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Research Article

Evaluation of the effect of magnesium in combination with organic manures on the growth and yield attributes and yield of cotton (*Gossypium hirsutum* L.) in *Typic Ustropept*

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Abstract
Cotton is India's most significant commercial crop and has a significant role in the agricultural economics of the nation. A field experiment was conducted in a farmer’s field located in Achchandavilthan village of Srivillipudhur block, Virudhunager District, from 28-Aug 2019 to Jan, 2020 to evaluate the response of cotton to foliar and soil application of magnesium combination with organic manures on the growth and yield attributes and yield of cotton in magnesium deficient soil. The soil was categorized as “Moderately deep clay *Typic Ustropept,* and medium N, P and high K content, in a randomized block design with fifteen treatments and three replications. The results revealed that the application of $MgSO_4$ at a rate of 50 kg ha^{-1} along with 250 kg vermicompost for 30 days (1:5 ratio) at critical stages of crop growth along with the Soil Test Crop Response (STCR) based N,P_2O_5 and K_2O RDF registered the maximum plant height at all three stages (40,70 and harvest) of crop growth (94.7, 122.3 and 222.2 cm), number of monopodial branches plant^{-1} (33.4), number of sympodial branches plant^{-1}(73.1), numbers of boll plant^{-1} (48.3), boll weight (3.9 g), and seed cotton yield (26.2 q ha^{-1}). This was followed by treatment (T_9) $MgSO_4$ at a rate of 50 kg ha^{-1} incubated with 500 kg FYM for 30 days (1:10 ratio) along with STCR) based N,P_2O_5 and K_2O RDF and the lowest treatment receiving the recommended dose of N, P_2O_5 and K_2O alone (80:40:40 kg ha^{1}). It was revealed that natural chelated fertilizer prepared from $MgSO_4$ incubated with organic manures for 30 days significantly improved the growth and yield of cotton.

Keywords: Cotton, *Gosipium hirsutum,* Magnesium, Vermicompost, Yield

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a major source of natural fiber growing all over the world. Cotton is known as "White Gold" and is regarded as the "King of Fiber Crops." It is India's most significant commercial crop, farmed over 12.65 million hectares and producing 40 million bales of lint. Cotton provides almost 60 million people with work and accounts for 80 percent of the raw material used in the textile sector. India is the world's largest cotton producer by area and is second in terms of production. Cotton productivity in India is much lower (518 kg ha^{-1}) than in other countries (Adnan 2020). Magnesium (Mg) fertilizer is needed for various of plant physiological activities. Mg plays a critical role in the creation and development of sink organs such as seeds and roots (Ceylan *et al.,* 2016). Its fertilization has a significant impact on crop yield and many physiological processes in various crop species, as well as Mg agronomic efficiencies, under various soil conditions. Its deficiency in plants resulted in lower amounts of starch, as well as reduced germination and seedling establishment, when compared to Mg adequate plants (Wang *et al.,* 2020). The use of locally available low-cost organic sources, such as manures, green manures, and biofertilizers, in combination with inorganics in a synergistic manner for sustainable crop production and soil health is demanded by the high cost of fertilizer and declining input subsidies (Laxminarayana 2016)

Among the secondary nutrients Mg plays a major role in cotton production. It is involved in the biosynthesis of nucleic acids. It also stabilizes the ribosomal structure. Mg mainly assists in the translocation of cellulose and controls the fiber quality of cotton. Symptoms of mg insufficiency often occur on older leaves. Chlorosis is a typical reaction of plants to Mg shortage, and it predicts significant yield loss due to decreased sugar transfer from the source to the sink organs and biomass buildup in the root and reproductive tissues. Tanoi and Kobayashi, (2015). In the intensive agricultural system, much importance is given to N, P and K based fertilizer and Mg is not generally applied to farmers. Hence, Mg deficiency has become a serious problem in the cotton-growing area of the Virudhunagar district of Tamilnadu, India. In calcareous soils, Mg combines with calcium hydroxide and forms magnesium hydroxide, and the availability of Mg to the labile pool is reduced. Keeping these points in view, the present study was conducted to evaluate the effect of magnesium sulphate alone and incubation with various organic manures on the growth, yield attributes and seed cotton yield in Mg deficient Virudhunagar district of Tamil Nadu.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out to understand the response of Mg to the growth and yield of cotton in a farm's field located in Achchandavilthan village of the Srivillipudhur block, Virudhunagar District, Tamil Nadu, during the *Kharif* season from 28 August 2019 to Jan 2020. The soil moisture regime is ustic, with a mean annual temperature of 25.4 ^{0}C. The mean annual rainfall (2019) in the Virudhunagar district was 840.5 mm.

Enrichment of organics fortified with Mg

The organic sources employed in the incubation of Mg are vermicompost and farmyard manure. The enrichment process included $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio), $MgSO_4$ @ 50 kg ha^{-1} incubated with 500 kg FYM for 30 days (1:10 ratio), $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 375 kg FYM for 30 days (1:10 ratio), $MgSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM for 30 days (1:10 ratio), $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 187.5 kg vermicompost for 30 days (1:5 ratio), and $MgSO_4$ @ 25 kg ha^{-1} incubated with 125 kg vermicompost for 30 days (1:5 ratio).

Experimental details

The field experiment was conducted in a randomized block design with fifteen treatment and three replication, 20m^2 (5 m x 4 m). The details of the treatments are given in Table 1.

Data collection and analysis

Before the experimentation, soil samples were collected at random at 0-30 cm depth across the experimental site and made in a single composite. The composite soil sample was processed and used for the analysis of physico-chemical characteristics viz., soil reaction (pH) (Potentiometry, Jackson, 1973), electrical conductivity (EC) (Conductometry, Jackson, 1973), soil organic carbon (Dichromate wet digestion method, Walkley and Black, 1934), available nitrogen (Alkaline permanganate method, Subbaiah and Asija, 1956), available phosphorus (Olsen method, Olsen *et al*., 1954), available potassium (neutral normal NH_4OAc method, Stan-

Table 1. Treatment details of the experiment

T_1 – Recommended dose of Fertilizer N, P_2O_5 and K_2O @ 80:40:40 kg ha^{-1}(control)
T_2 - N, P_2O_5 and K_2O on STCR basis
T_3 - T_2 + Basal application of $MgSO_4$ @ 37.5 kg ha^{-1}
T_4 - T_2 + $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 375 kg FYM for 30 days (1:10 ratio)
T_5 - T_2 +$MgSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM for 30 days (1:10 ratio)
T_6 - T_2+ $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 187.5 kg vermicompost for 30 days (1:5 ratio)
T_7 - T_2 + $MgSO_4$ @ 25 kg ha^{-1} incubated with 125 kg vermicompost for 30 days (1:5 ratio)
T_8 - T_2 + Basal application of MgSO4 @ 50 kg ha^{-1}
T_9 - T_2 + $MgSO_4$ @ 50 kg ha^{-1} incubated with 500 kg FYM for 30 days (1:10 ratio)
T_{10} - T_2 + $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio)
T_{11} - T_2 + Foliar application of $MgSO_4$ @ 1% on 20, 40 and 60 DAS
T_{12} - T_3 + Foliar application of $MgSO_4$ @ 1% on 20, 40 and 60 DAS
T_{13} - T_8 + Foliar application of $MgSO_4$ @ 1% on 20, 40 and 60 DAS
T_{14} - T_2 + Basal application of EDTA @ 2 kg ha^{-1}
T_{15} - T_2 + Foliar application of Mg EDTA @0.5%on 20, 40 and 60 DAS

ford and English,1949), DTPA extractable Zn, Fe, Cu, Mn (Atomic Absorption Spectrophotometer, Lindsay and Norvell, 1978). From each plot, five plants were selected randomly, and tagged, and the following growth and yield parameters were observed. Plant height was measured from the ground level to the tip of the terminal bud and expressed in cm. The number of monopodial and sympodial branches per plant was counted from the selected tagged plants, and the mean number of ball and ball weights per plant was determined and expressed in numbers. The yield data were collected at physiological maturity and after the crop was harvested. Analysis of variance (ANOVA) was used to examine the growth and yield (kg ha-1) obtained in the research, as recommended by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The present study showed that cotton (*Gossypium hirsutum* L.) SVPR 4, the plant growth and yield attributes were highly influenced by the soil application of Mg and enriched organics along with STCR based N, P_2O_5 and K_2O.

Initial properties

The data of various physico-chemical properties of the initial soil are presented in Table 2. The soil texture was clay loam in nature with a bulk density of (1.14 Mg m^{-3}) and a particle density of (2.47 Mg m^{-3}). The pH of the experimental field soil was moderately alkaline (8.45). The soil was low in alkaline $KMnO_4$-N (214 kg ha^{-1}), medium in Olsen P (14.3 kg ha^{-1}), and medium in NH_4OAc K (356 kg ha^{-1}) with a low organic carbon content (3.94 g kg^{-1}). The soil was deficient in Mg (0.68 mg kg^{-1}). The soil was categorized as "Moderately deep clay *Typic Ustropepts*" by The United State Department of Agriculture (USDA) soil taxonomy.

Effect of Mg and fortified organic manures on growth attributes

The application of Mg significantly influenced the growth attributes of cotton, as shown in Table 3. The plant height, number of monopodial and sympodial branches, number of bolls per plant and boll weight were significantly **(P=0.05**) higher in the treatment receiving $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio) along with the test crop response (STCR) basis (T_{10}) than in the other treatments. Thus, this result might be due to the increased availability of Mg for cotton during the critical stages, as Mg starvation greatly reduces the growth and development of cotton.

Plant height

The application of vermicompost incubated with Mg sulphate exhibited favourable results on plant height. Among the various treatments, application of $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio) along with STCR based N, P_2O_5 and K_2O (T_{10}) showed maximum plant height at various stages (flowering stage 94.7 cm, boll development stage 122.3 cm and harvest stage 222.2 cm) however the treatment T_{14} (Basal application of EDTA @ 2 kg ha^{-1} along with STCR based N, P_2O_5 and K_2O) was statistically on par with T_4 $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 375 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O), T_5 ($MgSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O) and T_6 ($MgSO_4$ @ 37.5 kg ha^{-1} incubated with 187.5 kg vermicompost for 30 days along with STCR based N, P_2O_5 and K_2O) Whereas irrespective of the stages, the lowest plant height of 80.1 cm at flowering stage, boll development stage (101.9 cm) and 193.5 cm at harvest stage were recorded in the treatment receiving recommended dose of N, P_2O_5 and K_2O alone (80:40:40 kg ha^1). Mg is a vital nutrient for plant growth and is involved in a variety of physiological and molecular processes. In an experimental field investigation, enriched $MgSO_4$ outperformed the control in terms of boosting growth metrics such as plant height, with $MgSO_4$ increasing plant height by 5.8% at square formation, 16.6% during boll formation, and 16.9% at harvest. Mg function in phloem loading and delivery of photo assimilates to younger plant sections is responsible for the rise in plant height (Raliya *et.al.,* 2014)

Table 2. Initial soil parameters of the experimental site

Particulars	Values
Physical properties	
Clay (%)	34.79
Silt (%)	27.53
Fine sand (%)	4.23
Coare sand (%)	29.45
Textural Class	Clay loam
Bulk density (Mg m^{-2})	1.14
Particle density (Mg m^{-2})	2.47
Physio-chemical properties	
pH	8.45
EC(dSm^{-1})	0.43
Organic carbon (%)	3.9
Chemical properties	
Available Nitrogen (kg ha^{-1})	218
Available Phophorus(kg ha^{-1})	14.3
Available Potassium(kg ha^{-1})	356
Exchangeable Magnesium (mg kg^{-1})	0.68

The availability of magnesium nutrients enhanced the chlorophyll content and ChSI of safflower leaves under salt stress. In a meta-analysis study, organic manures addition to the soil enriched the root growth of plants up to 50%. Xiang *et. al.,* (2017). The magnesium availability in the rhizosphere promotes root meristem activity and stem mobility in plants. A sufficient amount of magnesium stimulates the expression of a few key genes in root cells, including *AUX1, PIN2*, and *PIN3*, which play vital roles in auxin production and shipping in roots (Niu *et al.,* 2015). Magnesium is required for the structural and functional integrity of ribosomes. This nutrient is also involved in glucose metabolism, mitosis, and fast plant cell development. Magnesium is related to up to 90% of mobile cells or more, mostly in the ribosome, indicating the relevance of this nutrient in controlling cell division and plant growth (Fageria, 2016).

Sympodial and monopodial branches per plant

The number of sympodial and monopodial branches per plant was also enhanced by the application of Mg with vermicompost. The treatment $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio) along with STCRbased N, P_2O_5 and K_2O (T_{10}) achieved the highest number of sympodial (33.45) and monopodial branches (75.13). The treatment T_{14} (basal application of EDTA @ 2 kg ha^{-1} along with STCR based N, P_2O_5 and K_2O) was statistically on par with T_4 $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 375 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O), T_5 ($MgSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O) and T_6 ($MgSO_4$ @ 37.5 kg ha^{-1} incubated with 187.5 kg vermicompost for 30 days along with STCR based N, P_2O_5 and K_2O). Al-Barzinji and Naif, (2014) evaluated the application of different magnesium salts ($MgSO_4.7H_2O$) on garlic (*Allium sativum* L.). Positive and good vegetative growth of garlic was produced by magnesium salts. $MgCl_2$ generated the greatest amount of leaves. The foliar application of $MgSO_4$ and $Mg(NO_3)_2$ improved the yield components, such as head diameter, head weight, bulb production, and cloves per head, as well as the production and yield quality of garlic.

Hauer Jakli and Trankner (2019) reported that the availability of magnesium in rhizomes boosts plant leaf development by drawing antioxidants to leaf tissue. Under the impact of Mg salt, organic manures and biochar plants treated with nano composites, magnesium extended their root systems and shoot and leaf growth.Kobayashi *et al.* (2018) reported that magnesium has a few intricate interactions with other vitamins in plant growth. For example, adequate quantities of magnesium in the rhizosphere improve the leaf enlargement of flora by reducing leaf tissue, particularly iron toxicity.

Effect of Mg and fortified organic manures on yield attribute

Incubation of Mg with vermicompost showed a significant (P=0.05) impact on the number of bolls $plant^{-1}$, boll weight (g) and seed cotton yield (Table 4). Among the

Table 3. Effect of magnesium combined with organic manures on plant height (cm) and growth attributes at different stages of crop growth

Treatment*	Plant height			Growth attributes	
	Flowering Stage	Boll development Stage	At harvest	No. of monopodial branches plant	No. of sympodial branches plant
T_1	78.60	97.96	185.51	21.56	56.75
T_2	79.12	98.30	187.87	22.29	57.85
T_3	82.25	100.26	190.14	23.34	62.30
T_4	86.65	112.08	203.26	31.12	69.46
T_5	85.00	111.42	202.53	30.60	68.75
T_6	86.20	111.80	203.07	30.84	69.10
T_7	84.33	106.30	198.80	29.75	67.35
T_8	84.05	105.56	196.34	28.25	66.45
T_9	90.54	117.20	212.67	31.89	70.15
T_{10}	94.71	122.30	222.20	33.45	73.10
T_{11}	82.44	102.03	191.35	25.21	64.85
T_{12}	83.45	102.53	192.25	26.46	65.35
T_{13}	83.80	103.63	192.70	27.75	65.60
T_{14}	87.10	112.15	203.59	31.35	69.74
T_{15}	81.36	100.73	190.60	24.46	63.76
SEd±	1.59	2.44	4.24	0.64	1.35
CD(P=0.05)	3.35	5.04	9.28	1.42	2.88

*Treatment details are given in Table 1

Table 4. Effect of magnesium combined with organic manures on yield attributes and dry matter production at different stages of crop growth

Treatment*	Yield attributes			Dry matter production (kg ha^{-1})		
	No. of bolls plant^{-1}	Boll weight (g boll)	Seed cotton yield (q ha^{-1})	40 DAS	70DAS	Harvest stage
T_1	35.60	2.75	17.50	545	990	4235
T_2	35.29	2.80	18.65	750	1300	4435
T_3	39.01	2.87	19.50	780	1440	4550
T_4	43.51	3.52	24.05	870	1635	4935
T_5	40.61	3.30	23.22	857	1585	4870
T_6	41.56	3.38	23.62	865	1605	4900
T_7	37.81	3.18	22.25	820	1540	4840
T_8	41.56	3.08	21.35	810	1510	4820
T_9	46.51	3.79	25.20	890	1685	4990
T_{10}	48.30	3.98	26.25	915	1750	5050
T_{11}	38.76	2.98	20.05	790	1450	4620
T_{12}	39.56	3.00	20.23	795	1480	4710
T_{13}	39.80	3.02	20.36	805	1495	4790
T_{14}	44.64	3. 60	24.31	880	1640	4950
T_{15}	37.36	2.85	19.76	775	1410	4490
SEd±	0.82	0.08	0.44	16.07	29.42	80.54
CD(P=0.05)	1.69	0.18	0.96	34.60	61.20	169.6

*Treatment details are given in Table 1

various treatments, the combined application of $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio) along with STCR based N, P_2O_5 and K_2O at was found to be effective in increasing the number of boll plants^{-1} (48.3), boll weight (3.9 g), and seed cotton yield (26.2 q ha^{-1}), followed by $MgSO_4$ @ 50 kg ha^{-1} incubated with 500 kg FYM for 30 days (1:10 ratio) along with STCR based N, P_2O_5 and K_2O. The treatment T_{14} (basal application of EDTA @ 2 kg ha^{-1} along with STCR based N, P_2O_5 and K_2O) was statistically on par with T_4 ($MgSO_4$ @ 37.5 kg ha^{-1} incubated with 375 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O), T_5 ($MgSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O) and T_6 ($MgSO_4$ @ 37.5 kg ha^{-1} incubated with 187.5 kg vermicompost for 30 days along with STCR based N, P_2O_5 and K_2O) statistically on par with each other. The lowest number of boll plants^{-1} (35.6), boll weight (2.75), and seed cotton yield (17.5 q ha^{-1}) were recorded in the RDF treatment (T_1). Kanjana,(2020) reported that the application of Mg fertilizers, when compared to normal Mg fertilizer, had a profound influence on enhancing the highest number of bolls (20.6 g), seed cotton yield (1729 kg/ha^{-1}) and yield-related parameters of cotton.

Rathore and Tarafdar (2015) found that foliar application of 20 ppm biologically generated nano Mg and regular Mg enhanced grain yield in wheat by 63.2 and 35.1 percent, respectively, when compared to the control. Laxminarayana (2017) reported that the addition of liming and $MgSO_4$ to these acidic soils ascribed to neutralization of soil acidity resulted in greater absorption of all important nutrients from both native and applied sources, resulting in the best production response.

Noor *et al.* (2015) revealed that the residual nutrients, including Mg fertilizer along with manures and addition to 100% N resulted in a significant increase in the yield of *T. aman* rice, the highest grain ranged from 3.90 and 3.70 ha^{-1} in noncslcarious floodplain soils in Rangpur, Bangladesh, during 2010–201. Biswas *et al., (*2013) where the highest grain yield of rice was recorded in 60 kg $MgSO_4$ ha^{-1}.

Gokul *et al.,* (2021) reported that the number of fruits plant^{-1} significantly increased with the application of different combinations of inorganic fertilizers, organic manures. The highest number of fruits plant^{-1} (89.36) was registered with application of 75% recommended dose of fertilizers + poultry manure @ 5 t ha^{-1} + biofertilizers + 2% MgSO4. Geng *et al.* (2021) found that the average enhancement in seed yield increased by the application of Mg fertilizer with 100% RDF was approximately 29%. The average seed yield increased up to 2526 kg ha-1. The Mg treatment increased the number of pods per plant, and the seed yield, while the number of seeds per pod and 1000 seed weight were not affected by the Mg applications.

Dry matter production (kg ha^{-1})

Dry matter production is a direct correlation between yield and the growth, and development of various morphological components. The data defined in table revealed that application of $MgSO_4$ @ 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio) along with STCR based N, P_2O_5 and K_2O (T_{10}) delivered the highest dry matter production at 40 DAS (915 kg ha^{-1}), 70 DAS (1750 kg ha^{-1}) and at harvest (5050 kg ha^{-1}) followed by T_9 $MgSO_4$ @ 50 kg ha^{-1} incubated with 500 kg FYM for 30 days (1:10 ratio) along with STCR based N, P_2O_5 and K_2O was statistically on par with T_{14} Basal application of EDTA @ 2 kg ha^{-1}, T_4 $MgSO_4$ @ 37.5 kg ha^{-1} incubated with 375 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O), T_5 ($MgSO_4$ @ 25 kg ha^{-1} incubated with 250 kg FYM for 30 days along with STCR based N, P_2O_5 and K_2O) and T_6 ($MgSO_4$ @ 37.5 kg ha^{-1} incubated with 187.5 kg vermicompost for 30 days along with STCR based N, P_2O_5 and K_2O) but they were statistically on par with each other. Treatment T_1 had the lowest dry matter production at 40 DAS (545 kg ha^{-1}), at 70 DAS (990 kg ha^{-1}) and at harvest (4235 kg ha^{-1}). Similarly, Dromantiene *et al.,* (2017) observed that using mg at various stages of wheat growth resulted in the greatest increase in dry matter and yield. Mg fertilizer can boost overall plant biomass and crop yields while also improving chlorophyll concentration and reducing protein depletion. The total dry matter production under the JM3 (magnesium fertilizer + straw) treatment was increased by 7.91% on average compared with that under the JMO (no Mg fertilizer + straw) treatment. Zhang *et al.,*(2020) reported that the application of Mg fertilizer promoted the accumulation of DM in spring maize. Thus, earlier studies have been conducted by taking $MgSO_4$ as the Mg source, whereas in the present study, $MgSO_4$ was incubated with organic compounds for 30 days to prepare natural chelated compounds that significantly improved the efficiency of Mg compared with the use of $MgSO_4$ along with organic sources.

Conclusion

The application of Mg in conjunction with organic sources significantly (p=0.05) increased growth and yield parameters in cotton (*G. hirsutum* L). The results concluded that soil application of $MgSO_4$ at 50 kg ha^{-1} incubated with 250 kg vermicompost for 30 days (1:5 ratio) along with STCR based nitrogen, phosphorous and potassium (T_{10}) significantly increased the growth and yield of cotton. Thus, the application of T_{10} is recommended for better crop growth and yield of cotton.

Conflict of interest

The authors declare that they have no conflicts of interest.

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