Effect of $MgSO_4$ as a complement to NPK fertilizer on shallot growth

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Abstract. Climate change has a significant impact on crop failure and agricultural production. To overcome this issue, fertilization strategy is needed to increase plant growth. Magnesium Sulphate ($MgSO_4$) role in photosynthesis, enzyme activation, and synergism with other nutrients plays big part in increasing plant growth and harvest. Complementing NPK fertilizing with $MgSO_4$ can be a solution to fulfill nutrient needs with lower input and higher effectivity. This study aims to find best formula of $MgSO_4$ complementing NPK fertilizer in improving shallot growth. Experimental method was conducted using Randomized Complete Group Design (RCBD) with 9 treatments and 3 replications, namely: control, standard NPK (Urea 250 kg ha^{-1}, SP-20 130 kg ha^{-1}, and KCL 60 kg ha^{-1}), $MgSO_4$ (300 kg ha^{-1}), and six combinations of $MgSO_4$ with NPK. The results showed that application of $MgSO_4$ combined with NPK fertilizer significantly increases the growth of shallots. The addition of 300 kg ha^{-1} of $MgSO_4$ with ¾ doses of NPK fertilizer effectively increased shallot growth as indicated by the highest plant height, number of leaves, and number of tillers.

1 Introduction

Agriculture production is highly sensitive to climate change. Ozone leakage is able to reduce photosynthesis rate, slow plant growth, and increase susceptibility to diseases [1]. Changes such drought and rain pattern can reduce food and livestock production. To soil, high rainfall leads to nutrient leaching, decreasing soil fertility and contaminating water body [2]. Furthermore, change in rainfall pattern can increase soil degradation by erosion while higher temperature contributes to soil carbon loss, reducing microbial activity and nutrient availability [3]. These climate change impacts not only affect crop yields directly but also hinder soil fertility preservation, which is crucial for sustainable agricultural productivity.

Climate change can accelerate soil fertility decline by loss of organic matter, acidification, nutrient leaching, and increased nitrogen denitrification by the means of temperature and rainfall changes [4]. Therefore, maintaining fertility in soil is very important

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for crop productivity. Main actions can be done by pH monitoring, understanding soil and plant need for macro and micro nutrient, and optimizing fertilizer use [5]. Efficient nutrient management focusing on source, timing, and placement plays crucial role in reducing nutrient loss and promoting soil health and productivity [6].

One favourable solution to optimizing soil fertility and plant growth is by using Magnesium Sulphate ($MgSO_4$. $7H_2O$), also known as Epsom salt, a water-soluble fertilizer containing 15% MgO and 28% SO_3 for magnesium deficiencies in plant. Magnesium is forming element of chlorophyll, therefore magnesium deficiency indicated by yellowing of leaves [7]. Magnesium Sulphate is known for its effectivity for increasing crop biomass and yield under saline environment [8]. $MgSO_4$ with borax addition to urea can reduce NH_3 emissions and increases nitrogen uptake in plant and with sufficient addition of zeolite can reduce NO_2 emissions [9].

In Indonesia, shallot is one of valuable agriculture commodity. According to [10,11], national need for shallot is 1.2 million ton while production is 1.3 million ton. It also worth noting that shallot production has shown great increase in last 3 decades, FAO also states that Indonesia is top 4 shallot exporter in ASEAN region with USD 6.53 million worth [12]. With highest to lowest nutrient content in shallots are K > N > P=Mg > S [13], it is clear that NPK fertilizer is in high demand on shallot cultivation. However, with the expensive cost of non-subsidized NPK, it poses challenges to shallot cultivation. Therefore, there should be innovations to combat this problem, one of them is to complement it with natural amendment such as Magnesium sulphate. Magnesium sulphate application to onion has shown positive shallot yield and bulb quality. This because as Sulphate increases so will TSS (total soluble solid) resulting in higher flavour intensity [14]. It is also stated by [15], that application of $MgSO_4$ increases plant height and bulb diameter on garlic. Despite sulphate and magnesium are limiting factors in shallot growths [13] but relationship between $MgSO_4$ application to shallot growth is yet to be understood. Therefore, this research aims to address this problem.

2 Method

This research was located in Srigading, Karanganyar, Central Java province, Indonesia, located at 7°37’01.5’’ S, 111°04’21.8’’ E and geologically was lava flow formation from Mount Lawu. Soil in study area was Inceptisols with low to very low nutrient status including N (0.18%), P (2.16 ppm), K (0.36 cmol), Mg (0.04 cmol), and S (24.8 ppm), also slightly acidic soil pH (6.23).

Experimental method using Randomized Completely Block Design (RCBD) with 9 treatments and 3 replications (Table 1) was used for the research design. There are 27 plots with each plot measuring 2 x 4.5 m.

Table 1. Treatment of $MgSO_4$ and NPK fertilizers

Code	Treatment	NPK Fertilizer kg/ha		
		Urea	SP-20	KCl
A	Control	0	0	0
B	Standard NPK	250	130	60
C	300 kg ha^{-1} $MgSO_4$	0	0	0
D	½ NPK + 300 kg ha^{-1} $MgSO_4$	125	65	30
E	¾ NPK +300 kg ha^{-1} $MgSO_4$	187.5	97.5	45
F	1 NPK + 300 kg ha^{-1} $MgSO_4$	250	130	60
G	¾ NPK + 75 kg ha^{-1} $MgSO_4$	187.5	97.5	45

H	¾ NPK +150 kg ha^{-1} $MgSO_4$	187.5	97.5	45
I	¾ NPK+ 225 kg ha^{-1} $MgSO_4$	187.5	97.5	45

Note: NPK= Urea, SP-20 and KCl

The research began with land preparation, by clearing the remains of the previous crop. Shallot plants of the Bali Karet variety were planted with a spacing of 25 x 40 cm. $MgSO_4$ fertilizer was given at 14 Days After Planting (DAP), while Urea fertilizer was given at 0, 14, and 28 DAP. Fertilization of SP-20 and KCl at 0 and 28 DAP. The parameters observed included plant height, number of leaves, and number of tillers, which were measured once a week until maximum vegetative phase of plant. Research data were analyzed using variance (ANOVA) in determining treatment effect. Then, data were analyzed by Duncan's Multiple Range Test (DMRT) at the 95% level in comparing each fertilizing treatments significance.

3 Results and Discussion

3.1 Plant Height

Shallot plant height varied with various treatments and up to 56 DAP, but there were no differences between treatments. The effect of treatments was significantly different at 14 and 35 to 56 DAP (Table 2).

Table 2. Plant height of Shallot at various ages and treatments

Treatments	Plant height						
	14 DAP	**21 DAP**	**28 DAP**	**35 DAP**	**42 DAP**	**49 DAP**	**56 DAP**
A	21.6^{a}	28.0^{a}	36.0^{a}	38.5^{a}	38.7^{a}	39.7^{a}	33.9^{a}
B	24.7^{bc}	33.7^{b}	40.9^{bc}	46.1^{c}	46.6^{c}	48.1^{bc}	44.1^{c}
C	23.4^{ab}	33.4^{b}	38.7^{ab}	40.2^{ab}	40.3^{ab}	43.5^{ab}	37.0^{ab}
D	23.5^{abc}	33.3^{b}	39.1^{ab}	43.6^{abc}	44.4^{bc}	46.2^{bc}	42.8^{cd}
E	25.9^{c}	34.5^{b}	44.4^{c}	46.7^{c}	49.6^{c}	50.5^{c}	44.7^{c}
F	25.7^{bc}	34.8^{b}	44.1^{c}	46.3^{c}	49.6^{c}	49.0^{c}	43.5^{c}
G	24.6^{bc}	32.8^{b}	39.3^{ab}	45.1^{bc}	45.6^{bc}	46.2^{bc}	38.4^{abc}
H	25.1^{bc}	34.4^{b}	43.3^{c}	42.6^{abc}	45.3^{bc}	46.5^{bc}	41.8^{bcd}
I	25.6^{bc}	33.3^{b}	43.4^{c}	44.4^{bc}	45.6^{bc}	46.6^{bc}	38.3^{abc}

Note: DAP = day after planting
Number code followed by same lowercase letter in same column indicates significantly different according to DMRT test at level of 0.05

Analysis of variance test shows the provision of fertilization treatment only gives a significant effect on plant height at the age of 14 DAP and 35 to 56 DAP ($P < 0.05$). This is because shallot plants since planting until the age of less than 35 days after planting still use nutrients from the bulbs [16], so the effect of adding nutrients has not been seen. This result is in line with the research of Hardiansyah and Bambang [17] which shows that shallot growth is strongly influenced by nutrient reserves in seedling bulbs at the beginning of planting. The high carbohydrate content in the bulbs supports a more efficient photosynthesis process and has a positive impact on plant height growth [18,19].

Table 2 shows that all treatments show a response to plant height, where the combination of NPK fertilizer with $MgSO_4$ in the ¾ NPK + 300 kg ha^{-1} $MgSO_4$ treatment (E) produces a significantly higher plant height compared to treatment A and B, indicated by different letter notations in the DMRT test results, treatment E formed a statistically different group compared to other treatment groups and showed the superiority of the treatment combination. The addition of $MgSO_4$ can improve nutrient utilization by increasing the availability of specific nutrients that support plant height growth, thus potentially becoming a more

sustainable alternative fertilization strategy in reducing NPK fertilizers usage. These results are in line with the research of Poonpakdee et al [20] the application of $MgSO_4$ significantly increased plant height as well as magnesium (Mg) and sulfur (S) concentrations in leaves, and total chlorophyll levels that support overall plant growth. Differences in the dose of fertilization given result in differences in nutrient availability, especially nitrogen nutrients in supporting plant growth [21–23].

3.2 Number of leaves

Number of leaves increases closely related to roots ability in absorbing and translocating nutrients to whole plant tissue [24]. Research data showed that in average, number of leaves in each treatment was significantly different at 14 to 49 DAP (P< 0.05) (Table 3).

Table 3. Number of leaves of Shallot at various ages and treatments

Treatments	Number of leaves						
	14 DAP	**21 DAP**	**28 DAP**	**35 DAP**	**42 DAP**	**49 DAP**	**56 DAP**
A	8.9^{a}	12.3^{a}	16.1^{a}	17.5^{a}	18.7^{a}	18.7^{a}	13.9^{a}
B	14.3^{b}	18.9^{b}	25.1^{b}	29.4^{b}	30.4^{b}	30.7^{bc}	20.8^{ab}
C	14.4^{b}	19.5^{b}	26.4^{bc}	29.6^{b}	28.7^{b}	28.2^{b}	20.1^{ab}
D	16.2^{b}	19.5^{b}	29.0^{bc}	35.2^{bc}	33.7^{bc}	33.7^{bc}	21.4^{c}
E	17.3^{b}	24.0^{c}	33.1^{c}	39.4^{c}	37.8^{c}	37.7^{c}	22.4^{c}
F	14.1^{b}	23.9^{c}	31.6^{bc}	36.0^{bc}	33.8^{bc}	34.0^{bc}	21.4^{c}
G	16.5^{b}	22.4^{bc}	28.3^{bc}	35.2^{bc}	32.1^{bc}	32.1^{bc}	18.3^{ab}
H	15.1^{b}	21.1^{bc}	29.2^{bc}	32.3^{bc}	28.4^{b}	31.4^{bc}	18.6^{ab}
I	15.5^{b}	20.9^{bc}	30.9^{bc}	33.9^{bc}	33.6^{bc}	34.1^{bc}	18.2^{ab}

Note: DAP= day after planting
Number code followed by same lowercase letter in same column indicates significantly different according to DMRT test at level of 0.05

Research observation showed that number of leaves has increased until the plants reach the age of 35 DAP, then there is a decrease in the average number of leaves caused by shallot plants already entering the generative period (bulb formation). These results are in line with the research of Souminar *et al* [25] when entering the age of 35 DAP to 50 DAP shallot plants will experience the generative phase (optimum bulb formation) so that photosynthate is more concentrated in bulb formation than in the vegetative phase which is driven by the rate of leaf reduction.

All treatments affected a number of leaves, with the ¾ NPK + 300 kg ha^{-1} $MgSO_4$ (treatment E) leading to a significantly higher number of leaves compared to the control and the standard NPK treatments as seen from the different letter notations in the DMRT test results, treatment E was included in a statistically separate group, indicating the superiority of this treatment combination over the others(Table 3). $MgSO_4$ which provides magnesium and sulfur significantly increases nitrogen (N) uptake by improving soil properties and facilitating nutrient absorption in plants. These findings suggest that the combination of reduced NPK dosage with $MgSO_4$ supplementation can optimize nutrient efficiency, improve soil health, and enhance leaf growth, and offer a sustainable approach to nutrient management in crop production. Magnesium promotes root growth, increasing the plant's ability to absorb N, while sulfur is essential for protein synthesis, helping effective N utilization. In addition, kieserite ($MgSO_4$)neutralizes aluminum (Al^{3+}), limiting root development and calcium uptake, thus promoting better nutrient uptake [26].

3.3 Number of Tillers

The effect of combined treatment of NPK and $MgSO_4$ fertilizer on the number of tillers at the age of 14 to 56 DAP (Table 4). Research data showed that combining NPK and $MgSO_4$ fertilizer significantly affected the number of tillers until the age of less than 56 days after planting ($P < 0.05$).

Table 4. Number of tillers of Shallot at various ages and treatments

Treatments	Number of Tillers						
	14 DAP	**21 DAP**	**28 DAP**	**35 DAP**	**42 DAP**	**49 DAP**	**56 DAP**
A	2.1^{a}	2.8^{a}	3.0^{a}	3.2^{a}	3.1^{a}	3.2^{a}	3.6^{a}
B	3.2^{b}	3.8^{b}	4.2^{ab}	4.3^{ab}	5.0^{bc}	4.4^{b}	4.5^{bc}
C	3.1^{b}	3.8^{b}	4.6^{b}	4.5^{ab}	4.5^{bc}	4.5^{b}	4.8^{bc}
D	3.6^{b}	4.5^{b}	4.8^{b}	4.7^{bc}	4.8^{bc}	4.7^{bc}	5.6^{c}
E	3.8^{b}	4.5^{b}	5.3^{b}	6.0^{c}	5.7^{c}	5.8^{c}	5.8^{c}
F	3.5^{b}	3.9^{b}	5.1^{b}	5.1^{bc}	5.3^{bc}	5.0^{bc}	4.9^{bc}
G	3.7^{b}	4.3^{b}	4.9^{b}	5.0^{bc}	4.8^{bc}	4.8^{bc}	5.0^{bc}
H	3.4^{b}	3.9^{b}	4.4^{b}	4.4^{ab}	4.4^{b}	4.5^{b}	4.5^{bc}
I	3.8^{b}	4.5^{b}	4.8^{b}	4.8^{bc}	4.4^{b}	4.7^{bc}	5.0^{bc}

Note : Number code followed by same lowercase letter in same column indicates significantly different according to DMRT test at level of 0.05

The fertilization treatment with a dose of ¾ NPK + 300 kg ha^{-1} $MgSO_4$ (E) produced the highest average number of tillers from 14 to 59 DAP, although it was not significantly different from the other treatments (Table 4), indicating that all treatments exerted relatively similar effects on tiller formation during this growth period. This suggests that although fertilization can support tiller development, genetical factors are more dominant in determining the number of tillers [27]. These findings emphasize the importance of selecting high-yielding varieties with superior tillering potential, complemented by optimized fertilization strategies to maximize crop productivity. In line with the research of Napitulu [28] and Sumarni *et al* [29], number of bulbs and number of tillers are dominantly influenced by genetical factors than fertilization factors so that N, P, and K fertilizers do not give a significantly different effect on the number of tillers. Similar results were found in the research of Budianto *et al* [30] that the number of tubers is dominantly influenced by genetical factors and less influenced by environmental factors. The number of tillers is more related to size of the tuber where larger tubers will have fewer tillers.

4 Conclusions

The research findings indicate that combining NPK + $MgSO_4$ fertilizer significantly enhances shallot growth. Using ¾ NPK + 300 kg ha^{-1} $MgSO_4$ led to greater improvements in plant height, number of leaves, and number of tillers compared to using standard NPK fertilizer. These results of this study highlight the effectiveness of integrating $MgSO_4$ with NPK fertilizer can be used as new fertilizing method to minimize input cost, reduce fertilizer loss, and increase both quantity and quality of shallot harvest.

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