Potassium-magnesium interaction in coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Potassium-magnesium interaction in coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for award of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 18.11.2021

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CERTIFICATE

Certified that this thesis entitled **"Potassium-magnesium interaction in coleus (*Solenostemon rotundifolius* (Poir.) J.K. Morton) productivity"** is a bonafide record of research work done independently by **Ms. Aswani S. (2019-11-012)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the advisory committee of **Ms. Aswani S. (2019-11-012)**, a candidate for the degree of **Master of Science in Agriculture** with major field in **Agronomy**, agree that this thesis entitled **"Potassium-magnesium interaction coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity"** may be submitted by **Ms. Aswani S.** in partial fulfillment of the requirement for the degree.

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Introduction

1. INTRODUCTION

Root and tuber crops are plants bearing starchy roots, tubers, rhizomes, corms, and stems that serve as an important energy source. A wide variety of tropical root and tuber crops like cassava (*Manihot esculenta* Crantz.), sweet potato [*Ipomoea batatas* (L.) Lam.], yams (*Discorea* spp.), aroids and minor tuber crops are cultivated in our country.

Coleus [*Solenostemon rotundifolius*(Poir.) J.K. Morton] is a minor tuber crop belonging to the family Lamiaceae. The genus *Solenostemon* includes 60 species that is widely distributed among tropical region. Coleus is known by different names such as 'Chinese potato', 'Hausa potato' or 'poor man's potato' in different countries. In Kerala the crop is known as 'koorka' or 'cheevakizhanghu' and it is usually planted after the onset of monsoon (June-July). Initially the crop was confined to central Kerala, laterites of Malabar and sandy coastal soils but now due to good market demand its spread has been noticed in adjoining states like Tamilnadu and Karnataka.

Coleus is a short duration annual crop that completes its life cycle within 4-5 months. It is a succulent, herbaceous plant which develops lush green foliage. Its tubers develop from adventitious root modifications and they are heteromorphous in nature. This crop prefers a well-drained fertile soil with pH range of 5.5- 7.0.

The application of nutrients would increase growth, yield as well as returns from crop production. Though tuber crops are able to sustain even in marginal soil conditions, application of manures and fertilizers was found to improve the yield and quality of tubers (John *et al*., 2005). Hence, there is a scope to standardize nutrient management in minor tuber crops also.

Coleus is a short duration crop having high nutrient requirement. Many studies have already been done on requirement of major nutrients by this crop. Recently, secondary nutrient deficiencies have been reported to affect plant growth and biomass partitioning in root and tuber crops. In soils of Kerala leaching of nutrients especially Ca and Mg is high due to heavy rainfall and its deficiency has been reported.

Potassium is an important nutrient for the tuber bulking as well as for translocation of carbohydrates from source to sink. It is also required for disease resistance, stem strength and also for stomatal regulation. Magnesium is a primary element present in center of chlorophyll molecule and hence it is having major role in chlorophyll formation and photosynthetic activity of plants. Magnesium supplementation to crops is generally met through application of chemical fertilizers. The *ad hoc* blanket recommendation as per Package of Practices Recommendation (KAU, 2016) is application of magnesium sulphate at 80 kg/ha in deficient soils, irrespective of crop. Moreover, there are reports that magnesium deficiency in crops can be consequence of either low magnesium status of soil or an oversupply of K and Ca, indicating the importance of balanced nutrient application in enhancing the production and productivity. As the availability and use efficiency of these two nutrients are interrelated due to their antagonistic interaction, it is required to arrive at a balanced dose which can enhance the productivity of the crop in soil deficient in magnesium. Hence varied doses of potassium and magnesium was included in the present study.

As the deficiency of secondary nutrients is generally encountered in highly leached acid soils in Kerala and the research on balanced K-Mg supplementation in enhancing the productivity of coleus is limited, the present study was taken up to assess the effect of varied dose of potassium and magnesium sulphate on tuber yield of coleus.

Review of literature

2. REVIEW OF LITERATURE

Tuber crops are considered as ‘Treasures in the soil’ in view with the high yield that is hidden inside the soil. They play an important role in contributing to the food, nutritional, social and economic security in South and South East Asia, West Africa and the Pacific Ocean Islands, meeting the varied needs of 500 million people over there.

Coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] belongs to the family Lamiaceae and it is a minor tuber crop. Tuber crops are generally very much responsive to the added nutrients. Mohankumar *et al.* (2000) suggested fertilizer rates for the production of different tuber crops and for coleus it was 80:60:80 kg of NPK per ha along with wood ash @ 1.1-2.2 t/ha. Literature regarding effect of nutrient management on growth parameters, nutrient uptake, and chlorophyll content and yield of coleus is furnished in this chapter. Works related to minor root tuber crops are limited and hence research works in other tuber crops are also included in this chapter.

2.1 Nutrient management for tuber crops

a) Organic nutrition in tuber crops

In cassava, study on the effect of different organic manures like FYM, poultry manure and composted poultry manure on nutrient uptake, yield and soil-nutrient status was investigated by Amanullah *et al.* (2007) and reported that either poultry manure alone @ 10 t/ha or FYM @ 25 t/ha was the best and it also resulted in positive N balances in soil. Ramanandam *et al*. (2008) revealed that under rainfed conditions of Andhra Pradesh, application of recommended dose of N: P_2O_5: K_2O @ 100: 50: 100 kg/ha along with vermicompost @ 4 t/ha and Azospirillum @ 5 g/plant resulted in maximum tuber yield and improved quality parameters in cassava.

In elephant foot yam application of FYM @ 36 t/ha (cow dung+ neem cake mixed in ratio of 10:1, inoculated with *Trichoderma harzianum*), incorporation of green manure croplike cowpea and neem cake @ 1t/ha and ash @ 3t/ha resulted in 26% more net profit than conventional method of production (Suja *et al*., 2015).

Anju (2017) observed that application of 6T of FYM along with of 3T of each coir pith compost and wood ash per ha plus PGPR mix1 combined with 60:30:120 kg of NPK per ha recorded higher uptake of nutrients improved tuber yield and quality of coleus.

In coleus biomass partitioning, harvest index, soil and nutrient uptake was improved with organic nutrient scheduling when compared to conventional and integrated practices (John *et al*., (2019).

Field experiment conducted by Iwoh *et al.* (2020) in South Eastern Nigeria revealed that application of agro wastes such as saw dust at 5T/ha and other organic amendments was found effective in enhancing biological, microbial activities in soil and also increased yield of Chinese potato.

b) Effect of N, P and K application on growth parameters and yield of tuber crops

Nitrogen is important nutrient for growth and development of crops without which plants show severe deficiency symptoms. Nitrogen is required for vegetative growth and also for initial plant growth. Geetha (1983) reported that nitrogen had significant effect on plant height, plant spread, number of leaves, and leaf area index whereas varied rates of potash had not much effect on these aspects except at initial stage of coleus. As per the PoP Recommendations 60:60:100 kg/ha of NPK is considered as best for coleus growth and tuberisation (KAU, 2016).

Yong (1970) revealed that NPK in various combinations increased the yield of tuber crops while P and K applications without N decreased yield to considerable low levels.

In a study conducted by Singh *et al.*(1976) on *Dioscore aalata* with four levels of nitrogen and five levels of potash, observed an increase in yield with nitrogen applied at 80 kg/ha and K_2O at 120 kg/ha further increase in N decreased yield.

Application of nitrogen had a significant effect on dry matter production of coleus as it enhanced vegetative growth (Singh and Mandal, 1976).

In cassava, different combinations of NPK application had a significant influence on the tuber initiation as well as on number of tubers per plant (Nair and Aiyer, 1986).

Nair and Mohankumar (1991) reported higher tuber yield in elephant foot yam with fertilizer applied at the rate of N: P_2O_5: K_2O @100: 50: 150 kg/ha.

Phosphorus is an important nutrient element and it is required for much of vital plant functions such as energy transfer, nutrient uptake, protein synthesis, root development. Application of P_2O_5 from 30 to 60 kg/ha did not produce any significant influence on growth characters except Crop Growth Rate (CGR), Net Assimilation Rate (NAR) and tuber bulking rate (TBR)in cassava (Archana, 2001).

A field experiment with different varities of cassava conducted by Agbaje and Akinlosotu (2004) in Nigeria showed that yield was influenced by time of planting than fertilizer application.

Divya (2008) reported that in coleus application of rockdust @ 10 t/ha fortified with FYM had significant effect on plant spread, number of branches per plant and number of tubers per plant. Further leaf chlorophyll content also increased compared to POP recommendation.

According to Ogedegbe *et al.* (2015), application of NPK at the rate of 0 and 100 kg/ha produced similar yields in coleus but it was heavier than those produced with 300 kg NPK per ha. They further stated that seed tuber length had significant effect on yield but NPK didn't have significant effect on yield.

c) Potassium nutrition for tuber crops

Generally potassium is considered as essential for tuber crops due its role in tuber bulking and tuber development. Potassium is an important primary nutrient that is absorbed by the plant in larger quantity after nitrogen. It helps in starch synthesis, translocation, enzyme activation as well as disease resistance altogether contribute towards higher productivity of tuber crops.

Pillai (1967) after conducting field experiment reported that tuber yield increased with K application up to 120 kg/ha in cassava. Howeler (1971) came with conclusion that number of tubers per plant in cassava increased upto 100 kg/ha with K_2O application but beyond these levels depressed the yield. For rapid translocation of nutrients at the later stage of tuberisation and bulking, potash has been identified as the best nutrient when applied in split doses, and it was also found effective in absorption and translocation of nutrients from soil to plant in potato (Shukla and Singh, 1975). Indira and Ramanujam (1987) conducted a study to know the effect of K upon yield attributes of cassava and came up with conclusion that the plants which received K_2O up to 200 kg/ha had significant positive effect on plant height, number of leaves per plant as well as crop growth rate.

Field experiment carried out by Sadanandan and Mohankumar (1989) on taro observed that as application of K_2O at 100 kg/ha had significant effect on LAI and plant height.

Investigation conducted by Nair and Nair (1992) on sweet potato with different levels of potassium (50, 75 and 100 kg/ha) revealed that the levels of K had no significant influence on yield and yield components.

Sud and Grewal (1991) conducted a study in potato and they found that dry matter accumulation increased with application of potassium. The same trend was seen in case of K uptake by shoot. The combined application of potassium and magnesium resulted in the number of main stems, leaf area, total aerial fresh weight and dry weight.

Imas and John (2013) reported that cassava variety 'SreePavithra' performed well under low levels of K.

Bishwoyog and Swarnima (2016) came up with the findings that K application hada significant role in increasing tuber yield of potato that might be either due to formation of large sized tubers or increasing number of tubers per plant by helping in accumulation of carbohydrates. Urbashi *et al.* (2019) came up with the findings that 100 kg/ha of K_2O produced significantly higher leaf area, stem diameter and tuber yield of potato.

d) Magnesium nutrition for tuber crops

Magnesium (Mg) is essential for plant growth and it is one among secondary nutrient that modulates plant functions including the activation of more than 300 plant growth enzymes like ATPases, RNA polymerases, carboxylases, kinases and phosphatases (Mesngel *et al.*, 2001).

Magnesium fertilizes increased yield of most of the crops and the yield inturn varied according to crop species. An increase in yield with 9.4% is reported in tubers. However, Allison *et al.* (2001) revealed that magnesium fertilizer application in potato had no effect on fresh weight of tuber.

Magnesium is very essential for photosynthesis and also for translocation of photosynthates from source to the sink. Experiment conducted in cassava recorded higher tuber yield by $MgSO_4$ application at 20 kg/ha (John *et al*., 2005).

Deficiency of magnesium occurs frequently in acid soils of Kerala. Interveinal chlorosis and distinctive yellowing of lower margins are peculiar symptoms associated with magnesium deficiency. John *et al*. (2006) observed interveinal chlorosis of older leaves of lesser yam especially when it was continuously cultivated in magnesium deficient soils.

Gerendas and Fuhrs (2013) revealed that increasing magnesium supply in potato had positively influenced yield but to a small extent. Further, increasing magnesium resulted in the increase of toxic glycosides concentration in tuber. Application of magnesium had significant effect on tuber yield of cassava (36 t/ha) and the crop removed about 55 kg mg/ha from soil (John, 2016).

Parmoi (2020) came up with the findings that magnesium sulphate application had no direct effect on dry matter production in sweet potato, whereas NPK application and especially K had significant effect on dry matter production. Further higher tuber yield was obtained in treatments that received 40 kg/ha of $MgSO_4$ along with recommended dose of 75:50:75 kg/ha of N: P_2O_5: K_2O.

e) Effect of potassium and magnesium on nutrient uptake

Nutrients are taken up by plants in ionic form and it is essential for metabolic and physiological functioning. Nutrient uptake by plants depend on many factors such as soil nutrient interactions, plant nutrient status, root extension even weather influences. Maintaining a neutral pH would be a better practice for making nutrients in most available form for improving nutrient availability to the plant uptake.

Varis (1973) reported that phosphorus application increased the uptake of N, Ca and Mg as well as nitrogen fertilizers increased the uptake of NPK, Ca and Mg in potato. Nutrient uptake by plants especially cations is seriously influenced by K fertilization. Wild *et al*. (1972) and Tiwari *et al.* (1984) found that uptake of potassium by plants was influenced by potassium concentration in soil solution as well as its interaction with other cations like Ca and Mg.

Nair and Mohankumar (1984) observed that application of K at different levels had significant effect on K uptake in sweet potato.

Nayar *et al.* (1986) found that high yielding varieties of cassava under both irrigated and rainfed conditions absorbed high amounts of K under 100 kg/ha of K_2O application. Potassium deserves a distinct role in the production of tuber crops due to its very high K removal in the harvested produce. Split application of nitrogen and potassium was found effective in elephant foot yam with respect to its growth, dry matter production, tuber yield, N and K uptake when it was applied at the rate of 150 kg/ha each in two splits (Verma *et al.*, 1995).

Sethuraman *et al.* (2020) conducted field experiment in coleus and other major tubers and found that application of potassium and magnesium fertilizers increased the nutrient content in coleus tuber with 12025ppm of potassium and 1347ppm of magnesium which was comparatively higher than other tuber crops. Highest uptake of NPK was observed with a fertilizer application rate of 60:30:120 kg of NPK per ha than the usual recommended dose of 60:60:100 kg/ha.

f) Effect of secondary nutrients on tuber crops

Secondary nutrients such as Ca, Mg, and S play vital role in enhancement of growth and development of tuber crops. In the absence of these nutrients plants develop severe deficiency symptoms like mottling of leaves, necrotic tissues on young leaves, curling leaf margins, leaf chlorosis and so on. Hence, supply of fertilizers in appropriate quantities is a must if it is found limiting in soil. Mohankumar and Nair (1985) came up with the findings that application of sulphur increased the yield, total protein content, starch and also lowered the cyanogenic glucoside content in cassava.

According to Nasreen *et al.* (2003) application of sulphur resulted in least utilization of NPK and very low catalytic activities at all growth stages of potato.

Sud and Sharma (2003) reported that higher yield of potato was obtained from treatments which received calcium application through soil incorporation than which received foliar application.

Talukdar *et al*. (2009) found that application of Magnesium at 10 kg/ha increased tuber yield of potato and the increase was 31% more compared to no magnesium application. Laxminarayana and John (2014), observed highest tuber yield and vine yield from sweet potato by application of Zn at 20 kg/ha and $MgSO_4$ at 30 kg/ha. Further application of 15, 30 and 45 kg/ha of $MgSO_4$ increased the yield up to 7, 11, and 8% respectively in sweet potato.

Nasreen and Salma (2015) found that plant height, fresh weight, dry weight and average tuber yield in potato increased significantly with calcium application.

g) Effect of micronutrients on tuber crops

Micronutrients though required in smaller quantities but it is essential for many plant physiological as well as mechanical processes such as activation of enzymes, flower development, transportation of photosynthates, pollen development, role as catalyst etc.

Application of macro and micro nutrients was found effective in potato in terms of plant height, fresh weight, dry weight and average tuber yield (Chowdhur *et al.*, 2019).

Mohankumar and Nair (1985) reported that application of $ZnSO_4$ @ 12.5 kg/ha improved the quality of tubers by enhancing the starch content and lowering the cyanogenic glucoside content amongst different micronutrients applied.

Byju *et al*. (2007) revealed tuber cracking as a frequent phenomenon due to boron deficiency in sweet potato and application of boron was recommended at the rate of 1.5 kg/ha as method of correction.

The application of different doses of Mg, S, Zn, Bin different combinations in potato observed an increase in plant height, total number of tubers per plant, total tuber yield per plant to be higher in treatments which received sole Mg foliar application (Ramesh *et al.*, 2019).

h) Effect of potassium and magnesium on quality parameters of tuber crops

The application of potassium had positive effect on starch synthesis that increased translocation of synthesized photosynthates in cassava (Mukhopadhyay *et al.*, 1993).

In cassava, John *et al.* (2005) reported that magnesium lowered cyanide content and improved starch content due to the regulatory effect of magnesium on linamarase and starch synthatase enzymes.

Starch and protein tend to increase with increasing levels of potassium in sweet potato (Hathorn *et al*, 2008). Obigbesan (2009) observed that application of potassium fertilizer on cassava increased starch content of cassava tuber to a slight extent.

John *et al.* (2013) revealed that application of potassium lowered cyanogenic glucoside content in cassava also it improved starch content. Furthermore starch quality parameters like amylose content, granule size, pasting temperature, viscosity and swelling volume also increased with increase in K application rates.

In sweet potato combined effect of potassium and magnesium application on sugar content of tuber enhanced with translocation of starch and sugars in the form of sucrose from the leaves to the tubers (Esailyl and Naka, 2013; Laxminarayana and John, 2014). Protein content in coleus tubers didn't vary significantly with the application of organic as well as integrated nutrient management practices but starch content varied significantly with nutrient management (Anju *et al.*, 2017).

Higher amounts of starch, reducing, non-reducing and total sugars percentage as well as K and Mg percentage in potato tubers where noticed when the potato plants received $K_2SO_4$with $MgSO_4$ three times during the growing season **(**Zohiri and Asfour, 2007). Application of magnesium at 20 MgO/fed increased total sugar, reducing sugar and also carbohydrate content of sweet potato tubers (Al-Easailyl and Al-Naka, 2013).

Total amount of sugar and starch content per plant was less in treatments with low potassium and magnesium in potato (Koch *et al*., 2018).

2.2. Potassium and magnesium interaction in soil

Higher concentrations of cations in soil often interfere with nutrient uptake of other cations in plants and this is known as antagonist nutrient interaction in soil. Leonard *et al*. (1948) stated that magnesium deficiency is felt in plants that might have occurred either due to Mg deficiency in soil or presence of high amounts of Ca or K which inhibit Mg uptake by plant. Deficiency of magnesium is felt in sandy soils with application of high amounts of potassium or ammonium fertilizers (Mulder, 1956). However these interactions reduced in soils with more of exchangeable Mg than exchangeable K.

Magnesium sulphate applications depressed the K content of both potato foliage and tubers and the P content of the tubers. Magnesium sulphate sprays increased the K content of potato foliage but depressed the K content of the tubers and K removal by the tubers. Soil or foliar applications of magnesium sulphate had no significant effect on yield, K deficiency symptoms, N, Ca, Mg percentage or removal, Ca/Mg ratio, or sum of the cations (K, Ca, and Mg). These findings are in accordance with the research work of Winston (1966).

Mohankumar *et al*. (1990) stated that potassium-magnesium ratios are more important than available potassium magnesium content in soil.

In a study conducted by Devi and Padmaja (1999) in cassava observed that treatments with full K fertilizer dosage had a decrease in N and P content of shoot as well as absorption of Mg and Ca was affected when compared to other treatments during different stages of growth and was described at antagonism effect between K with Ca and Mg.

2.3. Economics of coleus production

Analysis of cost of cultivation of chinese potato in Thirunelveli district of Tamilnadu by Tavva (2007) revealed that Sreedhara variety gave higher yield and gross income of around ₹ 63,259 per ha with B: C ratio of 1.61.

Application of rock dust in coleus at the rate of 10 t/ha along with equal quantity of FYM and 50 per cent of chemical fertilizers NPK @ 30:30:50 kg/ha resulted in the B: C ratio of 2.63 equivalent to recommended dose B: C ratio of 2.39 (Divya, 2008).

Mostly farmers with low resources go with cultivation of tubers and hence a strategy to reduce over dependency on fertilizers paves the way. Standardizing the fertilizer recommendation has cut shot the cost of cultivation in many tuber crops. Cassava cultivation in Asia with soil fertility management alone had a remarkable increase in net profit (John, 2016).

Rice is the major crop taken up in Odisha but considering the erratic monsoon, cost of inputs plus low market prices make farmers shift to other the cropping system. Sahoo *et al.* (2019) have reported to go with site specific nutrient management in elephant foot yam in the Eastern regions of India to fetch higher prices in farm products also to reduce the higher prices to buy fertilizer.

In tuber crops use of good planting material, cost effective organic manure like the incorporation of green manure crop cowpea, soil test based application of fertilizers then use of effective biofertilizers including major secondary and micro nutrients made a 55% saving in the fertilizer inputs and raised the farm income B: C ratio up to 4.4:1 (John *et al.*, 2020).

Materials and methods

3. MATERIALS AND METHODS

The experiment entitled “Potassium-magnesium interaction in coleus [*Solenostemon rotundifolius*(Poir.) J.K. Morton] productivity” was conducted at College of Agriculture, Kerala Agricultural University, Vellanikkara, Thrissur. Materials and methodology followed for the study are detailed below.

3.1 GENERAL DETAILS

Location

The experiment was conducted at Agronomy farm, Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur located at geographical co-ordinates of 10º31' North latitude and 76º16' East longitude at an altitude of 40.3 m above Mean Sea Level.

Climate and season

The area experiences a tropical humid climate. The mean weekly averages of important meteorological parameters observed during the experimental period are presented in Appendix 1. During the experiment, maximum and minimum temperatures were in a narrow range between 30.2ºC-33.0ºC and 21.9ºC-23.1ºC respectively. The relative humidity varied from 65% to 88% in which maximum humidity was experienced during September and minimum during November. The total rainfall received during entire crop period was 2124.7mm. Highest amount of rainfall was received in the month of August and lowest in December.

Planting was done on July 2020, and harvesting was done during last week of November 2020.

Soil

The soil of the experimental site was well-drained, sandy clay loam and acidic in reaction with a pH of 5.2. The physio-chemical properties of soil are listed in Table 1.

Table 1. Physico-chemical properties of soil before the experiment

Particulars		Value	Method used
1. Physical properties (Particle size composition)			
Coarse sand (%)		31.90	Robinson's International Pipette Method (Piper, 1966)
Fine sand (%)		27.30	
Silt (%)		18.64	
Clay (%)		22.16	
2. Chemical properties			
		Status	
pH	5.2	Acidic	1:2.5 soil water ratio (Jackson, 1958)
Organic carbon (%)	0.88	Medium	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	113	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg/ha)	78	High	Ascorbic acid reduced molybdo phosphoric acid blue colour method (Bray and Kurtz, 1945)
Available K (kg/ha)	256	Medium	Neutral normal ammonium acetate extraction and estimation using flame photometry (Jackson,1958)
Available Ca (mg/kg)	124	Low	Neutral normal ammonium acetate extraction and estimation using Atomic Absorption Spectrophotometer (Jackson,1958)
Available Mg (mg/kg)	63	Low	Neutral normal ammonium acetate extraction and estimation using Absorption Spectrophotometer (Jackson,1958)
Available S (mg/kg)	13	High	Turbidimetric method (Massoumi and Cornfield, 1963)

3.2 EXPERIMENTAL DETAILS

Treatments details

The experiment consisted of twelve treatments which were replicated thrice and experimental design was factorial RBD. Potassium and magnesium sulphate was applied as treatments at different dosage combinations. Potassium (K_2O) was applied @ 60 kg/ha (soil test based), 100 kg/ha (PoP recommendation) and a check (no potassium). Magnesium sulphate doses tried were 0 kg/ha, 10 kg/ha, 20 kg/ha, 40 kg/ha. In addition to this nitrogen, phosphorus, lime, neem cake and FYM was applied as per POP recommendation (KAU POP, 2016). Layout of experiment is depicted in Fig 1.

Coleus variety Nidhi (released from RARS Pattambi) was used in this experiment. It is a clonal selection with duration of 120-130 days with an average yield of 28 t/ha. The tubers are oblong shaped, with good flavor, taste and cooking quality.

Treatment details

Treatments	**Nutrient dose (kg/ha)**
T_1	0 K_2O + 0 $MgSO_4$
T_2	0 K_2O + 10 $MgSO_4$
T_3	0 K_2O + 20 $MgSO_4$
T_4	0 K_2O + 40 $MgSO_4$
T_5	60 K_2O + 0 $MgSO_4$
T_6	60 K_2O + 10 $MgSO_4$
T_7	60 K_2O + 20 $MgSO_4$
T_8	60 K_2O + 40 $MgSO_4$
T_9	100 K_2O + 0 $MgSO_4$
T_{10}	100 K_2O + 10 $MgSO_4$
T_{11}	100 K_2O + 20 $MgSO_4$
T_{12}	100 K_2O + 40 $MgSO_4$

3.3 CULTIVATION PRACTICES

a. Field preparation

The experimental field was tractor ploughed, weeds and stubbles were removed and plots of size 5m x 3m were laid out. In each plot two raised beds of width 60cm were formed, leaving a space of 30cm between each so as to provide good drainage.

b. Application of lime, manures and fertilizers

Lime was added at the rate of 350 kg/ha and farm yard manure was also applied basally at the rate of 10 t/ha as per the 'Package of Practices Recommendations-Crops' of the Kerala Agricultural University (KAU, 2016).

Urea (46 percent N) and Rajphos (18 percent P2O5) were applied as the sources of nitrogen (N) and phosphorus (P) at the rate of 60:60 kg/ha. Half dose of nitrogen and full dose of phosphorus was applied basally. Next half of N was applied after 45 days of the first application. Muriate of potash (60% K_2O) was added as the source of potassium (K) and applied at various doses as per treatments. It was applied in two split doses first as basal dose along with N and P, other half at 45 DAP. $MgSO_4$ was added as source magnesium to treatments as per rates mentioned in treatment details and it was applied as single dose at 30 DAP. The lower dose of $MgSO_4$ @ 10 kg/ha (20 g $MgSO_4$/L) was applied as foliar spray at 30 DAP. $MgSO_4$ @ 20 kg/ha and 40 kg/ha was applied in soil directly.

c. Planting

Vine cuttings of 15 -20cm length were collected from nursery and two rows of vine cuttings were planted in each bed on 28th of July 2020. Gap filling was done two weeks after planting to maintain the optimum plant population.

d. Weeding and earthing up

Three manual weeding were carried out one at 30, 60 and 90 days after planting. Earthing up was done 45 DAP along with top dressing so as to promote tuber development.

e. Irrigation

The crop was irrigated immediately after planting for proper establishment. At later stages irrigation was not done as crop requirement was met through rainfall.

f. Plant protection

Neem cake was applied basally at the rate of 250 kg/ha in order to control root knot nematode.

g. Harvesting

Harvesting of tuber was done after 125 days after planting when aerial parts dried completely. By using spade tubers were dug out carefully. A light irrigation was done prior to harvest to facilitate easy harvesting.

3.4 OBSERVATIONS

Observations on biometric parameters, chlorophyll content, yield and dry matter production of coleus were recorded and the mean values were worked out.

Sampling procedure

For taking observations on growth and yield, five plants were selected at random and tagged from each bed. Destructive sampling was done for leaf area, dry matter estimation and plant analysis.

1. Crop growth observations

a. Plant height

The plant height was measured from collar region at to ground level to the tip of the growing apical bud of vine.

b. Total dry matter production

Dry matter accumulation per vine was recorded at 60, 90 days after planting and at harvest by destructive sampling of random plants (three plants per plot). These plants were uprooted from each plot carefully without damaging the roots and tubers. The plants were dried under shade and then oven dried at 70 ± 5°C, to constant weight. Cut tubers were also dried in the same manner.

The dry weight at harvest stage was found out by adding weights of aerial and underground parts and was expressed in grams per plant. This was multiplied with plant population to get dry matter production and expressed as kg/ha.

c. Leaf area index

Sample plants were uprooted at active vegetative stage (90 DAP). Total number of leaves was counted. The length and breadth of six leaves from each plant were measured and leaf area was calculated by using factor method (Ravi *et al*., 2011). The average leaf area per leaf was multiplied with total number of leaves to get total leaf area per vine (cm^2). The total leaf area was calculated and divided by spacing to get leaf area index.

d. Root to shoot ratio

Plant samples were collected from field and fresh weight of shoot and root was separately recorded at 30 and 60 DAP and the ratio was worked out. At harvest root to shoot ratio was worked on dry weight basis.

2. Leaf chlorophyll content

At active growth phase of the crop growth, leaf samples were taken and chlorophyll was estimated using DMSO method as per Yoshidha *et al.* (1972) and expressed as mg/g fresh weight of leaf.

3. Tuber yield

Total weight of tubers from each plot was recorded to get tuber yield per hectare and was expressed as t/ha.

4. Weight of unmarketable tuber

Very small tubers from each plot were separately collected and weighed and expressed as t/ha.

5. Incidence of pests and diseases

Incidence of pests and diseases during crop period was monitored and timely control measures were adopted.

6.Plant analysis

Uptake of primary and secondary nutrients at harvest

After harvest, plant samples were processed and analyzed for nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The samples were dried to constant weight in an electric hot air oven at 70 ± 5°C, ground into fine powder and used for analyzing N, P, K, Ca, Mg and S contents as per the methods detailed in Table 2. Uptake of nutrients at harvest was calculated by multiplying the values of dry matter production and per cent nutrient content in aerial part and tuber and expressed in kg/ha.

7. Soil analysis

After the harvest of coleus, soil samples were collected from each treatment. It was analyzed for pH, organic carbon, available nitrogen, available phosphorus, available potassium, available calcium, available magnesium and available sulphur as per the standard procedures mentioned in Table 1.

Table 2. Methods used for plant analysis

Nutrients	Method used	Reference
N	Modified micro Kjeldahl method	Jackson, 1958
P	Vanado-molybdo phosphoric yellow colour method	Piper, 1966
K	Flame photometry	
Ca	Neutral normal ammonium acetate using Atomic Absorption Spectrophotometer	
Mg	Neutral normal ammonium acetate using Atomic Absorption Spectrophotometer	
S	Turbidimetric method	Chesnin and Yien,1951

3.5 COST-BENEFIT ANALYSIS

Cost of cultivation was calculated based on the expenditure incurred. The market price of coleus was considered for working out the gross income. Net income was estimated by subtracting cost of cultivation from gross income and expressed in ₹/ha. Benefit-cost ratio was worked out as the ratio of gross income to the total cost of cultivation.

3.6 STATISTICAL ANALYSIS

The data was analyzed statistically by applying the techniques of Analysis of Variance (Gomez and Gomez, 1984). The collected data were analyzed using OPSTAT.

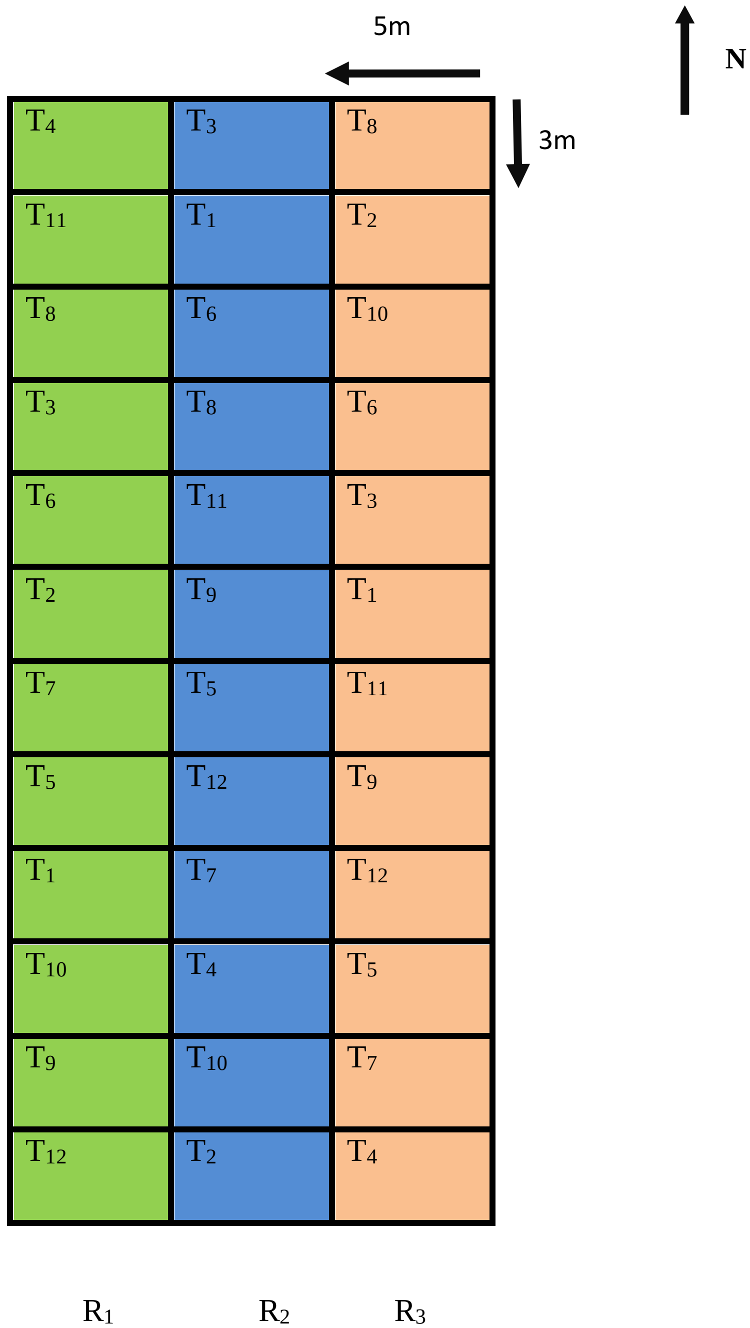


Figure 1. Layout of the field experiment

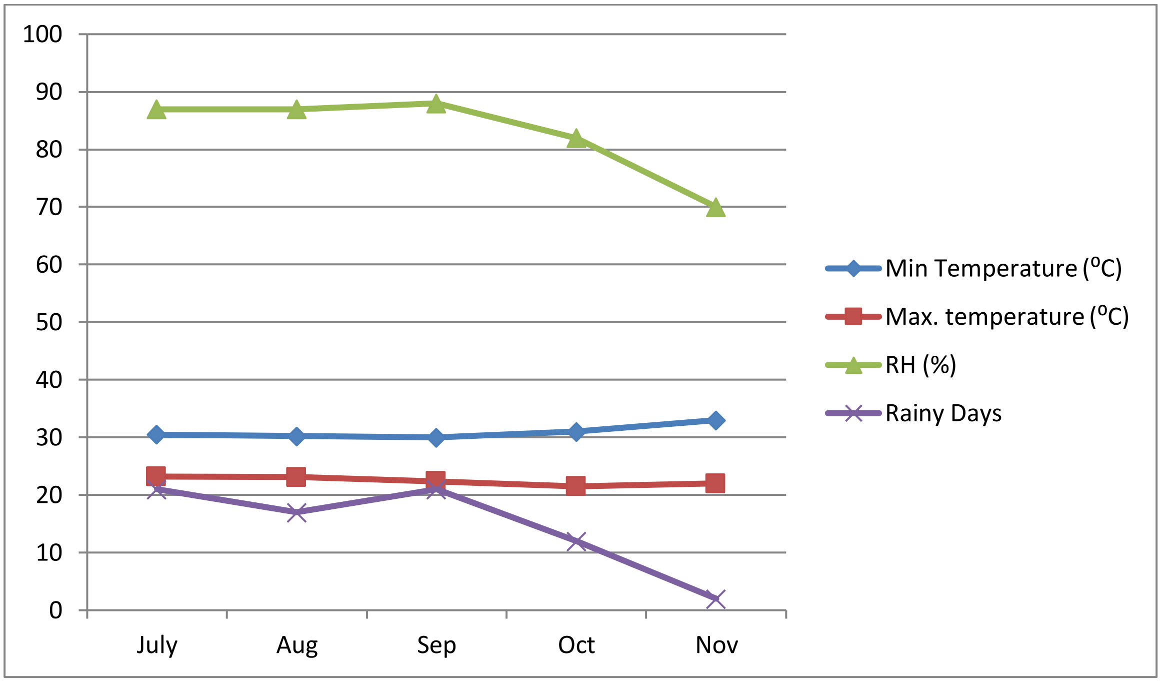


Figure 2. Monthly weather data during experimental period

Plate 1. Layout of field

Plate 2. Planting of vine cuttings

Plate 3.Two weeks after vine emergence

Plate 4. Field visit

Plate 5. Collection of sample for observation at 60 DAP

Plate 6. Crop stage at 90 DAP

Plate 7.Withering of crops (120 DAP)

Plate 8. Harvesting of coleus tubers

Plate 9 : Harvested tubers

Results

4. RESULTS

The results of the experiment entitled “Potassium-magnesium interaction in coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity” conducted at the Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur during July to November 2020 are presented in this chapter after statistical analysis.

4.1 Crop growth parameters

a) Plant height

Plant height of coleus was recorded at 30, 60 and 90 days after planting and data are presented in Table 3.

At 30 DAP, no significant difference in height could be observed with different rates of K_2O and $MgSO_4$ application and the average plant height was 24cm. However, at 60 and 90 DAP treatment effects were significant.

At 60 DAP, plants which received K_2O @ 60 kg/ha and 100 kg/ha registered comparable heights of 49.80cm and 47.75cm respectively and they were superior to plants without K_2O application which registered plant height of 42.50cm. However, at 90 DAP there was a change in trend and maximum plant height was registered under 0 kg/ha of K_2O application (75.91cm). The lowest plant height of 61.33cm was observed at 100kg/ha of K_2O application.

In the case of different rates of $MgSO_4$ application, plants which received dose of 0 kg/ha and 10 kg/ha of $MgSO_4$ registered higher and comparable heights at 60 DAP. The application of 20 kg/ha and 40 kg/ha $MgSO_4$ registered lower values which were also at par. The trend in performance changed by 90 DAP, plants which received 40 kg/ha of $MgSO_4$ registered superior height of 73.77 cm and all others were at par with average plant height of about 68cm.

Interaction of potassium and magnesium sulphate was significant only at 60 DAP. At 60 DAP maximum height was observed in treatment combination of K_2O @ 60 kg/ha with no $MgSO_4$ application and K_2O at 100 kg/ha with $MgSO_4$ @10 kg/ha and they were comparable statistically.

b) Dry matter production of shoot

The data on dry matter production of above ground portion is furnished in Table 5. Dry matter production was significantly influenced by both potassium and magnesium sulphate application at 60, 90 DAP and at harvest. At 60 DAP higher value of dry matter production of 2060 kg/ha was obtained from K_2O application @ 60 kg/ha and least value was observed when no potassium was applied. At 90 DAP similar trend as 60 DAP was observed. At harvest K_2O applied @ 100 kg/ha recorded the highest dry matter when compared to other two levels.

Effect of magnesium sulphate application on dry matter production of coleus was significant at 60 DAP and at harvest. However the trend was not consistent. At 60 DAP higher and comparable dry weight of 2115 kg/ha and 1920 kg/ha was obtained from $MgSO_4$ applied @ 10 kg/ha and 40 kg/ha respectively. Least values of 1151 kg/ha and 1440 kg/ha was obtained from plants which received 0 kg/ha and 20 kg/ha of $MgSO_4$ respectively and they were statistically on par. At 90 DAP the effect of magnesium sulphate application was non significant. At harvest the plants which received higher level of $MgSO_4$ (40 kg/ha) recorded superior value over lower rates.

Interaction effect of potassium and magnesium sulphate was non significant with respect to aerial dry matter production of coleus at 60, 90 DAP and at harvest.

c) Dry matter production of tuber

The data on dry matter production of coleus tubers is furnished in Table 6. Maximum dry weight of 4151 kg/ha was registered from treatment that received K_2O @ 100 kg/ha. Lowest dry matter production of tuber (3097 kg/ha) was recorded from low level of potassium application. Effect of magnesium sulphate application on dry weight of tuber was non significant.

Interaction effect of potassium and magnesium sulphate was significant with respect to dry matter production of tuber. Superior value of 4469 kg/ha and 4463 kg/ha was recorded from K_2O applied @ 100 kg/ha with $MgSO_4$ @ 40 kg/ha and 100 kg/ha of

K_2O with 10 kg/ha of $MgSO_4$ and they were statistically on par. Lowest value of 2573kg/ha was registered from no K_2O with 40 kg/ha of $MgSO_4$ application.

d) Total dry matter production of coleus

Potassium application had significant effect on total dry matter production (Table 6). Highest dry matter production was registered from higher rate of potassium application (100 kg/ha of K_2O). Effect of magnesium sulphate application on total dry weight of coleus was non significant. Interaction effect of potassium and magnesium sulphate was also non significant.

e) Leaf area index

Leaf area index of coleus was recorded at active growth stage and data is presented in Table 8. Different levels of potassium and magnesium sulphate application did not significantly influence LAI of coleus. Interaction effect of potassium and magnesium sulphate was also non significant with respect to LAI of coleus (Table 9).

f) Root to shoot ratio

Data on root to shoot ratio is furnished in Table 10. Root-shoot ratio was worked out at 30 and 60 DAP. Potassium had no significant effect on root to shoot ratio at both 60 and 90 DAP. Similar trend was seen in case magnesium sulphate application. Interaction of potassium and magnesium sulphate was also non significant.

The effect of potassium and magnesium sulphate application on root to shoot ratio at harvest was non significant. The root to shoot ratio at harvest was calculated based on dry weight basis and the ratio ranged between 1.28 to 2.55.

Table 3. Effect of K and $MgSO_4$ on plant height of coleus

Treatment		Plant height (cm)		
		30 DAP	60 DAP	90 DAP
K_2O	0 kg/ha	23.61	42.50	75.91
	60 kg/ha	26.42	49.80	70.75
	100 kg/ha	22.71	47.75	61.33
C.D (0.05)		NS	2.94	3.74
$MgSO_4$	0 kg/ha	22.62	51.11	68.11
	10 kg/ha	24.58	49.56	67.33
	20 kg/ha	25.24	42.16	68.11
	40 kg/ha	24.57	43.88	73.77
C.D (0.05)		NS	3.40	4.32

Table 4. Interaction effect of K and $MgSO_4$ on plant height of coleus at 60 DAP

Treatment	Plant height (cm)			
K_2O	**$MgSO_4$**			
	0 kg/ha	10 kg/ha	20 kg/ha	40 kg/ha
0 kg/ha	45.66	48.16	37.16	39.00
60 kg/ha	57.33	46.86	49.66	45.33
100 kg/ha	50.33	53.66	39.66	47.33
CD (0.05)	5.89			

Table 5. Effect of K and $MgSO_4$ on dry matter production of coleus (shoot)

Treatment		Dry matter production (kg/ha)		
		60 DAP	90 DAP	Harvest
K_2O	0 kg/ha	1366	3253	1600
	60 kg/ha	2060	4220	2100
	100 kg/ha	1813	3487	2266
C.D (0.05)		275	242	290
$MgSO_4$	0 kg/ha	1511	3600	1715
	10 kg/ha	2115	3520	1866
	20 kg/ha	1440	3831	2017
	40 kg/ha	1920	3662	2355
C.D (0.05)		318	NS	335

Table 6. Effect of K and $MgSO_4$ on total and tuber dry matter production of coleus

Treatment		Dry matter production of tuber (kg/ha)	Total dry matter production (kg/ha)
K_2O	0 kg/ha	3,097	4,724
	60 kg/ha	3,680	5,780
	100 kg/ha	4,151	6,376
C.D		345	482
$MgSO_4$	0 kg/ha	3,624	5,376
	10 kg/ha	3,710	5,588
	20 kg/ha	3,610	5,628
	40 kg/ha	3,626	5,915
C.D (0.05)		NS	NS

Table7. Interaction effect of K and $MgSO_4$ on total and tuber dry matter production of coleus

Treatment (K_2O x $MgSO_4$)		Dry matter production tuber (kg/ha)	Total dry matter production (kg/ha)
0 kg/ha	0 kg/ha	3,301	4,607
	10 kg/ha	3,356	4,876
	20 kg/ha	3,160	4,813
	40 kg/ha	2,573	4,599
60 kg/ha	0 kg/ha	3,791	5,737
	10 kg/ha	3,307	5,387
	20 kg/ha	3,779	6,019
	40 kg/ha	3,843	5,976
100 kg/ha	0 kg/ha	3,783	5,783
	10 kg/ha	4,469	6,502
	20 kg/ha	3,891	6,051
	40 kg/ha	4,463	7,169
CD (0.05)		691	NS

Table 8. Effect of K and $MgSO_4$ on LAI and leaf chlorophyll content

Treatment		Leaf area index	Leaf chlorophyll content (mg/g)
K_2O	0 kg/ha	8.46	0.122
	60 kg/ha	11.52	0.157
	100 kg/ha	9.59	0.121
C.D (0.05)		NS	NS
$MgSO_4$	0 kg/ha	10.21	0.129
	10 kg/ha	9.75	0.115
	20 kg/ha	10.31	0.125
	40 kg/ha	9.17	0.123
C.D (0.05)		NS	NS

Table 9. Interaction effect of K and $MgSO_4$ on LAI and leaf chlorophyll content

Treatment (K_2O x $MgSO_4$)		Leaf area index	Leaf chlorophyll content (mg/g)
0 kg/ha	0 kg/ha	9.35	0.113
	10 kg/ha	8.70	0.112
	20 kg/ha	9.17	0.108
	40 kg/ha	10.61	0.122
60 kg/ha	0 kg/ha	12.44	0.126
	10 kg/ha	13.91	0.142
	20 kg/ha	10.65	0.178
	40 kg/ha	9.05	0.157
100 kg/ha	0 kg/ha	8.82	0.103
	10 kg/ha	10.62	0.091
	20 kg/ha	11.09	0.114
	40 kg/ha	7.82	0.121
CD (0.05)		NS	0.032

Table10. Effect of K and $MgSO_4$ on root to shoot ratio

Treatment		Root to shoot ratio (fresh weight basis)		Root to shoot ratio (dry weight basis)
		30 DAP	60 DAP	Harvest
K_2O	0 kg/ha	0.17	0.13	2.02
	60 kg/ha	0.14	0.14	1.77
	100 kg/ha	0.17	0.11	1.89
C.D (0.05)		NS	NS	NS
$MgSO_4$	0 kg/ha	0.15	0.12	2.14
	10 kg/ha	0.18	0.10	2.03
	20 kg/ha	0.17	0.16	1.83
	40 kg/ha	0.15	0.13	1.59
C.D (0.05)		NS	NS	NS

4.2 Leaf chlorophyll content

Leaf chlorophyll content of coleus was estimated at 60 DAP and data are presented in Table 8. Application of different levels of potassium on leaf chlorophyll content of coleus was non significant. Effect of magnesium sulphate application also did not produce any significant variation on chlorophyll content of coleus leaves.

However, interaction effect of potassium and magnesium sulphate was significant (Table 10). Higher value of chlorophyll content in coleus leaves was registered from potassium application at 60kg/ha with 20kg/ha of $MgSO_4$ (0.178 mg/g) which was followed by K_2O applied at 60 kg/ha with $MgSO_4$ @ 40 kg/ha.

4.3 Tuber yield

Data regarding yield of coleus are furnished in Table 11. The tuber yield varied significantly with respect to different levels of potassium application. The highest value of 16.46t/ha was obtained in treatment which received 100 kg/ha of K_2O. Application of K_2O at 60kg/ha resulted in next best yield of 14.94 t/ha. The lowest yield of 13.80 t/ha was registered when no K_2O was applied.

Magnesium sulphate application had no significant effect on tuber yield of coleus. However, interaction of potassium and magnesium sulphate was found to be significant (Table 12). The highest yield was recorded from K_2O applied at 100 kg/ha with $MgSO_4$ at 40 kg/ha and it was on par with K_2O applied @ 100 kg/ha with $MgSO_4$ @ 10kg/ha and K_2O applied @ 60 kg/ha with $MgSO_4$ @ 40 kg/ha. Lowest yield was recorded from K_2O applied at 0kg/ha with $MgSO_4$ at 0kg/ha.

Weight of unmarketable tuber

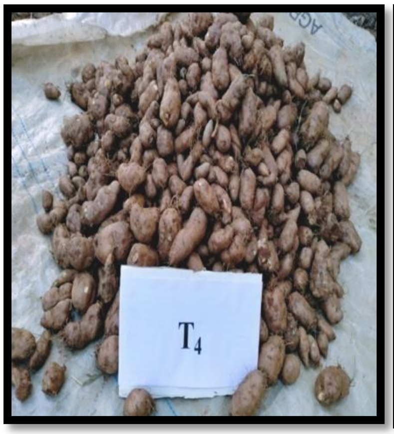
The undersized tubers were separated and weighed; data of the same are furnished in Table 11. Potassium as well as magnesium sulphate had no significant effect on weight of unmarketable tuber. Interaction effect of potassium and magnesium sulphate was also non significant.

Table 11. Effect of K and $MgSO_4$ on tuber yield of coleus

Treatment		Tuber yield (t/ha)	Unmarketable tuber (t/ha)
K_2O	0 kg/ha	13.80	1.61
	60 kg/ha	14.94	1.15
	100 kg/ha	16.46	1.28
C.D		1.11	NS
$MgSO_4$	0 kg/ha	15.02	1.05
	10 kg/ha	16.81	1.32
	20 kg/ha	15.05	1.06
	40 kg/ha	16.64	1.39
C.D		NS	NS

Table 12. Interaction effect of K and $MgSO_4$ on tuber yield of coleus

Treatment (K_2Ox $MgSO_4$)		Marketable tuber yield (t/ha)	Unmarketable tuber yield (t/ha)
0 kg/ha	0 kg/ha	10.71^{f}	0.81
	10 kg/ha	12.64^{ef}	1.93
	20 kg/ha	13.16^{def}	0.96
	40 kg/ha	13.75^{cdef}	0.92
60 kg/ha	0 kg/ha	13.60^{cdef}	1.11
	10 kg/ha	13.78^{cde}	1.02
	20 kg/ha	15.75^{cde}	1.11
	40 kg/ha	16.64^{abc}	1.35
100 kg/ha	0 kg/ha	12.79^{ef}	1.10
	10 kg/ha	19.01^{ab}	1.01
	20 kg/ha	16.21^{bcd}	1.10
	40 kg/ha	19.36^{a}	1.92
CD (0.05)		2.88	NS



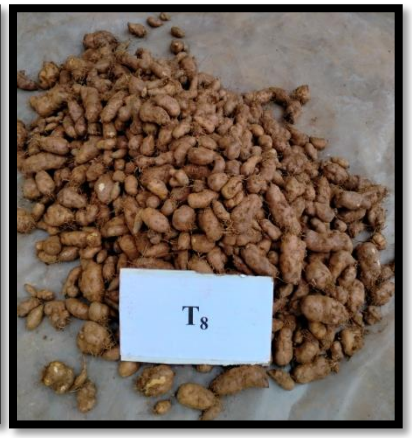


Plate 10. a) K_2O-0 kg/ha b) K_2O-60 kg/ha c) K_2O-100 kg/ha

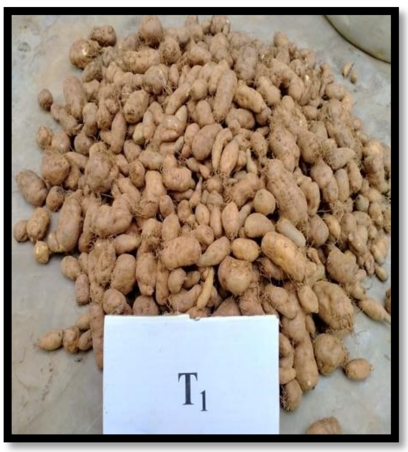


Plate 11.a) $MgSO_4$-0 kg/ha b) $MgSO_4$-10 kg/ha

c) $MgSO_4$-0 kg/ha d) $MgSO_4$-10 kg/ha

4.4 Incidence of pests and diseases

Root knot nematode attack was found in some tubers though as a preventive measure neem cake was applied initially at the time of land preparation. No major pest was observed during the growth period except for some minor leaf eating caterpillars, for which no control measures were necessary.

4.5 Plant uptake of nutrients

a) Primary and secondary nutrient content in coleus

Application of potassium and magnesium sulphate significantly influenced nitrogen content of coleus (Table 13). However, P and K content did not vary significantly. The N content in coleus ranged between 0.09 to 0.43%, P ranged between 0.07 to 0.50 % and K between 0.39 to 1.95%.

Effect of application of potassium and magnesium sulphate was non significant on secondary nutrient content of coleus (Table 14). Ca content ranged from 0.13 to 0.24 %. Mg concentration ranged from 0.29 to 0.62 %. S content ranged from 0.011 to 0.042 %.

b) Primary and secondary nutrient uptake by coleus at harvest

Potassium and magnesium sulphate application on uptake of primary nutrient was non significant except for K (Table 15). Nitrogen uptake of coleus ranged between 21.51 to 33.08kg/ha. Phosphorus uptake ranged between 18.20 to 31.17kg/ha and potassium uptake ranged between 76.53 to 132.40 kg/ha. Highest K uptake was observed when K_2O was applied at 60 kg/ha with $MgSO_4$ at 40 kg/ha which was on par with K_2O applied at 100 kg/ha with $MgSO_4$ at 10 kg/ha and K_2O applied at 100 kg/ha with $MgSO_4$ at 40 kg/ha.

The effect of potassium and magnesium sulphate application on secondary nutrient uptake by coleus was non significant (Table 16). Calcium uptake ranged between 1.77 to 5.16 kg/ha. Mg uptake by plants ranged between 0.62 to 1.41 kg/ha and S uptake ranged between 1.39 to 2.67 kg/ha.

Table 13. Primary nutrient content in coleus shoots

Treatment (K_2O x $MgSO_4$)		Nutrient content(%)		
		N	P	K
0 kg/ha	0 kg/ha	0.37	0.18	0.78
	10 kg/ha	0.35	0.26	0.88
	20 kg/ha	0.25	0.20	0.69
	40 kg/ha	0.33	0.20	1.50
60 kg/ha	0 kg/ha	0.09	0.50	1.30
	10 kg/ha	0.21	0.23	0.62
	20 kg/ha	0.25	0.35	1.95
	40 kg/ha	0.18	0.17	0.93
100 kg/ha	0 kg/ha	0.28	0.07	0.61
	10 kg/ha	0.43	0.13	0.90
	20 kg/ha	0.21	0.19	0.52
	40 kg/ha	0.31	0.21	0.39
C.D (0.05)		0.13	NS	NS

Table 14. Secondary nutrient content in coleus shoots

Treatment (K_2O x $MgSO_4$)		Nutrient content (%)		
		Ca	Mg	S
0 kg/ha	0 kg/ha	0.13	0.47	0.014
	10 kg/ha	0.19	0.48	0.015
	20 kg/ha	0.23	0.61	0.026
	40 kg/ha	0.15	0.50	0.024
60 kg/ha	0 kg/ha	0.14	0.29	0.018
	10 kg/ha	0.24	0.68	0.029
	20 kg/ha	0.13	0.34	0.016
	40 kg/ha	0.19	0.60	0.042
100 kg/ha	0 kg/ha	0.17	0.50	0.011
	10 kg/ha	0.23	0.55	0.019
	20 kg/ha	0.21	0.62	0.030
	40 kg/ha	0.13	0.50	0.020
C.D (0.05)		NS	NS	NS

Table 15. Effect of K and $MgSO_4$ on uptake of primary nutrients by coleus at harvest

Treatment (K_2O x $MgSO_4$)		Nutrient uptake (kg/ha)		
		N	P	K
0 kg/ha	0 kg/ha	24.65	22.54	87.43
	10 kg/ha	25.22	24.54	92.82
	20 kg/ha	22.98	21.16	87.42
	40 kg/ha	21.51	18.20	76.53
60 kg/ha	0 kg/ha	26.63	26.28	104.32
	10 kg/ha	24.61	23.72	89.02
	20 kg/ha	28.40	26.09	112.26
	40 kg/ha	31.40	30.90	132.62
100 kg/ha	0 kg/ha	23.65	20.32	84.40
	10 kg/ha	32.55	31.06	128.37
	20 kg/ha	27.29	26.77	104.78
	40 kg/ha	33.08	31.17	128.17
C.D (0.05)		NS	NS	22.04

Table 16. Effect of K and $MgSO_4$ on uptake of secondary nutrients by coleus at harvest

Treatment (K_2O x $MgSO_4$)		Ca (kg/ha)	Mg (kg/ha)	S (kg/ha)
0	0	1.77	0.62	1.64
	10	2.96	0.72	1.59
	20	3.96	1.02	1.40
	40	3.15	0.99	1.39
60 kg/ha	0	2.81	0.62	2.62
	10	5.16	0.72	1.69
	20	3.00	1.02	2.19
	40	4.17	0.99	2.67
100	0	3.53	1.03	1.45
	10	4.76	1.19	2.23
	20	4.76	1.41	2.03
	40	3.68	1.35	2.67
CD (0.05)		NS	NS	NS

4.6 Soil nutrient status

The data on pH, EC and soil chemical properties of soil after harvest is furnished in Table 17. The pH of soil in varied between 5.03 and 5.49. The EC of soil ranged between 0.501ds/m and 0.564ds/m. Organic carbon was 1.27 % on an average. There was a decrease in pH and EC an increase in OC as compared to initial soil status.

Primary nutrient status of soil

The analysis of soil after harvest of the crop indicated that the application of potassium and magnesium did not influence on primary nutrient status of soil. The average Available NPK content of soil was 81.4, 75.16 and 264.58 kg/ha respectively.

Secondary nutrient status of soil

Secondary nutrient status of soil did not show significant variation. Available Ca in soil ranged between 314mg/kg to 431mg/kg. Available Mg in soil ranged between 32 to 98 mg/kg. Available S ranged between 11 to 28 mg/kg. The values were higher compared to initial nutrient status.

Table 17. pH, EC and organic carbon content of soil after harvest of coleus

Treatment		pH	EC (ds/m)	Organic carbon (%)
K_2O	0 kg/ha	5.30	0.527	1.25
	60 kg/ha	5.24	0.533	1.31
	100 kg/ha	5.07	0.557	1.25
$MgSO_4$	0 kg/ha	5.49	0.564	1.26
	10 kg/ha	5.21	0.563	1.24
	20 kg/ha	5.08	0.526	1.43
	40 kg/ha	5.03	0.501	1.16
Initial value		5.20	0.600	0.88

Table 18. Primary nutrients status of soil after harvest of coleus

Treatment (K_2O x $MgSO_4$)		Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
0 kg/ha	0	75	96	263
	10	107	92	256
	20	78	55	312
	40	91	79	218
60 kg/ha	0	95	91	243
	10	69	54	286
	20	77	82	289
	40	75	71	235
100 kg/ha	0	79	50	278
	10	77	76	261
	20	76	75	278
	40	78	81	256
0CD (0.05)		NS	NS	NS
Initial status		113	78	256

Table 19. Secondary nutrient status of soil after harvest

Treatment (K_2O x $MgSO_4$)		Available Ca (mg/kg)	Available Mg (mg/kg)	Available S (mg/kg)
0kg/ha	0	415	98	23
	10	423	73	16
	20	324	83	25
	40	314	82	28
60 kg/ha	0	326	73	23
	10	362	46	16
	20	426	75	11
	40	412	54	15
100kg/ha	0	389	57	18
	10	365	32	26
	20	431	52	25
	40	413	35	21
CD (0.05)		NS	NS	NS
Initial status		124	27	13

4.7 Cost benefit ratio

Tuber yield of coleus on potassium and magnesium sulphate application ranged between 10.71-19.36 t/ha.

The cost of cultivation in coleus ranged from ₹1,37,080 to ₹1,52,174. Low cost of cultivation was incurred for treatment that received low rate of fertilizer application and expenditure increased upon increasing rates of fertilizer dose. High cost of cultivation was incurred in treatment that received high amounts of both potassium and magnesium sulphate application. Rest of the input cost involved like labour charge, FYM, lime application, planting material cost was same in all treatments.

The maximum gross returns was obtained from treatment that received high rate application of both potassium and magnesium sulphate. The lowest returns were obtained from treatment combination that which received no potassium as well as $MgSO_4$application due to lowest tuber yield.

Net returns was calculated after deducting cost of cultivation from gross returns and it turned out to be the highest (4,28,626 ₹/ha) in treatment combination which received 100 kg/ha of K_2O with 40 kg/ha of $MgSO_4$. The lowest net returns (1,84,520 ₹/ha) as well as B:C ratio was registered in treatment combination of no K_2O and no $MgSO_4$ application.

Benefit cost ratio was worked out to know the profitability of project undertaken. B: C ratio in the experiment ranged between 2.3 to 3.8 (Table 20). Maximum yield was obtained from higher rates of potassium and magnesium sulphate application, higher B:C ratio of 3.8 was obtained from 100 kg/ha K_2O of potassium applied along with 40 kg/ha of $MgSO_4$ and also from 100 kg/ha of K_2O with 10 kg/ha of $MgSO_4$. Lowest B:C ratio of 2.3was obtained from K_2O applied @ 0 kg/ha with $MgSO_4$ @ 0 kg/ha and 100 kg/ha of K_2O with 0 kg/ha of $MgSO_4$ application.

Table 20.Cost benefit analysis in coleus

Treatments	Yield (t/ha)	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio
0 kg/ha K_2O					
0 kg/ha $MgSO_4$	10.71	1,37,080	3,21,600	1,84,520	2.3
10 kg/ha $MgSO_4$	12.64	1,43,830	3,79,200	2,53,370	2.6
20 kg/ha $MgSO_4$	13.16	1,44,928	3,94,800	2,49,872	2.7
40 kg/ha $MgSO_4$	13.75	1,47,124	4,12,500	2,65,379	2.8
60 kg/ha K_2O					
0 kg/ha $MgSO_4$	13.60	1,46,516	4,08,000	2,61,484	2.7
10 kg/ha $MgSO_4$	13.78	1,47,614	4,13,400	2,65,786	2.8
20 kg/ha $MgSO_4$	15.75	1,48,908	4,72,500	3,23,592	3.1
40 kg/ha $MgSO_4$	16.64	1,50,908	4,99,200	3,48,292	3.3
100 kg/ha K_2O					
0 kg/ha $MgSO_4$	12.79	1,47,782	3,41,700	1,93,918	2.3
10 kg/ha $MgSO_4$	19.01	1,48,880	5,70,300	4,21,420	3.8
20 kg/ha $MgSO_4$	16.21	1,49,978	4,86,300	3,36,322	3.2
40 kg/ha $MgSO_4$	19.36	1,52,174	5,80,800	4,28,626	3.8

Discussion

5. DISCUSSION

The results of the experiment entitled "Potassium and magnesium interaction in coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity" are discussed in this chapter with relevant scientific literature.

There were 12 treatments in the experiment which consisted of varied dosage combinations of potassium and magnesium sulphate. Potassium was applied at three rates (0, 60 and 100 kg/ha) and magnesium sulphate at four rates (0, 10, 20, and 40 kg/ha). First four treatments (T_1 to T_4) received no K_2O application, but varied rates of magnesium sulphate from 0-40 kg/ha (T_1-0, T_2-10, T_3-20, T_4-40). The soil of the experiment site was medium in potassium and hence soil test based K_2O of 60 kg/ha was applied in T_5 to $T_8$with varied dosage of magnesium sulphate (T_5-0, T_6-10, T_7-20, T_8-40), andT_9 to T_{12} received of 100 kg/ha K_2O (PoP recommendation) with varied rates of magnesium sulphate from 0 to 40 kg/ha (T_9-0, T_{10}-10, T_{11}-20, T_{12}-40). Nitrogen and $P_2O_5$was applied uniformly in all treatments at the rate of 60:60 kg/ha as per Package of Practices Recommendation (KAU, 2016). The magnesium content in soil was low and varied doses of magnesium sulphate were applied to assess the response of the magnesium nutrition.

5.1 EFFECT OF POTASSIUM AND MAGNESIUM SULPHATE ON GROWTH PARAMETERS OF COLEUS

Potassium application had no significant effect on plant height at 30 DAP. However, at 60 and 90 DAP treatment differences were significant with respect to different levels of potassium application. This might be probably due to the reason that basal application of potassium had not shown any immediate effect on plant height. Also, K_2O at 60kg/ha and 100kg/ha was applied in two splits, one as basal and the other half at 45 DAP and thus it would have not shown any effect at 30 DAP. It was seen that by 45 and 60 DAP, application of K_2O at 60 and 100 kg/ha resulted in taller plants. A positive influence of potassium on crop growth parameters was reported by Ramanujam and

Indira (1987) in cassava. However, at 90 DAP lowest height of 61.33cm was observed at higher rate of K_2O application (100 kg/ha) and it differed significantly from others. This might be due to partitioning of photosynthates to underground parts as potassium has got a major role in starch synthesis and translocation.

Islam *et al*., (2014) reported that plant height of potato decreased at later stages of growth with increasing levels of potassium application. However, Geetha and Madhavan (1993) reported that application of potassium at 120 kg/ha had not shown much effect on plant height of coleus.

Effect of magnesium sulphate on plant height was non significant at 30 DAP as this nutrient was applied only at 30 days. Magnesium sulphate application significantly influenced plant height of coleus at 60 DAP and 90 DAP. At 60 DAP magnesium sulphate applied at the rate of0 and 10 kg/ha registered maximum height of 51.11cm and 49.56cm respectively they were on par as well magnesium sulphate applied at the rates 20 kg/ha and 40 kg/ha registered lower plant height and they were also at par. At 90 DAP a change in trend was observed with $MgSO_4$ application maximum height was registered from $MgSO_4$ application @ 40 kg/ha. Hermans *et al.* (2004) reported that magnesium deficiency in sugarbeet crop was found to reduce growth severely and it also affected root to shoot ratio. He further stated that magnesium deficiency severely reduced the aerial growth towards the end of crop stage over absolute control. In sweet potato no response to applied magnesium sulphate was observed at the rate of 40 to 100 kg/ha with respect to vine length (Nengparmoi, 2020).

Interaction effect of potassium and magnesium sulphate application was significant only at 60 DAP (Figure 1). Maximum plant height was noticed in treatment combination that received 60 kg/ha of K_2O with 0 kg/ha $MgSO_4$ (57.33cm) which was on par with K_2O applied @ 100 kg/ha with $MgSO_4$ @ 10 kg/ha 53.66cm. It is reported that application of magnesium and potassium exhibit mostly antagonistic interaction effect and hence magnesium and potassium fertilizer should not be applied together. Lower dose of magnesium sulphate application with higher dose of application of potassium was found to be best for the coleus growth at later stages of growth. Because of the antagonistic interactions of K^+ and Mg^{2+} in the process of absorption and, translocation, plants need to maintain a homeostatic balance between K^+ and Mg^{2+} in response to changing nutrient status in the soil for optimal growth and development (Rietra *et al*., 2015). Higher concentration of cations in soil often inhibit nutrient uptake by plants this is known as antagonistic nutrient interaction in soil. Leonardo *et al*., (1948) stated that magnesium deficiency is felt in plants that might have occurred either due to Mg deficiency in soil or presence of high amounts of Ca or K which inhibit Mg uptake by plant roots. Deficiency of magnesium is felt in sandy soils with application of high amounts of potassium or ammounium fertilizers (Mulder, 1956).

Plant growth and yield depend on leaf area as well as the total vegetative growth put forth by plants to a greater extent. Observation on LAI suggests that both potassium and magnesium sulphate application did not bring about much variation in leaf area index of coleus. N is a major nutrient supporting vegetative growth and all treatments received uniform quantity of N @ 60 kg/ha that might have led to comparable vegetative growth and LAI. The value of LAI ranged between 7.82 to 13.91(Table. 10, Figure 5).As coleus crop has a bushy growth habit with dense canopy at peak stage of vegetative growth and the total leaf area index was higher compared to other crops. Mohankumar and Sadanandan (1989) reported that potassium application in *Colocasia esculenta* brought a positive influence on leaf area index. Neenu and Sudarmaidevi (2012) found that potassium application @ 100 kg/ha resulted in higher number of functional leaves and LAI compared lower levels of potassium stating potassium had significantly influenced the growth parameters of coleus. Nengparmoi (2020) observed that leaf area index of sweet potato was the highest in treatment that received magnesium sulphate application at the rate of 60 kg/ha combined with $N:P_2O_5:K_2O$ applied at the rate of 75:50:75 kg/ha.

Though dry matter production is an important growth parameter, in the case of tuber crops it may not reflect economic yield as tuber yield is decided not only by the total photosynthates produced but also its translocation from the source (aerial portion) to sink (tubers). But dry matter accumulation during the early stages of growth is essential for better yield and productivity. Dry matter production increased during early stages of coleus growth and it showed a decline at 120 DAP indicating starch translocation to the tubers. Opaleye *et al*. (2018) conducted study on different accessions of coleus and found that total dry matter production increased up to 126 DAP then it decreased reaching towards maturity.

At 60 DAP higher dry matter production was noticed by K_2O application @ 60 kg/ha and 100 kg/ha and lowest at 0 kg/ha (Table 3, Figure 3). At 90 DAP maximum shoot growth was observed in treatments which received potassium @ 60 kg/ha (4220 kg/ha) which was followed by potassium 100 kg/ha showing similar trend as that of at 60 DAP. At harvest K_2O applied @ 100 kg/ha recorded the highest dry matter when compared to the other two levels. This may be due potassium having role in nutrient uptake and translocation that has increased the dry matter production of coleus at the initial stages of growth and at later stages of translocation of photo assimilates to the tubers. Enyi (1972) in a study conducted in *Dioscorea esculenta* found a positive influence of potassium on tuber yield and stated that it had greater leaf area and leaf duration that enhanced transfer of assimilates for tuberision. However contradictory to the result obtained potassium application didn't significantly increase vegetative growth and the tuber production in potato (Laughling 1966). But similar to the results obtained with potassium application there was a positive influence on dry matter production of in cassava and it lead to increase the shoot growth compared to lower levels of application (John, 2016).

A good soil condition with adequate amount of fertilizer application is required for better yield and production. Effect of magnesium sulphate application on dry matter production of coleus was significant at 60, 90 DAP and at harvest (Table 5), but a definite trend couldn't be observed. At 60 DAP higher dry weight of 2115 kg/ha was obtained from $MgSO_4$ applied @ 10kg/ha. Least values of 1151kg/ha and 1440 kg/ha was obtained from plants which received 0kg/ha and 20kg/ha of $MgSO_4$ respectively and they were statistically on par. At 90 DAP the effect of magnesium sulphate application was non significant. At harvest the plants which received higher levels of $MgSO_4$ (40 kg/ha) recorded superior value over lower rates. Interaction effect of potassium and magnesium sulphate was non significant with respect to shoot dry matter production of coleus at 60, 90 DAP and at harvest.

Dry matter production of tuber was significantly influenced by potassium application. Maximum dry weight of coleus tuber was registered from potassium application @ 100 kg/ha and this was followed by potassium application at 60 kg/ha (Figure 4). Skipping K_2Oapplication resulted in the lowest tuber dry weight and a similar trend as noticed in tuber yield and total dry matter production. Total dry matter produced by coleus was also highest in 100 kg/ha of K_2O application and it was followed by potassium application at 60 kg/ha (Table 7). This may be due to role of potassium role in tuber bulking and development. Bourke (1985) reported that potash fertilizer application had increased tuber yield, total plant dry weight, as well as harvest index in sweet potato. Ghuman and Lal (1973) also found that potassium fertilizer increased the tubers numbers in sweet potato.

Magnesium sulphate application had no significant effect on dry matter produced of coleus tuber as well as on total dry matter production. However, interaction effect of potassium and magnesium sulphate application influenced dry matter production of tuber. Superior value of 4469 kg/ha and 4463 kg/ha was recorded from K_2O applied @ 100 kg/ha with $MgSO_4$ @ 40kg/ha and 100 kg/ha of K_2O with 10 kg/ha of $MgSO_4$ and they were statistically on par. Lowest value of 2573 kg/ha was registered from no K_2O with 40kg/ha of $MgSO_4$ application. Nengparmoi (2020) reported that magnesium sulphate applied had not shown much responses dry matter production of tuber.

Root to shoot ratio indicate the efficiency of translocation and partitioning of photosynthates to underground parts. Application of potassium and magnesium sulphate didn’t influence root to shoot ratio of coleus neither at 30 days nor at 60 days. This might be due to the fact that in coleus tuberisation was not started by 60 DAP. Also coleus is a very short duration tuber crop and probably the requirement of secondary nutrient may be low. Hahn (1977) reported that application of high level of potassium increased leaf area duration and suppressed leaf growth in sweet potato that resulted in higher root yield and increased root to shoot ratio. John *et al*. (2015) reported that application of K_2O at the rate of 200 kg/ha increased root to shoot ratio of cassava.

5.2 EFFECT OF POTASSIUM AND MAGNESIUM SULPHATE ON TUBER YIELD

The tuber yield varied significantly with respect to different levels of potassium application (Figure 6). The highest yield of 16.46t/ha was obtained in treatment which received 100 kg/ha of K_2O which was 19% higher than no potassium application. Soil test based application of K_2O (60kg/ha) resulted in next best yield of 14.08 t/ha and it was only 8% higher compared to control. The tuber yield was 13.80 t/ha when no potassium was applied. This indicate that a blanket dose of 100 kg/ha is essential to attain higher productivity. This higher requirement may be probably due low efficiency of potash fertilizers together with very short duration of this tuber crop. Potassium is a nutrient having major role in starch synthesis and translocation and it is very important in tuber crop nutrition. Mohankumar *et al*. (2000) suggested fertilizer rates for the production of different tuber crops and for coleus it was 80:60:80 kg of NPK per ha along with wood ash @ 1.1-2.2 t/ha. Howeler and Cadavid (1990) noticed low yield in cassava when no potassium was applied and further increase in yield was noticed when K_2O applied at 150 kg/ha. Application of K_2O at the rate of 120 kg/ha had yielded highest tuber yield in coleus (Geetha and Madhavan, 1993).

Carsky and Toukourou (2005) came up with positive results of potassium application on tuber weight of cassava. Imas and John (2013) also reported increase in yield with respect to potassium application. Similar results were seen in cassava by Muthuswamy and Rao (2013).Study conducted by Ogedegbe *et al.,* 2015 in coleus found that application of potassium at 100 kg/ha yielded tubers of higher fresh weight. Similar to the results K_2O application at 300 kg/ha produced maximum tuber weight of 1.14 kg per plant and tuber yield of 49.38 t/ha in coleus.

Magnesium sulphate application didn't influence tuber yield of coleus unlike potassium application. The tuber yield varied from 15.02 t/ha to 16.64 t/ha in no $MgSO_4$ application to 40 kg/ha. Though the soil was low in magnesium status the crop response to magnesium application was poor. This may be probably due to the short duration of coleus and the requirement of magnesium may be low and soil status was enough to meet the crop requirement. Also the efficiency of applied magnesium may be poor as $MgSO_4$ is a highly soluble fertilizer. The high rainfall might have resulted in leaching losses and less absorption. Putz *et al*., (1976) reported that application of magnesium in potato had increased tuber yield by 10 per cent. He also stated that magnesium is required in adequate amounts for tuber bulking and if soil is deficient in magnesium foliar application will be beneficial. Talukdarv *et al*. (2009) also found that foliar application of 10 kg/ha of $MgSO_4$ increased yield in potato and this was on par with 15 and 20 kg/ha of $MgSO_4$ but increasing further dosage tend to decrease tuber yield. Similar to this result obtained long term fertilizer experiment conducted by John *et al*., (2015) in cassava reported that $MgSO_4$ application at 20 kg/ha positively influenced tuber yield. Generally application of magnesium fertilizers increased yield of most of the tuber crops by 9.4% yield in turn varied depending on crop sp (Wang *et al*., 2020).

However, interaction of potassium and magnesium sulphate was found to be significant. The highest yield was recorded from K_2O applied at 100 kg/ha with $MgSO_4$ at 10 kg/ha and 40 kg/ha and followed by K_2O applied @ 60 kg/ha with $MgSO_4$ @ 40 kg/ha. Lowest yield was recorded from K_2O applied at 0 kg/ha with $MgSO_4$ at 0 kg/ha. The comparable yield at $MgSO_4$ 10 kg and 40 kg might have resulted from better absorption of Mg through foliar application when low dose was applied. $MgSO_4$ 10 kg was supplied as foliar spray of 2 % solution at 30 DAP whereas 20 kg/ha and 40 kg/ha was applied in soil directly.

5.3 EFFECT OF POTASSIUM AND MAGNESIUM SULPHATE APPLICATION ON NUTRIENT UPTAKE OF COLEUS

In agricultural production system, the availability of nutrients is a critical factor and it can vary with factors such as soil texture, CEC, climate, management factors etc. N content in coleus shoot had not shown significant variation with potassium and magnesium sulphate application. N content in coleus shoot ranged between 0.09 to 0.53%. N content was highest in treatment combination that received 100 kg/ha of K_2O with 10 kg/ha of $MgSO_4$. N content in tubers were higher than shoot with an average value of 0.56%. Nitrogen uptake by coleus ranged between 21 kg/ha to 33.08 kg/ha. Increase in yield and total nitrogen uptake was reported by Aulakh and Malhi (2005) upon potassium application in cassava. Potassium has increased availability of nitrogen due to suppressing of N fixation and making it more available in soil. In cassava synergistic interaction between N and K was observed by Rani (2000).

Phosphorus was applied at the rate of 60 kg/ha in one split dose as per Package of Practices for Crops Recommendation (KAU, 2016).Potassium and magnesium sulphate application did not cause much variation in P uptake by coleus. Phosphorus content in coleus shoot ranged between 0.07 to 0.26% and it was 0.46% in tuber. P uptake in coleus ranged between 18.20 to 31.17 kg/ha.

K content in tuber (2.83%) was higher than those in shoot. K uptake in coleus ranged between 84 to 132 kg/ha. Potassium uptake was highest in treatment that received 60 kg/ha of K_2O with 40 kg/ha of $MgSO_4$which was on par with100 kg/ha K_2O application at 40 kg/ha and10 kg/ha $MgSO_4$ (Table 16, Figure 8). Calcium content in coleus was in a narrow range between 0.13 to 0.24 %. Calcium uptake by coleus ranged between 1.77 to 5.16 kg/ha.

As magnesium is highly mobile (Mg^{2+}), it is amenable to leaching loses due to high solubility. Soil acidity is also another factor and this will also reduce nutrient use efficiency. Mg concentration ranged from 0.29 to 0.62 %. And Mg uptake by plants ranged between 0.62 to1.35 kg/ha. Not much variation was found in Mg uptake by coleus, however Mg uptake exhibited a decreasing trend upon increasing potassium fertilizer level. This could be due to antagonistic nutrient interaction of potassium and magnesium in soil. Increasing potassium solution concentration in soil reduced calcium as well as magnesium uptake in cassava (Spear *et al.*, 1978). Sulphur content in shoot ranged between 0.011 to 0.042% and the Sulphur uptake by coleus ranged between 1.40-2.67 kg/ha.

The analysis of soil after harvest of the crop indicated that the application of potassium and magnesium did not influence on primary nutrient status of soil. The average available NPK content of soil was 81, 75, 264 kg/ha respectively and the initial status in soil was 113, 78 and 256 kg/ha. Initial secondary nutrient status of soil was available Ca-124 mg/kg, available Mg-27 mg/kg, available S-13 mg/kg. Available Ca in soil after harvest ranged between 314 mg/kg to 431 mg/kg, Available Mg was in a range between 32-98 mg/kg and Available S ranged between 11-28 mg/kg.

ECONOMICS

The cost incurred in adopting technology was worked out after estimating cost of cultivation, gross returns and net returns. Cost of cultivation ranged between Rs.1,37,080 to1,52,174 and highest cost of cultivation was incurred for higher dose of fertilizer application. Higher cost of cultivation was incurred in treatment with potassium applied @ 100 kg/ha with $MgSO_4$ @ 40 kg/ha, but it had the highest net return of Rs 4,28,626 per ha. This was closely followed by potassium applied at 100 kg/ha with $MgSO_4$ @ 10kg/ha. Gross returns ranged between Rs.3,21,600 to 5,80,800. Highest gross returns was obtained from treatment that received 100 kg/ha of K_2O with40 kg/ha of magnesium sulphate application.

Net returns was lowest when no potassium was applied and $MgSO_4$ @ 40 kg/ha with a net returns of 1.74 lakhs which had lowest yield and also lowest BC ratio of 2.18. The BC ratio ranged between 2.1 to 3.8 (Table 20). The highest BC ratio was for the potassium application at 100 kg/ha with $MgSO_4$ at 10 kg/ha followed by potassium at 100 kg/ha with $MgSO_4$ 40 kg/ha. Though highest net returns was obtained from 100 kg/ha of K_2O with 40 kg/ha of $MgSO_4$ while highest BC ratio of 3.8 was obtained from treatment that received potassium @ 100 kg/ha and $MgSO_4$ @ 10 kg/ha.

The data on net returns and BC ratio indicate that profitability of coleus cultivation can be enhanced with application of blanket dose of 100 kg K_2O/ ha along with 40 kg $MgSO_4$as soil application. Instead of soil application $MgSO_4$ can be supplied as foliar spray also @10 kg/ha and in such case 2 % spray of $MgSO_4$ can be recommended.

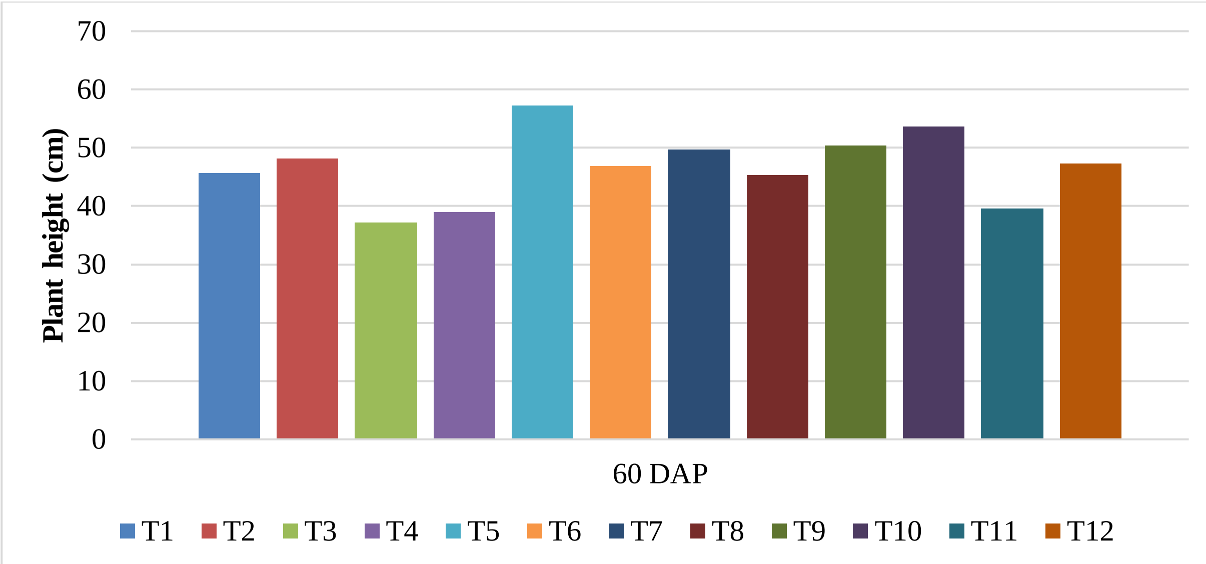


Figure 3. Interaction effect of K_2O and $MgSO_4$ application on plant height at 60 DAP

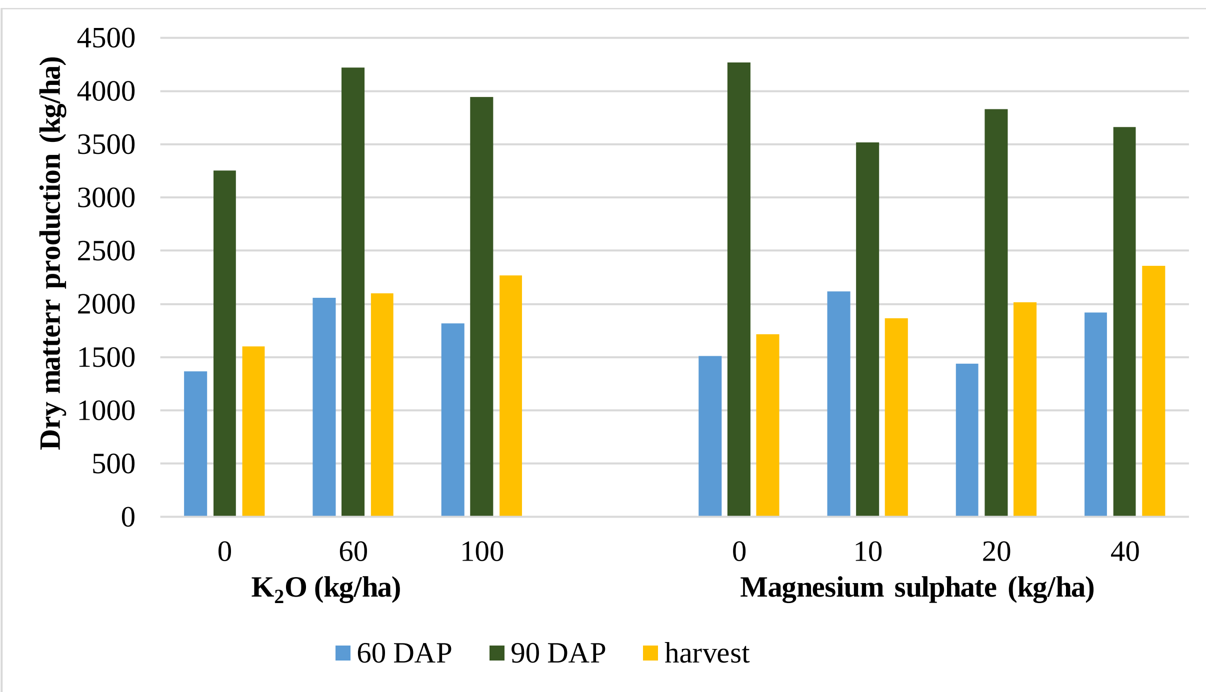


Figure 4. Dry matter production of shoot as influenced by K_2O and $MgSO_4$ application

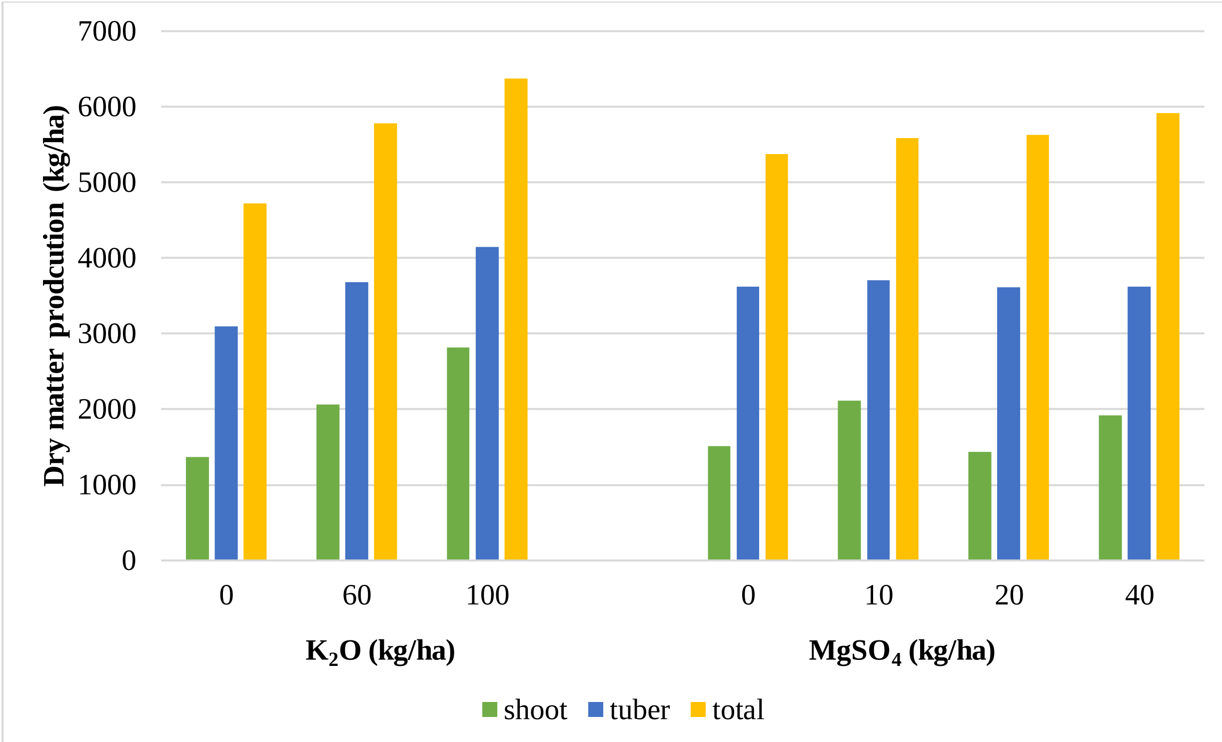


Figure 5. Effect of K_2O and $MgSO_4$ on dry matter production of coleus

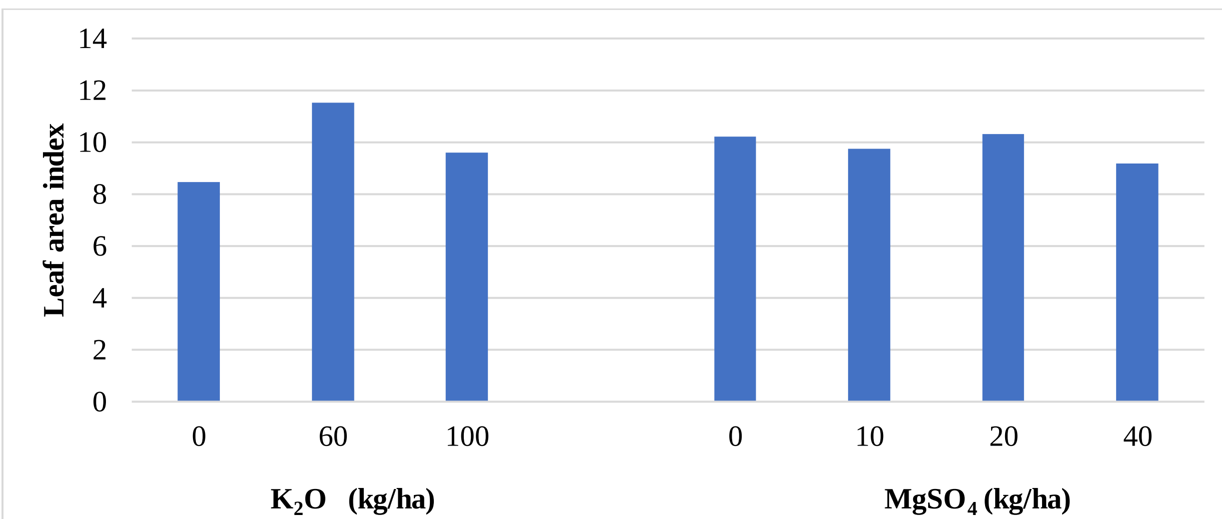


Figure 6. Effect of K_2O and $MgSO_4$ on LAI of coleus at 60 DAP

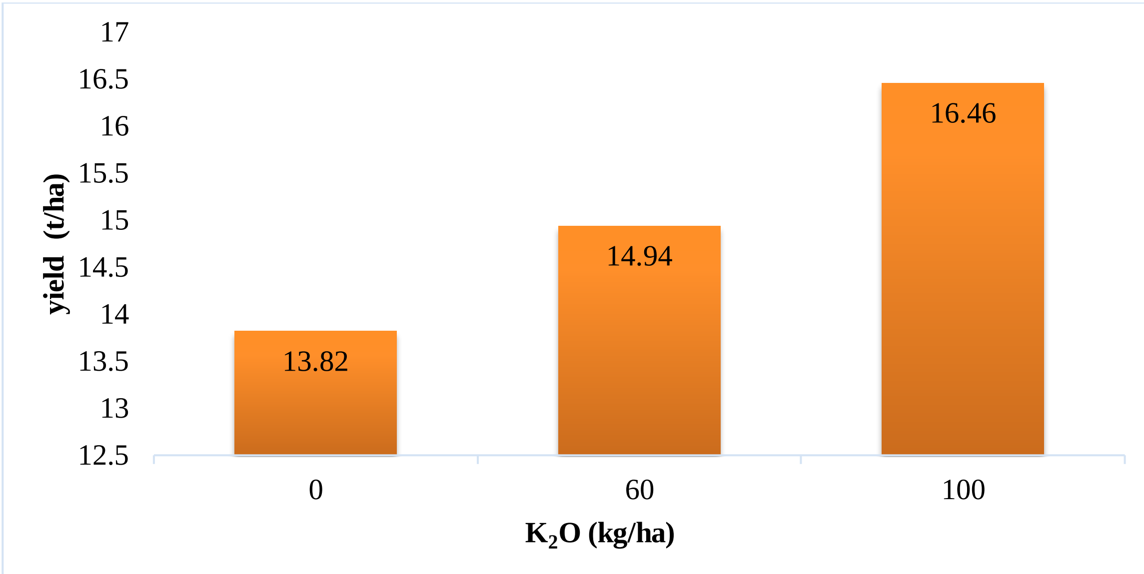


Figure 7. Effect of K_2O application on yield of coleus

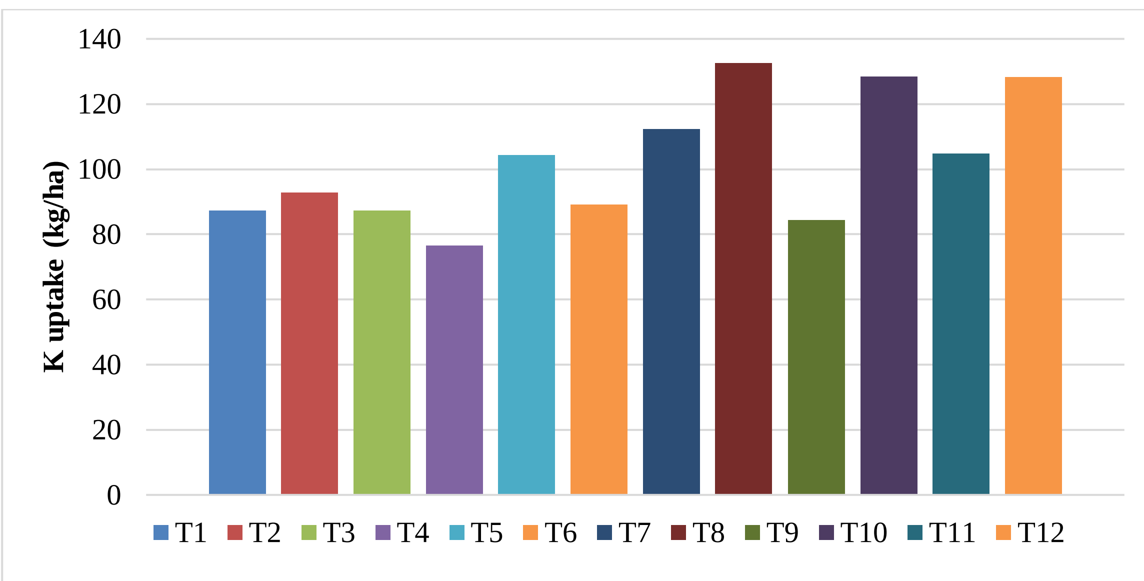


Figure 8. Effect of K_2O and $MgSO_4$ application on K uptake

Summary

6. SUMMARY

The experiment entitled “Potassium magnesium interaction in coleus [*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity was undertaken with the objective to assess the effect of varied dose of potassium and magnesium sulphate on tuber yield of coleus. The study was conducted at the Department of Agronomy, College of Agriculture, Vellanikkara, Thrissur during July to November 2020. The important findings from the experiment are summarized below.

1. At 30 DAP, the effect of application of K_2O and $MgSO_4$ on plant height was non significant. At 60 and 90 DAP the plant height varied with K_2O and $MgSO_4$ application. At 60 DAP, higher and comparable plant height was recorded with potassium application at 60 and 100 kg/ha. $MgSO_4$ applied at 0 and 10 kg/ha recorded higher values compared to two other levels. However, at 90 days after planting (DAP), statistically lower value of plant height was registered with application 100kg/ha of K_2O. Interaction effect of potassium and magnesium sulphate was significant only at 60 DAP and maximum height was observed in treatment combination of K_2O @ 60 kg/ha with no $MgSO_4$ application followed by K_2O at 100 kg/ha with $MgSO_4$ @ 10 kg/ha and were comparable statistically.
2. Effect of potassium application was found significant on dry matter production (DMP) of aerial portion at all stages of growth. Application of potassium at 60 or 100 kg/ha recorded higher as well as comparable dry weight of shoot at 60 DAP and at harvest. However interaction of potassium and magnesium sulphate was non significant at all stages of growth.
3. Magnesium sulphate application influenced drymatter accumulation in aerial part at 60 DAP as well as at harvest. At harvest stage significantly higher DMP was registered with application of 40 kg/ha magnesium sulphate, whereas other rates of application from 0 to 20 kg/ha produced comparable DMP.
4. Potassium magnesium interaction was not significant with respect to aerial drymatter accumulation at different growth stages of coleus

5. Dry matter production of tubers increased significantly with potassium application. Higher dry weight of 4151 kg/ha was registered from treatment that received K_2O @ 100 kg/ha.
6. However, effect of magnesium sulphate application on dry weight of tuber was non significant. But, the interaction of potassium and magnesium sulphate was significant. Higher and comparable values of 4,469 kg/ha and 4,463 kg/ha was recorded from K_2O applied @ 100 kg/ha with $MgSO_4$ @ 40 kg/ha or with 10 kg/ha. Lower values of tuber DMP was registered in treatments where potassium was not applied, irrespective of dose of magnesium sulphate and values were statistically comparable.
7. Total dry matter production of coleus was significantly influenced by potassium application. The highest and superior DMP of 6376 kg/ha was registered with application of 100 kg/ha K_2O. Effect of magnesium sulphate application on total dry weight of coleus was non significant. Interaction effect of potassium and magnesium was also non significant.
8. Varied doses of potassium and magnesium sulphate or their interaction did not significantly influence LAI of coleus.
9. Root- shoot ratio at 30 and 60 DAP was also unaffected by potassium and magnesium sulphate nutrition.
10. Leaf chlorophyll content did not show any significant variation with respect to different levels of potassium or magnesium sulphate application. However, interaction effect of potassium and magnesium sulphate was significant with respect to chlorophyll content. Higher value of chlorophyll in coleus leaves was registered from potassium application at 60 kg/ha with 20 kg/ha of $MgSO_4$ (0.178 mg/g)
11. With increasing level of potassium tuber yield increased. Application of K_2O @ 100 kg/ha produced the highest tuber yield of 16.46 t/ha, which was about 20 % higher than no potassium supplementation. Tuber yield did not exhibit significant variation with $MgSO_4$ application. However, interaction effect potassium and magnesium sulphate influenced tuber weight significantly. Higher tuber yield was registered in treatments which received 100 kg potassium with 10 kg or 40 kg magnesium sulphate as well as 60 kg potassium with 40 kg magnesium sulphate.

12. Unmarketable tuber weight did not vary significantly with potassium and magnesium sulphate application or due to their interaction effect
13. N content in coleus shoots varied significantly with potassium and magnesium sulphate application but P and K content did not show much variation.
14. Secondary nutrient content in coleus did not exhibit much variation with potassium and magnesium sulphate application.
15. Potassium uptake by coleus varied significantly and higher uptake of K was registered in treatments which received 100 kg potassium with 10 kg or 40 kg magnesium sulphate as well as 60 kg potassium with 40 kg magnesium sulphate. The values ranged from 76.53 kg/ha to 132.62 kg/ha in various treatments. Phosphorous uptake was on an average 25 kg/ha and nitrogen uptake 29 kg/ha. Average N and K content in shoot was lesser than content in tuber.
16. Available NPK content in soil did not vary significantly. Available N content showed a decline after harvest compared to initial value whereas available P and K in soil increased compared to initial status.
17. The soil status of Ca, Mg and S did not show much variation in soil with application of varied doses of potassium and magnesium sulphate.
18. The cost - benefit analysis revealed that potassium application resulted in higher yield, gross returns as well as net returns. Magnesium sulphate application also lead to increase I n returns at all levels of potassium. The higher net returns as well as B-C ratio (3.8) resulted from application of 100 kg K_2O along with either $MgSO_4$ @ 10 kg/ha (as foliar spray) or 40 kg/ha(soil application).
19. The results indicate that it is economic to apply potassium at the rate of @ 100 kg/ha with $MgSO_4$ @ 10 kg/ha (foliar spray at 30 DAP) or 40 kg/ha (soil application at 30 DAP) for higher yield, productivity and profitability of coleus cultivation in soils deficient in magnesium and medium in potassium.

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Appendix

Appendix 1. Monthly weather data during experimental period

(July 2020- November 2020)

Month	**Maximum temperature (^oC)**	**Minimum temperature (^oC)**	**Relative humidity (%)**	**Rainfall (mm)**	**Rainy days**	**Evaporation**	**Sunshine hours**
July	30.5	23.2	87	563.0	21	2.5	2.8
August	30.2	23.1	87	607.7	17	2.5	3.1
September	30.0	22.4	88	587.6	21	2.1	2.4
October	31.0	21.5	82	310.3	12	2.4	5.5
November	33.0	22.0	70	56.1	2	3.6	6.6

Appendix 2. Cost of cultivation

- Cost of coleus vine cuttings : Rs 1/vine cutting
- Cost of FYM : Rs 1.5/ kg
- Cost of labour : Rs 628/head/day
- Cost of fertilizers : Urea - Rs 7/kg,Rajphos- Rs 7/kg,MOP - Rs 19/kg, $MgSO_4$ – Rs 18/kg

	Labour cost (₹)	Cost of vine cutting (₹)	FYM (₹)	Lime (₹)	Fertilizers (₹)	Total cost of cultivation (₹)	Net returns (₹)	B:C ratio
K_2O – 0								
$MgSO_4$- 0	40,804	80,000	13,000	700	2,576	1,37,080	2,75,420	3.00
$MgSO_4$- 10	46,456	80,000	13,000	700	3,674	1,43,830	2,53,370	2.61
$MgSO_4$- 20	46,456	80,000	13,000	700	4,772	1,44,928	2,49,872	2.72
$MgSO_4$- 40	46,456	80,000	13,000	700	6,968	1,47,124	1,74,476	2.18
K_2O –60								
$MgSO_4$- 0	48,340	80,000	13,000	700	4,476	1,46,516	2,61,484	2.78
$MgSO_4$- 10	48,340	80,000	13,000	700	5,574	1,47,614	2,65,786	2.80
$MgSO_4$- 20	48,340	80,000	13,000	700	6,672	1,48,908	3,23,592	3.17
$MgSO_4$- 40	48,340	80,000	13,000	700	8,868	1,50,908	3,48,292	3.30
K_2O – 100								
$MgSO_4$- 0	48,340	80,000	13,000	700	5,742	1,47,782	1,93,918	2.31
$MgSO_4$- 10	48,340	80,000	13,000	700	6,840	1,48,880	4,21,420	3.83
$MgSO_4$- 20	48,340	80,000	13,000	700	7,938	1,49,978	3,36,322	3.24
$MgSO_4$- 40	48,340	80,000	13,000	700	10,134	1,52,174	4,28,626	3.81

Potassium-magnesium interaction in coleus

[*Solenostemon rotundifolius* (Poir.) J.K. Morton] productivity

By

ASWANI S.

(2019-11-012)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN AGRICULTURE

(Agronomy)

Department of Agronomy

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ABSTRACT

An experiment entitled 'Potassium-magnesium interaction in coleus [*Solenostemon rotundifolius* (Poir.) J.K.Morton] productivity' was conducted during the period from July to November 2020 at Agronomy Farm, College of Agriculture, Vellanikkara, Thrissur, with the objective to assess the effect of potassium and magnesium sulphate application on tuber yield of coleus. Potassium (K_2O) was applied @ 60 kg/ha (soil test based), 100 kg/ha (PoP recommendation) and a check (no potassium). Magnesium sulphate doses tried were 0 kg/ha, 10 kg/ha, 20 kg/ha, 40 kg/ha. The treatments consisted of twelve different combinations of K_2O and magnesium sulphate which was replicated thrice in RBD design. The soil of the experimental field was medium in potassium and low in magnesium status. Magnesium sulphate was soil applied at 30 days of planting and in the case of lower dose of 10 kg/ha, it was foliar applied (2 per cent spray). N and P_2O_5 were applied as per PoP recommendation of 60:60 kg/ha. Coleus variety Nidhi was used for the study.

Growth parameters such as plant height, dry matter production of aerial portion, dry matter production of tubers as well as total dry matter production were significantly influenced by potassium application. However, LAI and root to shoot ratio at vegetative stage did not vary significantly with potassium dose. Taller plants were observed with potassium application @ 60 and 100 kg/ha at 60 DAP.But at 90 DAP lower value of plant height was registered at higher level of 100 kg/ha K_2O. Magnesium sulphate application also influenced plant height at 90 DAP taller plants were observed in plants which received 40 kg/ha of $MgSO_4$.

Varied levels of potassium as well as magnesium sulphate did not bring about variation in chlorophyll content of coleus leaves. However, interaction of potassium and magnesium sulphate on leaf chlorophyll content was significant and higher values were observed when K_2O was applied @ 60 kg/ha along with $MgSO_4$ @ 20 or 40 kg/ha.

Dry matter production (DMP) of aerial portion increased with increasing levels of K_2O. At 60 DAP and at harvest plants which received 60 or 100 kg/ha potassium registered higher and comparable aerial DMP. Magnesium sulphate

application did not show any significant influence on DMP at 90 DAP. However at harvest, aerial DMP with the application of 40 kg magnesium sulphate was superior to other levels which were at par statistically.

Tuber yield showed significant increase with increase in rate of potassium applied and showed an increase of 19 per cent when 100 kg of K_2O was applied compared to control (13.80, 14.94 and 16.46 t/ha, at 0, 60 & 100 kg/ha K_2O, respectively). Various levels of magnesium sulphate applied did not show any influence on tuber yield. However interaction effect of K and Mg was significant and best combination was 60 K_2O with 40 kg $MgSO_4$, 100 kg K_2O with 10 or 40 kg magnesium sulphate, which registered statistically comparable yields. Magnesium and potassium levels had no influence on yield of unmarketable tuber.

Application of K_2O @ 100 kg/ha recorded higher DMP of tuber and total DMP over 0 and 60 kg potassium. Effect of magnesium sulphate application on dry matter production of tuber and total dry matter production was non significant. However interaction effect of potassium and magnesium sulphate was significant with respect to tuber DMP. Higher and superior values were registered under 100 kg of K_2O with 10 kg $MgSO_4$ and 40 kg $MgSO_4$.

Higher K uptake was noticed when K_2O was applied @ 60 kg/ha with 40 kg/ha $MgSO_4$ which was on par with K_2O at 100 kg/ha with $MgSO_4$ at 10 kg/ha or 40 kg/ha. Potassium and magnesium sulphate application did not cause significant variation in N, P and secondary nutrient uptake by coleus.

Net returns as well as B-C ratio were higher for K_2O application @ 100 kg/ha along with $MgSO_4$ @ 40 kg/ha or 10 kg/ha. The results of the study indicate that for better productivity in coleus, potassium may be applied at the rate of @ 100 kg/ha, even in soils with medium status of available K. Also, K- Mg balance is important and hence in soils deficient in magnesium and medium in potassium, soil application of magnesium sulphate @ 40 kg/ha or foliar spray @ 10 kg/ha at 30 DAP, together with K_2O dose of 100 kg/ha can enhance the productivity of coleus.