

## Research Article

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# The efficiency of magnesium (Mg) on rice growth, biomass partitioning and chlorophyll contents in alkaline soil condition

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### Citation

Niaz Ahmed, Adnan Khalil, Allah Bakhsh Gulshan, Safdar Bashir, Muhammad Saleem, Riaz Hussain, Muhammad Arif Ali, Javaid Iqbal and Saqib Bashir. The efficiency of magnesium (Mg) on rice growth, biomass partitioning and chlorophyll contents in alkaline soil condition. Pure and Applied Biology. Vol. 10, Issue 1, pp325-333. <http://dx.doi.org/10.19045/bspab.2021.100035>

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Received: 30/07/2020

Revised: 12/09/2020

Accepted: 15/09/2020

Online First: 21/09/2020

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### Abstract

Magnesium (Mg) is recognized as an essential macronutrient because of its involvement in several morphological and physiological processes in numerous plant species. While, its deficiency in the soil lead to cause the severe reduction in plant growth and yield. The purpose of the current study was to evaluate the efficiency of Mg at (40, 80 and 160 kg/ ha) for rice growth, yield, biomass production and chlorophyll contents as well as Mg availability in calcareous soil. Results demonstrated that the addition of Mg showed the prominent increase in rice plants vegetative growth, shoot and root fresh and dry biomass as well as enhance the availability of NPK in calcareous soil. Similarly, the significant increase in chlorophyll contents was also observed with the increasing rate of Mg fertilization. In conclusion, addition of Mg fertilizer in calcareous soils is considered an effective strategy for the rice growth.

**Key words:** Alkaline soils; Chlorophyll; Magnesium; Rice; Yield

### Introduction

Rice (*Oryza Sativa*) is recognized as one of the world's most important staple food crops; it has a major share to fulfil the food demand of the world population. According

to the FAO 2016 statistics, globally rice production was more than 749 million tons, superseded by maize that accounts for 959 million tons. While, In Pakistan, Punjab and Sindh provinces have greater share in rice

production that accounts 88% of the total country's basic food needs. Rice is cultivated on about 2.5 million hectares' area which has major share after cotton and wheat production. Recently, the cultivated land is shrinking due to the huge rise in urbanization, industrial revolution, environmental and agro climatic conditions, which pose a serious threat to is the huge world population food requirement [1].

It is interesting to address some important counter measures to increase crops yields including, well organized water conservation projects, ameliorate soil quality, innovative techniques that should be implemented to manage plant protection and fertilizers applications. The use of fertilizers is an important strategy to meet the large population food demands all around the world. However, the nutrient use efficiency was very low in Pakistani soils, especially Nitrogen (N) and Phosphorus (P)/ due to calcareous nature relative to European countries [2]. Therefore, the use of secondary nutrient such as Mg as a mixture and alone nutrient is considered the beneficial approach for rice growth and yield.

Magnesium (Mg) is recognized an essential nutrient for various living organisms including, plant species, animals and as well as human beings [17] and thereby its deficiency may cause the reduction in sustainable agricultural production and negative impacts on other organisms [13]. Several edible agricultural products have the sufficient amount of Mg for humans and animals. Thus, it's an important task to maintain the quantity of Mg in agricultural products within sufficient amount. Unfortunately, noticeable symptoms of Mg deficiency often occur in edible plants, especially at their vital developmental stage with fast carbohydrate accumulation, which is widely grown in acidic soils across the world [17].

The solubility of Mg in the soils and its uptake by crops depends on several factors such as soil texture, agronomic practices, cation exchange capacity and plants types [8, 14]. The sufficient amount of Mg in the soil is considered a key to promote crop growth and development. The availability of Mg in soils depends on its main four forms including, exchangeable, replaceable, complexation with natural organic substances and auxiliary structures [11].

Magnesium (Mg) deficiency in farmlands and its availability to plants is become a considerable problem because of chlorosis in the interveinal parts of leaf and induce reduction in photosynthetic pigments in plants leaves [10]. Chlorosis is a most noticeable reaction of crops to identify the Mg deficiency that results the reduction in sugar transport from the source to sink organs and biomass accumulation to the root and reproductive tissues [4, 8, 22]. The chlorosis development requires former degradation of chlorophyll, since Mg acts as a vital element in the chlorophyll molecule. When Mg is strongly bound to this molecule chlorosis appears to be a late response to Mg deficiency.

Recently, more attention has been paid on the primary macronutrients N, P and K related fertilizers than secondary nutrients Ca, Mg and S to attain maximum crops yield [4, 22]. While, there is also little information is available regarding the significant importance of Mg for agricultural production, contribution in plant structure and physiological attributes as well as its deficiency in farmlands and crops [1, 4]. However, it is essential to recognize the behavior of crop yield to Mg-fertilization under various soils types, cropping pattern, and fertilizer management strategies in large-scale field experiments. There has been no effort made to examine the effects of Mg as a fertilizer on rice growth and development. In this study, a meta-analysis

was conducted to (1) examine the overall impacts of Mg applications on rice yield and subsequent agronomic efficiencies; (2) To understand the effects of Mg fertilization on the photosynthetic rate of rice plants in alkaline condition.

## Materials and Methods

### Experimental particulars

The impact of Mg on rice crop growth and yield was investigated by conducting a field trial at the Research site of College of agriculture, Bahauddin Zakariya University, Multan. The research site was organized with Randomized Complete Block Design (RCBD). The research site was divided and managed into small plots with 5m length and 2m width. Super Basmati rice was selected as a test plant, seeds were sown in the month of July, 2018. Rice nursery was transplanted manually. The experimental units were amended with MgSO<sub>4</sub> at the following doses: (T1), Control; (T2), 40 Kg Mg/ ha; (T3), 80 Kg Mg/ha; (T4), 160 Kg Mg/ ha along with the basic application of NPK fertilizers. Super Basmati Punjab II rice variety was selected as a test crop. Recommended dose of NPK (75:76:60 kg/ha) fertilizer was added from the sources of Urea, MOP and DAP, respectively at the time of seedling transplantation. The physico-chemical properties were presented in the (Table 1).

### Growth and yield attributes

Plant height in (cm) was measured by taking plants above ground biomass to the tip of the panicle at the time maturity and harvesting stage using meter rod. Similarly, other crop growth and yield attributes were measured including, number of tillers (m<sup>-2</sup>), shoot diameter (cm), thousand grain fresh weight (g), thousand grain dry weight (g), total grain yield (kg/ha), fresh shoot weight (g) and dry shoot weight (g).

### Soil analysis

Soil pH and EC were measured using the 1:2.5 and 1:5 of experimental soil and water

ratio, after the harvesting of crop using pH and EC meter [4-6]. Soil organic matter was calculated using the wet oxidation method by taking 1.0 g of studied air dried soil sample [5]. The available phosphorus concentration was also determined by taking 5.0 g of tested soil into plastic sample tubes and add 15 ml of 0.5 M NaHCO<sub>3</sub> extractant. The soil sample was shaken and centrifuge at 3000 rpm [5]. Extractable soil Potassium was estimated by extracting the 2.0 g of studied soil with the 10 ml of 1 N C<sub>2</sub>H<sub>7</sub>NO<sub>2</sub> solution with 1:5 ratios. Then the suspension was shaken for 30 minutes at 200 to 300 rpm. The extractable K contents from studied soil were estimated using the flame. A calibration curve was developed which showed the K levels. Exchangeable Mg from studied soil was measured using the normal ammonium acetate extraction method. Extraction was taken and an aliquot was titrated using EDTA solution and extractable Mg contents were determined using atomic absorption spectrophotometer.

### Plant analysis

Harvested plant tissues were collected, dried and ground for chemical analysis. Fresh plants leaves were used for chlorophyll analysis. The dried and ground portion of 1g of rice plant tissues were digested using Diacid (2:1) (HNO<sub>3</sub>+HCl<sub>2</sub>) [4, 5]. Similarly, N contents from rice tissues were measured using 0.25 g of rice tissues (root and leaf) and were taken in sample digesting tube with 2 ml of H<sub>2</sub>SO<sub>4</sub> [4, 6]. Then 30% pure Hydrogen peroxide was added and digested plant tissues at 100 °C for 20 minutes [3]. Phosphorus contents in rice tissues were measured by the following method [20]. We took 0.05 ml of digesting plant sample and took 0.025 ml of grain sample was diluted in 0.950 ml 0.975 distilled water. Finally, 0.2 ml of the reagent 1 was added into tubes and left the suspension for 15 minutes.

### Statistical analysis

The subjected parameters were analysed by using their means with the software (statistics 8.1). Analysis of variance (ANOVA) technique was used for the respective statistical analysis (RCBD). The least significant difference (LSD) test was used  $p \leq 0.05$  to understand the mean difference among the amended doses of Mg.

### Results

#### Effect of Magnesium on rice growth, yield and soil

The results recorded from the present study showed a significant ( $P \leq 0.05$ ) (Table 2 & 3) effectiveness of Mg on rice growth and yield as well as Mg availability in soil. Results showed that the efficiency of Mg along with the basal levels of NPK has the significant improvements in rice growth parameters relative to the experimental unit which were not amended with Mg. The prominent increment in the number of plants per square meter was observed by (18.3) in T4 after the addition of Mg at 160 kg/ha. Similarly, the maximum number of spikelet plants<sup>-1</sup> were calculated in T4 (13), while the minimum was recorded in T1 (9.7). The prominent increment in plant height was recorded by enhancing the levels of magnesium. Likewise, the greater increase in plant height was obtained in T4 (69.7 cm) relative to T1 (54.0 cm).

Data regarding the number of thousand grain weight was significantly differed after Mg incorporation. Then statistical observation showed that Mg play an important role to improve the weight of thousand grain. The greater increment in grain weight was recorded Mg was applied at 160 kg/ha by (27.3 g) compared to T1 by (23.4 g) (Table 1). The significant difference in shoot dry biomass and diameter was recorded in the highest rate of Mg treated soil. The maximum shoot dry biomass and diameter

was recorded by 57.3 g and 13.3 cm respectively. The SPAD values regarding chlorophyll contents were altered with the various Mg levels (Table 4). The greater values were recorded in T4 by (0.23 mg/g) where the application of Mg was applied at 160 kg/ha dose, while the minimum contents were observed in T1 by (0.15 mg/g) where minimum Mg was applied (Table 4).

#### Role of MgSO<sub>4</sub> on organic matter and Mg availability in soil

Soil organic matter was effectively altered after the incorporation of Mg fertilizer (Fig. 1). The greater amount of OM was estimated under T4 by 0.91 %, while the low contents were measured in T1 by 0.68 %. The greater increase in Mg contents were recorded in the soil, where the application of Mg was applied in T4 48.7 mg/g while minimum was observed in T1 by 21.6 mg/g, where no Mg was applied.

#### Effect of Mg on NPK contents

The accumulation of nitrogen (N), phosphorous (P) and Potassium (K) in rice shoot was significantly altered ( $P \leq 0.05$ ) among the treatments (Table 4 & 5). The highest N, P and K contents was calculated in rice shoot in T4 by 1.29, 0.24 and 155 mg kg<sup>-1</sup> respectively, while low N, P and K contents were recorded in T1 by 0.74, 0.2 and 129 mg kg<sup>-1</sup> respectively. Data about the contents of N, P and K in rice grains was significantly altered ( $P \leq 0.05$ ) (Table 4 & 5). The maximum N, P and K contents were determined in rice grain in T4 0.76, 0.37 and 69 mg kg<sup>-1</sup> respectively, while the minimum were measured in T1 0.19, 0.27 and 57.3 mg kg<sup>-1</sup> respectively. Similarly, highest concentration of N, P and K was determined in rice leaf in treatment T4 by 1.052, 0.33 and 165 mg kg<sup>-1</sup> where Mg level was maximum, while minimum Mg dose was determined in control treatment T1 by 0.86, 0.26 and 136 mg kg<sup>-1</sup> respectively.

**Table 1. Selected basic physico-chemical properties**

Properties of soil	Values	Units
Sand	28	%
Silt	50	%
Clay	22	%
Textural Class	Silt loam	
pH	8.11	-
EC	2.1	dS/m
Mg	21.23	mg/kg
K	161	mg/kg
P	4.98	mg/kg
Organic matter	0.78	%

**Table 2. Effect of treatments on plant growth attributes; T1 (Control), T2 (40 kg Mg/ha), T3 (80 kg Mg/ha), T4 (160 kg Mg/ha)**

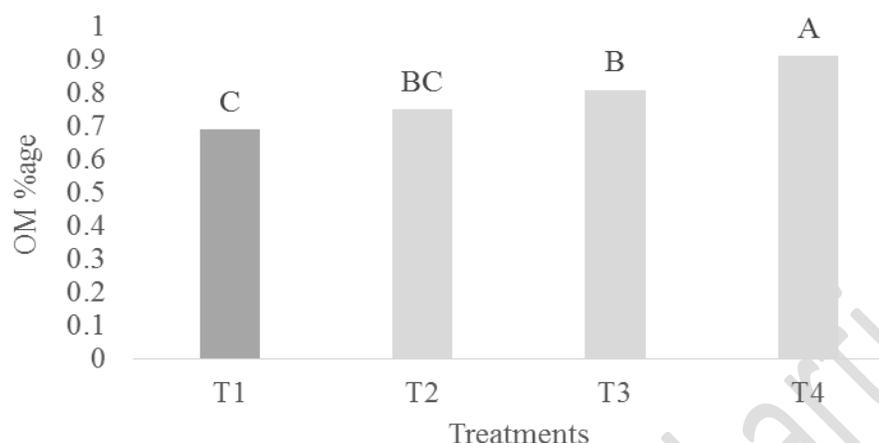
Treatments	Plant height	No. of Plants	No. of Spiklets	Spike length	No. of Tillers	1000-grain weight
T1	54.0 B	15.0 B	9.7 B	9.3 B	11.0 C	23.4 C
T2	55.3 B	15.7 B	10.7 B	10.8 AB	12.0 B	25.1 BC
T3	58.3 B	18.0 A	11.3 AB	11.0 AB	13.3 AB	25.7 AB
T4	69.7 A	18.3A	13.0 A	12.0 A	14.7 A	27.3 A

**Table 3. Effect of treatments on plant growth attributes; T1 (Control), T2 (40 kg Mg/ha), T3 (80 kg Mg/ha), T4 (160 kg Mg/ha)**

Treatments	Shoot fresh weight (g/plant)	Shoot dry weight (g/ Plant)	Shoot diameter (cm)	Biological yield (t/ha)	Chl	Grain yield/ ton
T1	81.1 D	44.4 C	9.7 C	6.1 B	0.15 B	2.2 B
T2	85.0 C	47.2 C	12.0 B	6.2 B	0.16 B	2.3 B
T3	95.7 B	50.8 B	12.7 B	6.4 AB	0.22 A	2.9 A
T4	99.4 A	57.3 A	13.3 A	6.6 A	0.23 A	3.3 A

**Table 4. Effect of treatments on Magnesium and Nitrogen accumulation in plant tissues and soil; T1 (Control), T2 (40 kg Mg/ha), T3 (80 kg Mg/ha), T4 (160 kg Mg/ha)**

Treatments	Soil	Mg (mg/kg)			N (mg/kg)			
		Shoot	Leaf	Grain	Soil	Shoot	Leaf	Grain
T1	21.6 D	13.9 D	20.5 D	12.8 D	0.19 D	0.74 B	0.86 B	0.59 B
T2	33.5 C	19.3 C	35.9 C	15.8 C	0.28 C	0.98 AB	0.95 AB	0.66 B
T3	41.5 B	25.6 B	48.5 B	19.9 B	0.41 B	1.11 AB	0.98 AB	0.69 B
T4	48.7 A	31.3 A	60.1 A	25.1 A	0.61 A	1.29 A	1.05 A	0.75 A



**Figure 1.** Effect of treatments on soil organic matter (%age); T1 (Control), T2 (40 kg Mg/ha), T3 (80 kg Mg/ha), T4 (160 kg Mg/ha)

**Table 5.** Effect of treatments on Phosphorus and Potassium accumulation in plant tissues and soil; T1 (Control), T2 (40 Kg Mg/ha), T3 (80 Kg Mg/ha), T4 (160 Kg Mg/ha)

Treatments	Soil	P (mg/kg)			K(mg/kg)			
		Shoot	Leaf	Grain	Soil	Shoot	Leaf	Grain
T1	0.57 B	0.19 B	0.27 B	0.27 C	18.0 C	128.0 D	135.7 C	57.3 C
T2	0.59 B	0.20 AB	0.31 AB	0.31 B	21.7 B	137.3 C	161.3 B	65.3 B
T3	0.61A	0.22 AB	0.31 AB	0.35 AB	21.7 B	145.0 B	163.3 B	68.0 A
T4	0.64 A	0.24 A	0.33 A	0.37 A	25.3 A	155.0 A	165.0 A	69.0 A

### Discussion

The present study confirmed that the incorporation of Mg in rice plots effectively altered rice growth and yield as well as enhance soil Mg and organic matter contents in the soil relative to without Mg amended soil. The prominent increment in plant height and dry biomass after the amendments of Mg is also frequently documented [20, 25]. The current study also confirmed that the addition of Mg at different dose levels effectively increased NPK contents in rice shoots and grains relative to without Mg incorporation. Similarly, the previous study described by [14], who suggested that the uptake of Mg by plants roots could contribute to enhance the photosynthesis, sugar contents

translocation of starch, energy formation and dry biomass and plant height.

Present study suggested that the contents of Mg in rice grains, leaves and shoot was relatively low when rice was grown in alkaline soil without Mg application. The highest amount of Ca and K in calcareous soil might play role to decrease the availability of Mg to the rice. Likewise, [7, 10] also confirmed that both Ca and Mg has an antagonistic relationship and Ca effectively suppress the mobility of Mg that led to the deficiency Mg in plants especially in seedling stage. It was interesting to explain that the prominent increment in N and P contents in rice grains, leaves and shoots of rice after the addition of Mg in calcareous soil was because of synergic

effect of N and P [8, 9]. This increment might be due to the synergistic role of Mg with N and P in the soil.

The efficiency of magnesium in plants plays role to enhance the enzymatic activates such as nitrate reductase and sucrose-phosphate synthase, which support the better consumption of N and carbon [23]. The present study confirmed the addition of Mg showed the significant improvement in chlorophyll concentration which led to enhance the photosynthetic rate ultimately promote plant growth and yield [4]. The application of 200 mM MgSO<sub>4</sub> resulted in enhancing the number of spikelet/plant [4]. A previous study suggested that with the application of magnesium enhanced the sunflower height with more efficiently with other nutrients [10]. In the current study, spike length and grains of rice were also increased after Mg addition. It has been reported that the maximum spike weight in barley (1.31 g) where maximum fertilizer applied as compare to the control treatment (1.2 g) [15].

It has been explained that the use of Mg for crop growth played the significant role to increase dry biomass, enhance the thickness of plant stem and root [21]. Similarly, another study proposed by [21] reported that the effect of Mg on maize crop yield and production that was increased with the increasing rates of Mg fertilizers. Results regarding the plants growth attributes revealed that the addition of Mg in calcareous soils showed the effectiveness to improve rice grains weight, dry shoot and root biomass, plant height and shoot diameter. These attributes also changed with climatic change.

Present study suggested that the addition of Mg in calcareous soils could increase the availability of Mg in soils for plants growth as well as Mg accumulation in plants tissues especially in edible portion. Several previous studies [16, 17] indicated that

availability of Mg in calcareous soils play a vital role to promote soil fertility status as well as enhance nutrient uptake ability in plant. In the current study, the increased the level of Mg significantly enhance the organic matter contents in the soil [16].

### Conclusion

The deficiency of Mg in alkaline soils seriously compromises physiological efficiency of rice plants. The fertilization of rice plants with the Mg source (MgSO<sub>4</sub>) showed the prominent alteration in growth and yield. The Present study suggested that the addition of Mg with the basal dose of NPK in alkaline soil showed the prominent increment in rice growth and yield traits with its increasing dose. The prominent increase in chlorophyll contents were also recorded with the increasing Mg levels in rice crop. Several large scale studies should be performed to examine the efficacy of Mg fertilization by growing of various crops in calcareous soils that might have great contribution to our knowledge associated with the stressing impact of soil Mg.

### Authors' contributions

Conceived and designed the experiments: N Ahmad & AB Gulshan, Performed the experiments: A Khalil & S Danish, Analyzed the data: J Iqbal, Contributed reagents/ materials/ analysis tools: R Hussain & MA Ali, Wrote the paper: S Bashir & S Bashir.

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