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Interactive Effect of Conservation Tillage, Potassium and Magnesium Sulphate Fertilization on Dry Matter Production, Physiological and Yield Parameters, and Yield of Grain Cowpea

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study conducted in Kerala, evaluated the role of conservation tillage (zero tillage (ZT), minimum tillage (MT), and conventional tillage (CT)) with five treatment combination of potassium (12 kg/ha, 20 kg/ha, 40 kg/ha) and magnesium sulphate (60 kg/ha and 80 kg/ha) on total DMP, physiology and grain yield of the test variety *Anaswara* (cowpea). In pot culture study, application of K: $MgSO_4$, 10:80 kg/ha resulted in highest total chlorophyll content. While higher chlorophyll a content was obtained with the levels 20:60 kg/ha, and highest total DMP was recorded with the

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application at 40:100 kg/ha. Different levels of K and $MgSO_4$ nutrition positively influenced 100 seed weight and grain yield, while there found no significant difference on chlorophyll b content, days to flowering, and grains/pod with any of the treatments imposed. Higher values for test weight and grain yield were recorded with K: $MgSO_4$ 40:60 kg/ha. In field experiment, tillage practices failed to produce notable difference in chlorophyll a, chlorophyll b, total chlorophyll contents, chlorophyll a/b ratio, grains per pod and test weight. Early flowering (45 DAS) and highest total DMP up to 75 DAS were recorded under CT. ZT produced highest LAI, while highest grain yield was noted under MT practice (734.5 kg/ha). Nutrient treatments failed to produce significant differences in chlorophyll b and chlorophyll a/b ratio. However, application at 40:80 kg/ha produced highest LAI, and higher content of chlorophyll a and total chlorophyll content (1.34 mg/g). K:$MgSO_4$ applied at 40:60 kg/ha recorded highest grain yield. LAI was recorded highest under ZT with K:$MgSO_4$ at 40:80 kg/ha. MT + K:$MgSO_4$ at 40:60 kg/ha reported highest chlorophyll a/b ratio (4.71). K: $MgSO_4$ applied at 40:60 kg/ha produced highest grain yield (806 kg/ha). In interactions, MT + K: $MgSO_4$ at 40:60 kg/ha registered highest grain yield (914.8 kg/ha). Overall, in terms of grain yield, the test crop responded well to MT with application of K: $MgSO_4$ at 40:60 kg/ha.

Keywords: Conservation tillage; cowpea; magnesium sulphate; potassium; LAI; chlorophyll; yield.

1. INTRODUCTION

Under the present scenario of climate change, challenge before farmers and scientists is achieving sustainable pulse production ensuring food and nutritional security. Besides, declining nutritional security, increase in cost of inputs, lack of availability of skilled labors, fluctuating market prices, is a matter of concern. Major factor contributed towards poor nutritional security and yield gaps is, continuous adaptation of mono-cropping, supply of primary nutrients alone, and conventional tillage, which accelerated erosion, making soil vulnerable to nutrient leaching and leading to poor soil health. Whereas conservation tillage practices such as zero tillage, zone tillage, mulch tillage and minimum tillage improves soil physical and biological properties leading to higher yield and productivity of the crop. It also aims at increasing agricultural production and productivity by maintaining the present natural resource base adopting minimum or no soil disturbance, permanent soil cover with stubbles, cover crops, and crop rotations involving legumes. For proper crop growth and to maintain soil quality, maintaining soil physical and biological properties in optimal condition is important. Method of tillage profoundly affects these. Hence it is important to select a suitable type of tillage practices without compromising successful growth and yield of crops.

Pulses performs well under conservation tillage due to their deep tap root system and rapid crop growth rate at the initial growth stages. Besides, legumes have good potential to restore soil fertility especially due to its symbiotic association with N fixing bacteria. Ruhlemann and Schmidtke [1] in their study on cover crops observed that, though biomass production in common vetch was lower, nitrogen fixation was higher under organic no-tillage system. In no tilled soil, microbial diversity was found to be higher, [2]. Under these circumstances, conservation tillage can play a key role for higher and sustainable productivity with less deterioration of soil health.

India which produces 22.95 million tons of pulses from a total area of 29.5 million ha, is the largest pulse producing country contributing 25% to the pulse production globally, with an average productivity of 779 kg/ha which is much lower compared to other pulse producing countries, [3]. Although pulses play a vital role in farming by improving soil health, they are often cultivated as a catch crop *i.e.* with low input supply under rainfed condition, [4]. In Kerala, the widely cultivated pulse crop cowpea, is cultivated in *rabi* or summer in rice-fallows as a rainfed catch crop under conventional tillage practice, which again leads to low crop productivity.

In Kerala, recently, symptoms of secondary nutrient deficiency have been reported in cowpea from many areas. The acidic soils of Kerala are inherently deficient in secondary nutrients and high rainfall leading to leaching of nutrients to deeper layers aggravates this problem. Heavy rainfall causing leaching of nutrients makes the availability of Ca and Mg very low in Kerala soils and about 80 per cent of soils are deficient in available calcium and magnesium [5]. Although liming can meet the crop requirement of calcium, but magnesium and sulphur must be supplied through fertilizers. Samui and Mandal (2003) reported that lime application in acidic soils ameliorates soil acidity as well increases crop calcium uptake. Studies also shows that secondary nutrient requirement of crops is almost like phosphorus demand. Hence the present study was formulated with the objectives of studying soil biological properties and crop establishment under conservation tillage, and nutrition on cowpea grain yield.

2. MATERIALS AND METHODS

The experiment was conducted in two parts. First part included a pot culture where cowpea was raised in March-July in 2017 and the second part was field experiment from November- March 2017–2018 and 2018–2019. Location was paddy fields at College of Agriculture, Vellanikkara, Thrissur (10^o 31'N, of 76^o 13'E and 40 masl) of the Kerala Agricultural University, India which enjoys a typical tropical humid climate.

The mean maximum temperature and mean minimum temperature was 34.2^oC and 22.5^oC respectively. Type of soil is sandy loam, with a pH of 4.6 and 1.1% organic carbon content. Available nitrogen, phosphorus and available potassium was 410 kg/ha (high), 4 kg/ha, (low), and 107 kg/ha, (low) respectively. it was soil was deficient in magnesium (60 mg/kg).

Soil for potting mixture preparation was taken from the experimental field. Potting mixture was prepared by mixing sand, soil and manure in 1:1:1 ratio and filled in pots at 10 kg per pot. Experimental design adopted was CRD with 14 treatment consisting combination of K_2O- $MgSO_4$ doses, which was replicated thrice. A semi trailing dual purpose high yielding cowpea variety with medium-long pods with bold grains having a 100 seed weight of 16 g released from KAU, Anaswara, was the test crop. *Rhizobium* treated seeds were sown. Lime was applied at 2 g/kg soil 15 days before sowing. Pseudomonas and Trichoderma at 20 g each per pot was also applied. One week after sowing, magnesium sulphate was applied and seedlings were thinned retaining one healthy plant per pot. Micronutrient (KAU vegetable mixture) spray was given in treatment $T_{14.}$

Treatments for pot culture:

T_1 - K_2O 10 kg/ha +$MgSO_4$ 40 kg/ha; T_2 - K_2O 10 kg/ha +$MgSO_4$ 60 kg/ha; T_3 - K_2O 10 kg/ha +$MgSO_4$ 80 kg/ha; T_4 - K_2O 10 kg/ha+$MgSO_4$ 100 kg/ha;

T_5 - K_2O 20 kg/ha+$MgSO_4$ 40 kg/ha; T_6 - K_2O 20 kg/ha+$MgSO_4$ 60 kg/ha; T_7 - K_2O 20 kg/ha +$MgSO_4$ 80 kg/ha; T_8 - K_2O 20 kg/ha+$MgSO_4$ 100 kg/ha;

T_9 - K_2O 40 kg/ha+$MgSO_4$ 40 kg/ha; T_{10} - K_2O 40 kg/ha+$MgSO_4$ 60 kg/ha; T_{11} - K_2O 40 kg/ha+$MgSO_4$ 80 kg/ha; T_{12} - K_2O 40 kg/ha+$MgSO_4$ 100 kg/ha;

T_{13} - K_2O 10 kg/ha+No $MgSO_4$ (POP);

T_{14}-Soil test based nutrient application.

The field experiment was conducted in rice fallow and experimental design was RBD with factorial combination of three tillage practices and five K_2O-$MgSO_4$ doses as treatments. In zero tillage (ZT), glyphosate was sprayed @ 0.85 kg/ha two weeks before sowing. In minimum tillage (MT), strip tillage was adopted at a spacing of 30 cm. In conventional tillage (CT) land was ploughed twice followed by formation of small ridges and furrows at a spacing of 30 cm. Seeds were dibbled on ridges at plant to plant spacing of 15 cm.

The K_2O and $MgSO_4$ doses included K_2O 10 kg/ha + $MgSO_4$ 80 kg/ha (S_1), K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha (S_2), K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha (S_3), K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha (S_4), K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha (S_5).

A uniform dose of Lime, FYM, N and P_2O_5 were applied @ 650 kg/ha, 20t/ha, 20 kg/ha and 30 kg/ha respectively [6]. Half of the N was applied as basal and other half was given as foliar spray at 15 DAS. Potassium was applied as basal dose and $MgSO_4$ was applied two weeks after K application. Hand weeding was done at 15 and 30 DAS. A pre sowing irrigation was given and seeds were dibbled. Crop was irrigated daily till seedling establishment. Later on, irrigation was given twice a week till third harvest and weekly once thereafter. Gap filling was completed within 10 DAS. Thinning was done at 15 DAS to obtain optimum plant population.

In pot culture study, observations on total DMP, chl a, chl b and total chlorophyll content, days to flowering, and at harvest 100 seed weight, grains/pod, grain yield per plant were recorded.

In field study, observations on chlorophyll contents leaf area and LAI at actively growing stage was recorded. Leaf area was measured using leaf area meter. Fully open leaflets were separated and reading was taken immediately. Area thus obtained was multiplied with total number of leaves per plant and the mean was expressed in cm^2. Leaf area index (LAI) was expressed as ratio of leaf area to the unit land area.

Grain yield per plot was recorded at harvest. Data was pooled and analyzed by using OPSTAT statistical software.

3. RESULTS AND DISCUSSION

3.1 Total DMP

Tillage practices significantly influenced drymatter production throughout the growth stages (Table 1a & 1b). Among various tillage practices, higher DMP was registered under CT practice till 60 DAS compared to conservation tillage systems (zero and minimum Tillage). Later stages, 75 DAS highest dry matter was produced under MT (3240 kg/ha). However at 90 DAS this trend changed and DMP under MT and CT were comparable (2043 kg/ha and 2085 kg/ha respectively).

It could be noted that ZT consistently accumulated lowest dry matter of cowpea through out the growth. This might be attributed to the highest root weight, root length and root spread recorded under zero tillage, and the photosynthate partitioning might have concentrated more towards the development of root rather than shoot and pods. Lopez-Bellido et al. (2007) also reported that CT practices significantly produced higher biomass and total DMP in pea, than under ZT. These findings are in line with the reports of Meena et al. (2015) in green gram.

When comes to nutrient treatments, highest DMP at 15 DAS was registered under K: $MgSO_4$ @ 20:60 (S_2), 20:80 (S_3) and 40:60 (S_4) kg/ha which were on par to each other. From the data it is very clear that nutrient combinations failed to produce significant effect on DMP at 30 DAS and at 45 DAS. However, at 60 DAS highest DMP (2906.1 kg/ha) was noticed with the application of K: $MgSO_4$ @ 40:60 kg/ha (S_4) and the lowest content (2232.6 kg/ha) was noticed under K: $MgSO_4$ @ 20:60 kg/ha (S_2). Nutrient treatments S_2, S_3 and S_4 resulted in higher dry matter production (3033 kg/ha, 2974.3 kg/ha and 3025 kg/ha respectively) at 75 DAS. At 90 DAS, S_1 and S_4 registered higher dry matter production and they were at par. The treatment which received lower dose of potash (20 kg/ha) with higher level of Mg (80 kg/ha) produced lowest dry matter at 90 DAS.

Since the soil Mg content was low, response to applied magnesium was good. Cakmak et al., 1994, reported that Mg plays specific roles in carbon partitioning as well as DMP to plant parts which act as sink, Mg deficiency of leaves are seen with carbohydrates accumulation.

Many workers reported positive effect of magnesium application in dry matter production in pulse. In common bean, plant height, total dry matter produced, as well as leaf area were larger when magnesium sulphate was applied @ 324 kg of $MgSO_4$/ha as reported by Oliveira et al. (2000).

According to Kurdali et al. (2002), highest dry matter in faba bean and chickpea was reported with higher rate of potassium. Ganga et al. [7] reported that application of K_2O @ 60 kg/ha produced significantly higher total dry matter in chickpea which was in line with the findings of Boulbaba et al. (2005). Hamid et al. (2010) reported that potassium had an impact on growth parameters of soybean and it increased plant dry matter and LAI of the crop.

Ibrahim et al. (2010) found that a significant increase in plant height and dry matter production of french beans due to application of MgO @ 6 kg/ha. Foliar application of Mg-EDTA @ 1mM in pea plants at 25 and 40 DAS resulted in a significant increase in dry matter; leaf area as well as plant height compared no Mg application (Howladar et al., 2014). Thalooth et al. [8] reported that, foliar application of Zn, potassium and magnesium resulted in improved growth parameters of mungbean.

At 75 DAS and 90 DAS, higher dry matter production (3996 kg/ha and 2461 kg/ha respectively) was noticed under minimum tillage along with K-$MgSO_4$ @ 40:60 kg/ha. Results indicated that, dry matter production increased gradually till 75 DAS and declined at later stage due to senescence of leaves.

Potassium applied @ 40 kg/ha along with higher level of Mg, *i.e.* 80 kg/ha, produced lower dry matter than K-Mg @ 40:60 kg/ha. This might be due to the antagonistic affect between K and Mg at higher levels. Narwal et al. (1985) reported that dry matter yield increased when K was applied up to 150 ppm with Mg up to 20 ppm, and dry weight of roots increased when the Mg level was increased to 40 ppm.

3.2 Leaf Area Index

Leaf area index was studied only in field experiment. Various tillage types with K and $MgSO_4$ doses and their interaction had significant effect on leaf area index recorded at active growth stage of cowpea (45 DAS) (Table 2). Pooled analysis showed that among different tillage systems, highest LAI was observed under zero tillage. Followed by LAI recorded under MT. The tillage system to record lowest LAI was conventional tillage.

The treatment application of K: $MgSO_4$ @ 40:80 kg/ha resulted in highest LAI, whereas soil test based nutrition where K: $MgSO_4$ was applied @ 12:80 kg/ha, resulted in lowest values. Interaction effect was also significant and application of K: $MgSO_4$ @ 40:80 kg/ha under zero tillage registered highest LAI. Lower LAI were recorded with CT along with various nutrient combinations registered and were at par with each other.

3.3 Days to Flowering

Influence of application of K and $MgSO_4$ in pot culture study and field study, found to be non significant in Days to 50% flowering and the plants flowered by 43 DAS.

3.4 Chlorophyll Contents

Chlorophyll contents were estimated at active growth stage of cowpea (45 DAS). In pot culture, treatment effect of nutrients application showed, significant variations in chl a and total chlorophyll contents (Table 3). However, in chl-b no significant variation was observed.

Application of K: $MgSO_4$ @ 20:60 kg/ha (T_6) registered highest content of chl-a (1.31 mg/g). While higher total chlorophyll content was registered in soil test based nutrition (T_{14}).

In field experiment, although tillage practices did not had significant influence on chlorophyll content (chlorophyll a, b, a/b ratio, and total chlorophyll) (Table 3), the nutrient doses and interaction significantly influenced chlorophyll a, a/b ratio and total chlorophyll content. Highest total chlorophyll content (1.34 mg/g) was noted in application of K: $MgSO_4$ @ 20:60 kg/ha and K: $MgSO_4$ @ 40:80 kg/ha. Magnesium is a constituent of chlorophyll and the role of magnesium in chlorophyll formation is well established. Application of K: $MgSO_4$ @ 40:60 kg/ha resulted in higher chlorophyll a/b ratio (3.84). Teklić et al. (2009) reported that foliar application of Mg favoured rate of photosynthesis as magnesium is associated with increase in leaf chlorophyll content.

Fernández et al. (2015) suggested that the reason for higher magnesium content in corn leaves with application of Mg might be due to the rapid absorption of Mg by plants, and another reason might be the high mobility of magnesium in the phloem. These reasons also might have resulted in the higher Mg content in cowpea, with application of K: $MgSO_4$ @ 40:80 kg/ha.

Altarugio et al. (2017) also stated that foliar application of magnesium increased leaf Mg content in soybean and there was a significant increase in SPAD index values. Canizella et al. (2018) noticed that Mg and Zn fertilization increased the chlorophyll content from 283.4 mg/m^2 to 329.7 mg/m^2 leaf area in soybean cultivars.

3.5 Grain Yield and Yield Parameters

Yield is a result of total uptake of nutrients, total photosynthates produced during crop growth and as well as the portion of photosynthates partitioned towards the economic part.

Grain yield of cowpea was found to be significant (Fig. 1, Table 4). Data pertaining to total grain yield per plant recorded significant influence of K and Mg levels on grain yield of cowpea. Higher grain yield per plant was registered in application of K @ 40 kg/ha along with $MgSO_4$ at 60, 80, and 100 kg/ha which were statistically on par to each other. Whereas lower grain yield was obtained with treatments containing lowest dose of K_2O @ 10 kg/ha along with $MgSO_4$ @ 40, 60, 80 and 100 kg/ha. These treatments were also on par to each other. grains per pod test weight.

In field experiment, effect of various tillage types and K-$MgSO_4$ doses was observed to be non-significant with regard to grains per pod. During both 2017 and 2018, average number of grains per pod recorded was 15. Highest grain yield was recorded with MT (Table 4). Whereas, lower and statistically comparable yields were noticed in CT and ZT. The minimum soil disturbance in this tillage system might have conserved soil moisture reducing evaporative loses making it available for consumptive use by cowpea. Deep growing tap roots of cowpea, reduction in evaporative loss, conserved soil moisture, might resulted in higher grain yield. Similarly, hard soil pan in ZT might have affected early establishment of crop and resulted in decreased grain yield. The results indicated the suitability of minimum tillage for rice fallow cowpea production.

Onyari et al. [9] also observed that, compared to double digging, furrow tillage, and conventional tillage, highest plant biomass production at reproductive stage, grain yield and number of pods of chickpea was noticed in strip tillage.

Interaction between tillage and nutrient also had significant effect on grain yield. Minimum tillage with K: $MgSO_4$ @ 40:60 kg/ha recorded in highest grain yield of cowpea (2.3 kg/25.2m^2). Treatments which yielded higher number of pods per square meter, resulted in higher grain yield of cowpea. This can be attributed to cowpea with deep roots, provided with the optimum availability of primary and secondary nutrients as well as soil moisture resulted in improved crop growth. A reduction in water loss from the top soil under minimum tillage was also reported by Ruhendi and Litsinger [10].

Ploughing the ridges alone before sowing of cowpea helps in decreasing evaporation and conserving soil moisture, which might have allowed maximum absorption of water, also the undisturbed area near the strips might have reduced nutrient leaching, also lower weed density in less disturbed soil resulting decreased weed competition might have resulted in higher grain yield. Chaghazardi et al. [11], also reported that, in chickpea, number of pods per plant and grain was higher under reduced tillage than in zero tillage and conventional tillage.

Application of K with $MgSO_4$ @ 40 kg/ha and 60 kg/ha respectively might have attributed in increasing the photosynthetic rate of the crop, ultimately leading to increased grain yields. Zörb et al., 2014 reported that potassium is fundamental for activating enzymes essential for many metabolic processes, and also for water management in plants. Effect of various levels of potassium on chickpea yield varied significantly with higher yield noted under application of K_2O 60 kg/ha and the increase was due to higher number of pods per plants, seeds per plant and 100-grain weight, Ganga et al. [7].

Whereas K deficiency reduced photosynthetic rate and the rate of ATP production [12]. This finding is one of the reasons for the key role played by K in increasing grain yields. Mona et al. [13], reported similar findins that K fertilization applied as potassium sulphate increased the number of pods in faba bean. Thalooth et al. [8] found that, foliar application of K or Mg resulted in higher yields and number of pods in mungbean than that in control plots.

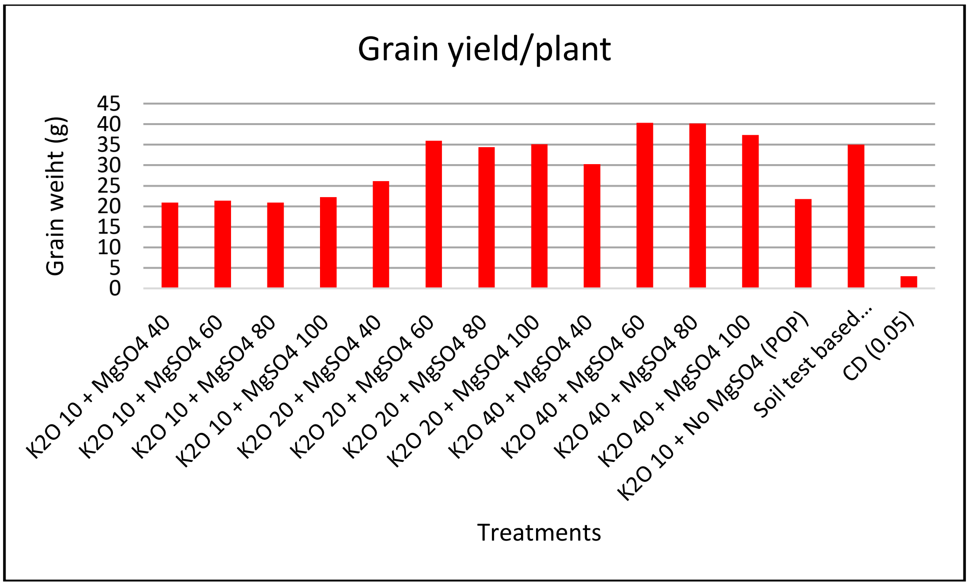

Fig. 1. Effect of K and $MgSO_4$ application on grain yield of cowpea

Table 1a. Effect of tillage and nutrients on dry matter production of cowpea

	15 DAS	30 DAS	45 DAS
Tillage			
M_1- Zero tillage (ZT)	25.1^{c}	$5.6\ (326)^{c}$	$7.7\ (998)^{c}$
M_2- Minimum tillage (MT)	35.0^{b}	$7.7\ (434)^{b}$	$9.7\ (1219)^{b}$
M_3- Conventional tillage (CT)	50.6^{a}	$10.6\ (587)^{a}$	$13.5\ (1707)^{a}$
C.D (0.05)	**2.5**	**0.6**	**0.5**
SE(m)	**0.85**	**0.19**	**0.18**
S_1- Soil test based recommendations	36.3^{b}	7.9 (439)	10.1 (1274)
S_2- K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	37.6^{ab}	8.4 (439)	9.0 (1148)
S_3- K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	37.2^{ab}	8.2 (468)	10.6 (1377)
S_4- K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	39.6^{a}	7.9 (438)	10.6 (1340)
S_5- K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	33.7^{c}	7.7 (460)	11.0 (1400)
C.D (0.05)	**3.2**	**NS**	**NS**
SE(m)	**1.09**	**0.25**	**0.23**
M_1S_1: ZT + Soil test based	30.4^{gh}	$5.9\ (340)^{fg}$	$8.7\ (1127)^{f}$
M_1S_2: ZT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	23.6^{ij}	$6.4\ (365)^{f}$	$7.6\ (972)^{fg}$
M_1S_3: ZT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	27.9^{hi}	$7.7\ (437)^{de}$	$8.4\ (1073)^{f}$
M_1S_4: ZT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	24.6^{i}	$4.8\ (268)^{g}$	$7.5\ (1005)^{fg}$
M_1S_5: ZT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	19.0^{j}	$3.5\ (217)^{h}$	$6.1\ (812)^{h}$
M_2S_1: MT + Soil test based	28.8^{ghi}	$6.2\ (289)^{f}$	$7.0\ (915)^{gh}$
M_2S_2: MT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	32.5^{fgh}	$6.7\ (359)^{ef}$	$6.5\ (785)^{gh}$
M_2S_3: MT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	43.1^{cd}	$8.8\ (541)^{cd}$	$12.7\ (1726)^{cd}$
M_2S_4: MT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	36.2^{ef}	$8.0\ (482)^{cd}$	$10.6\ (1236)^{e}$
M_2S_5: MT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	34.2^{fg}	$9.0\ (500)^{c}$	$11.5\ (1434)^{de}$
M_3S_1: CT + Soil test based	49.7^{b}	$12.1\ (689)^{a}$	$14.5\ (1781)^{ab}$
M_3S_2: CT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	56.8^{a}	$11.5\ (593)^{ab}$	$12.8\ (1688)^{c}$
M_3S_3: CT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	40.6^{de}	$8.2\ (426)^{cd}$	$10.9\ (1332)^{e}$
M_3S_4: CT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	57.9^{a}	$10.7\ (562)^{b}$	$13.7\ (1778)^{bc}$
M_3S_5: CT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	47.8^{bc}	$10.7\ (662)^{b}$	$15.3\ (1953)^{a}$
C.D (0. 05)	**5.5**	**1.3**	**1.2**
SE(m)	**1.89**	**0.43**	**040**

Table 1b. Effect of tillage and nutrients on dry matter production of cowpea (60 DAS, 75 DAS, 90 DAS)

	60 DAS	75 DAS	90 DAS
Tillage			
M_1- Zero tillage (ZT)	2099.8^{c}	$9.0\ (2358)^{c}$	$13.3\ (1893)^{b}$
M_2- Minimum tillage (MT)	2624.5^{b}	$12.4\ (3240)^{a}$	$14.7\ (2043)^{a}$
M_3- Conventional tillage (CT)	3196.7^{a}	$10.5\ (2976)^{b}$	$14.1\ (2085)^{a}$
C.D (0.05)	**97.9**	**0.5**	**0.7**
SE(m)	**33.63**	**0.2**	**0.2**
S_1- Soil test based recommendations	2610.3^{c}	$9.4\ (2603)^{b}$	$15.6\ (2258)^{a}$
S_2- K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	2232.6^{d}	$11.1\ (3033)^{a}$	$13.7\ (1995)^{b}$
S_3- K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	2750.5^{b}	$11.1\ (2974.3)^{a}$	$12.7\ (1880)^{c}$
S_4- K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	2906.1^{a}	$11.5\ (3025)^{a}$	$14.7\ (2069)^{a}$
S_5- K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	2702.0^{b}	$10.0\ (2654)^{b}$	$13.5\ (1883)^{b}$
C.D (0.05)	**126.4**	**0.7**	**0.9**
SE(m)	**43.41**	**0.2**	**0.3**
M_1S_1: ZT + Soil test based	2230.0^{f}	$7.4\ (2019)^{h}$	$16.1\ (2365)^{bc}$
M_1S_2: ZT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	1627.7^{g}	$10.7\ (2857)^{def}$	$12.7\ (1836)^{fg}$
M_1S_3: ZT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	2763.5^{d}	$10.9\ (2940)^{de}$	$12.0\ (1726)^{g}$
M_1S_4: ZT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	2234.5^{f}	$8.6\ (2134)^{g}$	$13.2\ (1813)^{efg}$
M_1S_5: ZT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	1643.2^{g}	$7.2\ (1840)^{h}$	$12.7\ (1723)^{fg}$
M_2S_1: MT + Soil test based	2207.7^{f}	$10.7\ (2857)^{def}$	$13.7\ (1847)^{def}$
M_2S_2: MT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	2162.1^{f}	$12.3\ (3274)^{bc}$	$14.8\ (1979)^{cd}$
M_2S_3: MT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	2536.7^{cd}	$10.5\ (2645)^{ef}$	$14.2\ (2138)^{def}$
M_2S_4: MT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	3374.1^{e}	$15.0\ (3996)^{a}$	$17.7\ (2461)^{a}$
M_2S_5: MT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	2841.7^{d}	$13.1\ (3425)^{b}$	$13.4\ (1791)^{efg}$
M_3S_1: CT + Soil test based	3393.1^{a}	$10.2\ (2932)^{ef}$	$17.1\ (2510)^{a}$
M_3S_2: CT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	2908.1^{cd}	$10.2\ (2968)^{ef}$	$13.6\ (2075)^{def}$
M_3S_3: CT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	2951.3^{cd}	$11.8\ (3339)^{cd}$	$12.1\ (1774)^{g}$
M_3S_4: CT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	3109.8^{c}	$10.7\ (2945)^{def}$	$13.2\ (1932)^{efg}$
M_3S_5: CT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	3621.2^{a}	$9.7\ (2697)^{fg}$	$14.5\ (2135)^{de}$
C.D (0.05)	**218.9**	**1.1**	**1.5**
SE(m)	**75.19**	**0.4**	**0.5**

Table 2. Effect of tillage and nutrients on LAI of cowpea

Treatment	**LAI**
Tillage	**Pooled**
M_1- Zero tillage (ZT)	6.3^{a}
M_2- Minimum tillage (MT)	5.0^{b}
M_3- Conventional tillage (CT)	3.2^{c}
C.D (0.05)	**0.6**
SE(m)	**0.21**
Nutrients	
S_1- Soil test based recommendations	6.0^{d}
S_2- K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	6.6^{c}
S_3- K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	6.9^{c}
S_4- K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	7.9^{b}
S_5- K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	8.8^{a}
C.D (0.05)	**0.8**
SE(m)	**0.31**
Interaction	
M_1S_1: ZT + Soil test based	6.6^{c}
M_1S_2: ZT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	6.1^{cd}
M_1S_3: ZT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	8.2^{b}
M_1S_4: ZT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	8.4^{b}
M_1S_5: ZT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	9.4^{a}
M_2S_1: MT + Soil test based	6.1^{e}
M_2S_2: MT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	8.2^{cd}
M_2S_3: MT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	6.8^{de}
M_2S_4: MT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	7.4^{bc}
M_2S_5: MT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	7.4^{b}
M_3S_1: CT + Soil test based	3.4^{f}
M_3S_2: CT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	3.4^{f}
M_3S_3: CT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	3.5^{f}
M_3S_4: CT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	3.8^{f}
M_3S_5: CT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	3.3^{f}
C.D (0.05)	**0.7**
SE(m)	**0.49**

Table 3. Effect of tillage and nutrients on chlorophyll contents of cowpea

Treatment	**Chl a**	**Chl b**		**Total Chl**	**Chl a/b**	
Tillage	**Pooled**	**2017**	**2018**	**Pooled**	**2017**	**2018**
M_1- Zero tillage (ZT)	14.3 (1.06)	0.31	0.25	1.28	3.76	3.95
M_2- Minimum tillage (MT)	12.9 (0.98)	0.26	0.23	1.24	3.95	4.21
M_3- Conventional tillage (CT)	13.7 (1.04)	0.26	0.29	1.32	4.10	3.71
C.D (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
SE(m)	**0.17**	**0.01**	**0.01**	**0.02**	**0.06**	**0.05**
S_1- Soil test based recommendations	13.7 (1.04)^{a}	0.27	0.27	1.29^{b}	3.91	3.84
S_2- K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	14.3 (1.07)^{a}	0.31	0.26	1.34^{a}	3.70	3.80
S_3- K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	13.0 (0.96)^{b}	0.27	0.22	1.17^{d}	3.92	4.13
S_4- K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	12.9 (0.98)^{b}	0.24	0.25	1.26^{c}	4.24	4.23
S_5- K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	14.3 (1.08)^{a}	0.28	0.28	1.34^{a}	3.91	3.78
C.D (0.05)	**0.60**	**NS**	**NS**	**0.1**	**NS**	**NS**
SE(m)	**0.22**	**0.01**	**0.01**	**0.02**	**0.08**	**0.06**
M_1S_1: ZT + Soil test based	15.9 (1.19)^{a}	0.33	0.28	1.49^{ab}	3.90	3.98^{de}
M_1S_2: ZT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	14.1 (1.06)^{cd}	0.31	0.26	1.34^{cd}	3.67	3.93^{de}
M_1S_3: ZT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	13.3 (0.99)^{defg}	0.29	0.20	1.08^{i}	3.82	4.35^{b}
M_1S_4: ZT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	13.8 (1.02)^{cdef}	0.29	0.25	1.29^{de}	3.86	3.91^{ef}
M_1S_5: ZT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	14.2 (1.07)^{cd}	0.31	0.26	1.23^{efg}	3.57	3.58^{gh}
M_2S_1: MT + Soil test based	12.7 (0.97)^{fg}	0.24	0.25	1.24^{efg}	4.03	3.91^{de}
M_2S_2: MT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	12.9 (0.96)^{efg}	0.29	0.19	1.13^{hi}	3.58	3.88^{efg}
M_2S_3: MT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	12.8 (0.96)^{efg}	0.26	0.26	1.26^{def}	3.98	4.22^{bcd}
M_2S_4: MT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	12.3 (0.94)^{g}	0.22	0.20	1.21^{efgh}	4.20	4.71^{a}
M_2S_5: MT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	13.8 (1.05)^{cde}	0.27	0.24	1.35^{cd}	3.85	4.29^{bc}
M_3S_1: CT + Soil test based	12.6 (0.96)^{g}	0.25	0.29	1.18^{fgh}	3.78	3.64f^{gh}
M_3S_2: CT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	15.8 (1.20)^{ab}	0.31	0.34	1.58^{a}	3.85	3.57^{gh}
M_3S_3: CT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	12.8 (0.95)^{efg}	0.27	0.20	1.16^{ghi}	3.98	3.83^{efg}
M_3S_4: CT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	12.7 (0.98)^{g}	0.19	0.28	1.26^{def}	4.31	4.07^{cde}
M_3S_5: CT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	14.7 (1.13)^{bc}	0.25	0.35	1.43^{bc}	4.30	3.42^{h}
C.D (0.05)	**1.1**	**NS**	**NS**	**0.1**	**NS**	**0.29**
SE(m)	**0.38**	**0.01**	**0.02**	**0.04**	**0.14**	**0.10**

Table 4. Interaction effect of tillage and variable doses of potassium and magnesium sulphate on grain yield of cowpea

Treatment	Grain yield per plot (kg /25 m^2)		
	2017	**2018**	**Pooled**
Tillage			
Zero tillage (ZT)	1.4^{b}	1.8^{b}	1.6^{b}
Minimum tillage (MT)	2.0^{a}	1.7^{b}	1.9^{a}
Conventional tillage (CT)	1.2^{c}	2.0^{a}	1.6^{b}
C.D (0.05)	**0.1**	**0.1**	**0.1**
Nutrients			
S1- K_2O 12 kg/ha + $MgSO_4$ 80 kg/ha (Soil test)	1.6^{b}	1.6^{c}	1.6^{b}
S2- K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	1.4^{c}	1.6^{c}	1.5^{c}
S3- K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	1.4^{c}	1.8^{bc}	1.6^{b}
S4- K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	1.9^{a}	2.2^{a}	2.0^{a}
S5- K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	1.5^{bc}	1.9^{b}	1.7^{b}
C.D (0.05)	**0.2**	**0.1**	**0.1**
Interaction			
ZT + K_2O 12 kg/ha + $MgSO_4$ 80 kg/ha (Soil test)	1.2^{cd}	2.0^{cd}	1.6^{defg}
ZT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	1.1^{cd}	1.3^{g}	1.2^{i}
ZT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	1.1^{d}	1.8^{def}	1.4^{h}
ZT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	1.7^{b}	2.0^{bcd}	1.8^{cd}
ZT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	1.8^{b}	1.7^{ef}	1.7^{cdef}
MT + K_2O 12 kg/ha + $MgSO_4$ 80 kg/ha (Soil test)	2.6^{a}	1.6^{f}	2.1^{b}
MT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	1.8^{b}	1.7^{ef}	1.7^{cdef}
MT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	2.0^{b}	1.3^{g}	1.6^{defg}
MT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	2.5^{a}	2.1^{bc}	2.3^{a}
MT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	1.2^{cd}	1.8^{cde}	1.5^{gh}
CT + K_2O 12 kg/ha + $MgSO_4$ 80 kg/ha (Soil test)	1.1^{d}	1.3^{g}	1.2^{i}
CT + K_2O 20 kg/ha + $MgSO_4$ 60 kg/ha	1.3^{cd}	1.9^{cde}	1.6^{defg}
CT + K_2O 20 kg/ha + $MgSO_4$ 80 kg/ha	1.1^{d}	2.2^{b}	1.6^{defg}
CT + K_2O 40 kg/ha + $MgSO_4$ 60 kg/ha	1.4^{c}	2.5^{a}	1.9^{bc}
CT + K_2O 40 kg/ha + $MgSO_4$ 80 kg/ha	1.4^{c}	2.2^{b}	1.8^{cd}
C.D (0.05)	**0.3**	**0.3**	**0.2**

Similarly, Mg nutrition increases chlorophyll content and leaf area, hence application of $MgSO_4$ @ 60 kg/ha also might be another reason for higher grain yields of cowpea. Similarly, White and Broadley [14] observed that in plant system, magnesium is phloem mobile and is readily translocated to actively growing parts of crop. Though key function of Mg is phloem loading, it also plays vital role in chlorophyll formation, accelerating rate of photosynthesis, in physiological processes, a co-factor and allosteric modulator for more than 300 enzymes including Calvin cycle, kinases, RNA polymerases and ATPases [15,16,17]. Increase in crop yield was observed in faba bean with foliar application of Magnesium [18-20].

4. CONCLUSION

From the results obtained it can be concluded that, practicing herbicide based zero tillage increases root spread of the cowpea compared to other tillage systems. Cowpea having a deep tap root system yields higher under conservation tillage practices and the crop responses well to the application of potassium and magnesium sulphate fertilization. Conservation tillage results in higher LAI, leading to improved yield. Adoption of minimum tillage along with application of potassium and magnesium sulphate @ 40:60 kg/ha can be followed in rice fallow cowpea production for good LAI, root development and higher grain yield of cowpea in soils deficient in potassium and magnesium.

HIGHLIGHT

This study could identify best tillage system and K and MgSO4 doses for improved physiological parameters and higher yield in grain cowpea.

DISCLAIMER

Some part of this manuscript was previously presented in the conference: 3rd International Conference IAAHAS-2023 "Innovative Approaches in Agriculture, Horticulture & Allied Sciences" on March 29-31, 2023 in SGT University , Gurugram, India. Web Link of the proceeding:
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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