15.23	19.69	27.43	38.67	41.48
	150kg S/fed	9.85	13.13	19.58	25.92	37.72	40.47
	Mean	10.28	15.65	20.83	28.67	40.02	43.02
150kgN/fed	Control	12.21	18.38	25.43	36.18	44.03	48.33
	50 kg S/fed	12.00	16.77	24.92	33.87	41.28	46.64
	100 kg S/fed	11.61	15.37	23.26	30.33	39.47	45.40
	150kg S/fed	10.85	14.27	21.82	29.60	37.47	43.63
	Mean	11.67	16.20	23.86	32.50	40.56	46.00
Mean	Control	10.54	16.82	22.84	32.28	42.64	46.46
	50 kg S/fed	10.27	15.00	21.47	30.01	39.96	44.51
	100 kg S/fed	9.87	13.86	20.07	27.56	38.22	42.61
	150kg S/fed	9.33	12.65	18.91	26.16	37.05	40.93
L.S.D. at 5%	N levels	0.25	0.23	0.21	1.19	0.76	0.75
	S levels	0.28	0.19	0.20	0.97	0.59	0.82
	Interaction	ns	0.28	0.29	1.38	0.85	1.17

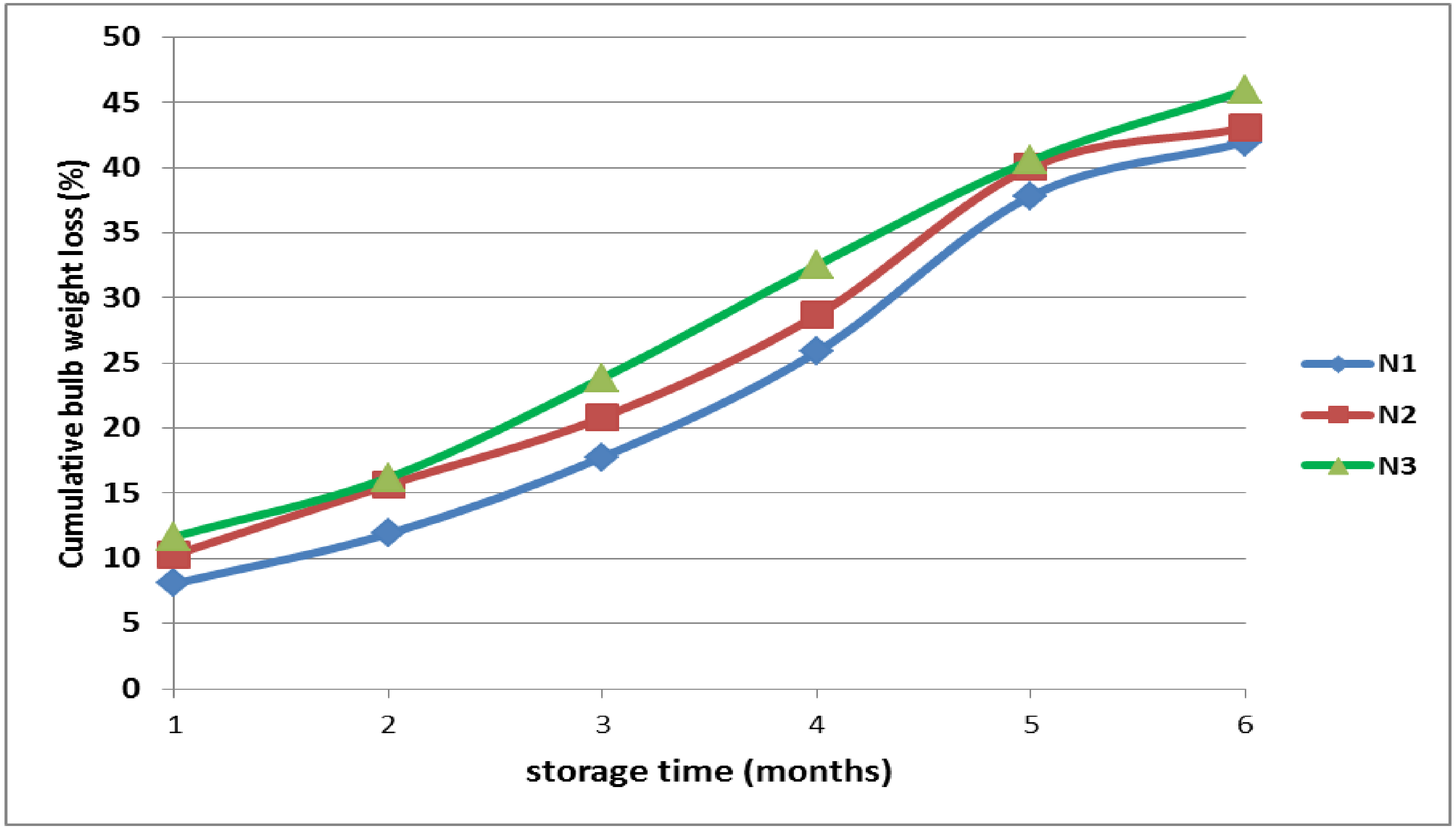

Figure 5. Effect of N fertilization on bulb weight loss during Storage

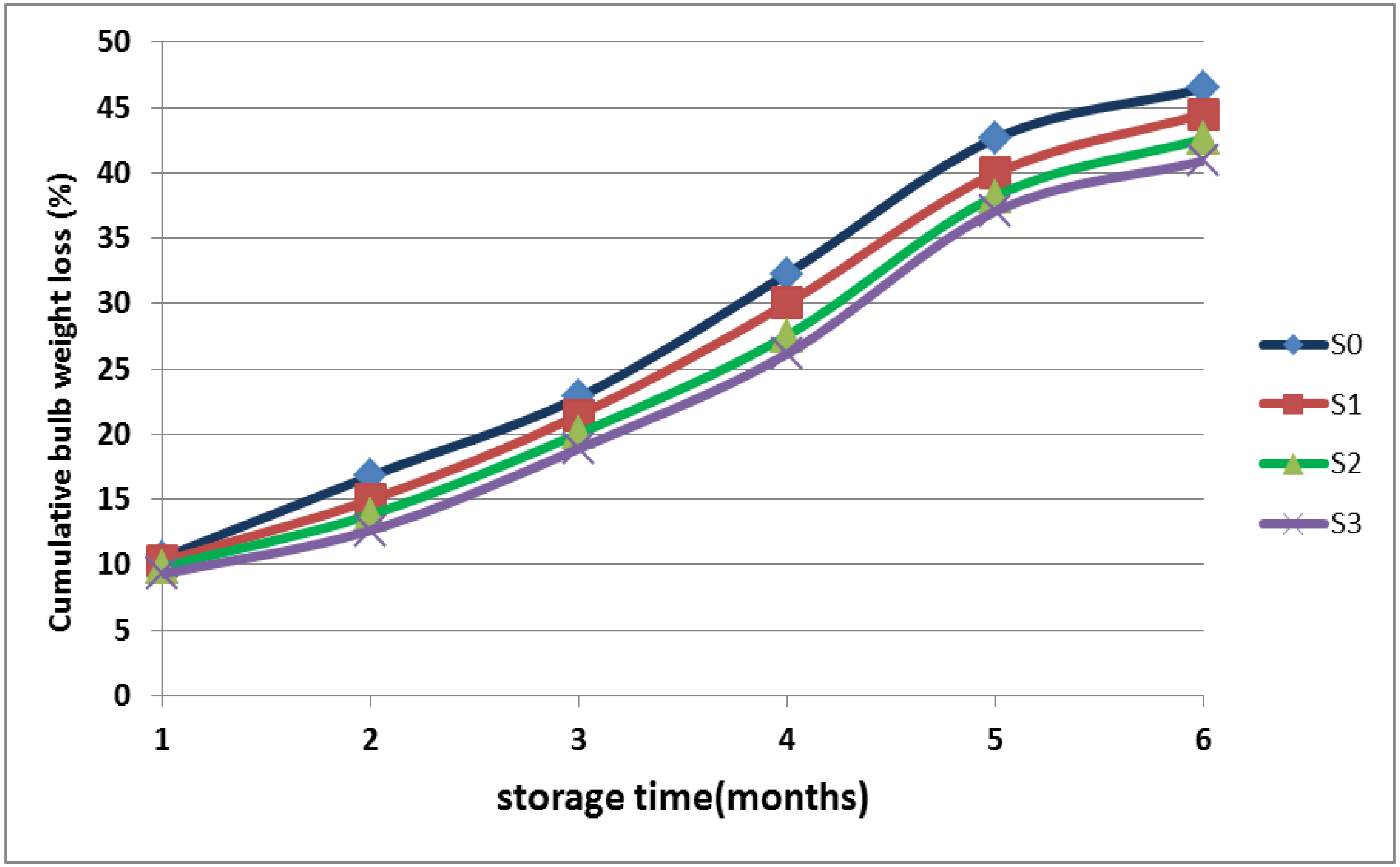

Figure 6. Effect of S fertilization on bulb weight loss during Storage