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Effect of Intercropping Systems with Different Levels of Sulphur on Protein Content, Nitrogen Uptake and Yield Attributes of Mungbean

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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

Mungbean is the most important crop in arid Rajasthan. Improving productivity by improving soil fertility is essential for farmers' economic viability. The effect of sulphur graded doses on yield attributes of mungbean grown as (mungbean + sesame) intercropping was studied in the field. For these four sulphur levels, *viz*., 0, 15, 30, and 45 kg sulphur ha^{-1} in five intercropping systems, *viz*., sole mungbean and sole sesame, mungbean + sesame in 2:1, 3:1, and 4:1. Harvest index, MEY, LER, N concentration, total nitrogen uptake, protein content, seed, and straw yield were all significantly higher than other crop yield attributes. Mungbean protein content, nitrogen content, uptake, and yield were highest when mungbean and sesame (4:1) was used, with levels reaching 45 kg S ha^{-1}. In case of sulphur, the maximum quality parameters were observed when sulphur was applied to 45 kg ha^{-1} of mungbean.

Keywords: MEY; LER; protein content; nitrogen uptake; harvest index; mungbean yield.

1. INTRODUCTION

"Mungbean scientifically known as *Vigna radiate* (L.) Wilczek is a plant species in the legume family and commonly called as moong in India. India is its primary origin and is mainly cultivated in East Asia, Souteast Asia and the Indian subcontinent. It is the third important pulse crop of India grown in nearly 16% of the total pulse area of the country" [1]. "The important mungbean producing states in the country are Rajasthan, Maharashtra, Andhra Pradesh, Madhya Pradesh and Bihar. Andhra Pradesh ranks 6^{th} in mungbean production with 0.83 lakh tonnes under an area of 1.13 lakh ha with productivity of 735 kg/ha according to third advance estimates of 2020-21 (DES, AP). It contains 24.7% protein, 0.6% fat, 60% carbohydrate, 0.9% fiber and 3.7% ash. It can also be used as a green manure crop in certain areas" [2,3]. "Crops, as well as every other living organism, require certain amounts of nutrients for a normal and healthy life. Each nutrient plays a different role, regarding crop growth and development" [4]. "Green gram is generally grown as a rain-fed crop during Kharif season" [5]. "Intercropping is practiced because of some of the established and anticipated advantages, such as greater yield stability and land-use efficiency, increased competitive ability towards weeds and extraction of resources from different depths of soil" [3,6]. The main advantage of intercropping is that the component crops are able to use resources differently and make better use of resources than when grown separately [7-9].

"The system of intercropping not only improves the yield and net returns but also reduces the risk of complete crop failure as compared to the sole cropping system" [10]. The yield advantage obtained through intercropping is owing to efficient utilization of available growth resources like water, nutrients [11,12] and sunlight. Intercropping, besides utilizing growth resources efficiently, suppressed weeds and disease-pest incidences [13,14], resulting in an overall improvement in crop production over sole cropping with an efficient land-use system. "Crop rotation with cereals and legumes, as well as organic manure addition and optimal N P K application to the soil system, are crucial for maize-chickpea crop yield and soil health" [15,5]. Sulphur plays an inevitable and imperative role in the formation of amino acids, viz. methionine and cysteine. It is also associated with synthesis of vitamins, metabolism of carbohydrates, proteins and fats [16,17]. Sulphur deficiency results in poor flowering, fruiting and cupping of leaves, reddening of stems, petioles and stunted growth [18,17]. Keeping these considerations in view, the present experiments was carried out on growth, yield and quality parameters as influenced by different sulphur levels of (Mungbean + Sesame) intercropping system.

2. MATERIALS AND METHODS

A field experiment was conducted during the kharif season of 2017-18 at Agriculture Farm of O.P.J.S. University, Churu district of Rajasthan, India. Experiments comprise of twenty treatments including five inter-cropping systems (Cropping history Table 1) *viz.,* sole mungbean (var.-RMG-268), sole sesame (var.-RT-125), mungbean + sesame in 2:1, 3:1 and 4:1 row magnitude relation with 4 sulphur levels *viz.,* 0, 15, 30 and 45 kg sulphur ha^{-1}. An experiment was conducted in RBD with three replications. The soil samples were collected during the crop season prior to both the sowing of both the mungbean and sesame crops. The collected soil samples were ground passed through 2 mm sieve and kept in air-tight plastic containers. Soil was used for analysis of different physico-chemical parameters. The turbid metric method outlined by [19] is used for the determination of sulphur in soil. Available nitrogen was estimated by Kjeldhal's method [20]. Phosphorus was estimated by the ammonium vando-molybdate yellow colour method as described by Chapman and Pratt (1961). Potassium was estimated by flame photometer [20]. The chemical characters like pH [21], EC [22], Soil organic carbon [23]. The soil of experimental plots is loamy sand in texture, alkaline in soil reaction (pH 8.2), low in organic carbon (0.16%), available nitrogen (132.5 kg ha^{-1}), available phosphorus (16.0 kg P_2O_5 ha^{-1}), on the available SO_4 -2-S (8.16 mg kg^{-1}) and available potassium (142.2kg K_2O ha^{-1}) content. The mungbean equivalent yield was calculated by converting the grain yield of sesame into mungbean yield on the basis of existing market price. Crops were raised as per standard methods and practices. Observations on the growth and dry matter yield of mungbean and sesame were recorded. The mungbean equivalent yield was calculated by changing the seed yield of sesame into mungbean yield on the premise of existing market costs of the crops. The different parameters of the mungbean crop were analysed. Data was subjected to an analysis of variance. The mean values were grouped for comparisons and the least significant differences among them were calculated at $P< 0.05$ confidence level using ANNOVA statistics [24].

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Attributes

3.1.1 Seed, straw yield and harvest index

It is evident from data (Table 2) that among different intercropping systems, the sole mungbean gave significantly the highest seed yield (1207 kg ha^{-1}) as compared to all intercropping in different row ratios. The increase in seed yield under sole mungbean was 70.48, 43.35 and 24.30 per cent as compared to 2:1, 3:1 and 4:1 row ratios, respectively. Among intercropping, 4:1 row ratio also recorded significantly higher seed yields over 2:1 and 3:1 row ratios to the tune of 37.15 and 15.32 per cent, respectively. Application of increasing levels of sulphur to 30 kg ha^{-1} produced significantly higher seed yield (986 kg ha^{-1}), which was 23.40 and 9.80 per cent higher over control and 15 kg S ha^{-1}, respectively. The sole mungbean gave significantly the highest straw yield (2457 kg ha^{-1}). The increase in straw yield under sole mungbean was 64.12, 42.76 and 26.65 per cent over 2:1, 3:1 and 4:1 row ratios, respectively. The intercropping in 4:1 row ratio also recorded significantly higher straw yields over 2:1 and 3:1 row ratios, which were higher by 29.60 and 12.72 per cent, respectively. Application of graded levels of sulphur upto 30 kg/ha significantly increased the straw yield of mungbean. The increase in straw yield was 15.93 and 6.86 per cent higher as compared to control and 15 kg S ha^{-1}, respectively. The harvest index of mungbean cannot be affected significantly by different intercropping systems and sulphur. The seed and straw yields, being the function of growth and yield attributes, are reduced with the reduction in these parameters under the influence of intercropping. The best productivity in terms of mungbean equivalent yield (1.21 t ha^{-1}) was obtained under sole mungbean followed by mungbean + sesame, at 4:1. Higher growth and yield of mungbean and sesame was recorded with an increase in levels up to 45 kg S ha^{-1} [2]. These results are in close conformity with those of [25] who reported significant reduction in yield of chickpea when grown in association with mustard. [26] Also reported reduction in seed yield of pigeonpea, soybean, mungbean, urad bean and rajmah in intercropping with pigeonpea as compared to their sole stands. [27] Also reported seed and straw yield of fenugreek crop was found, the maximum 300 gm pot^{-1} of vermicompost and followed by FYM and Rhizobium. [28] Also reported application of 90 kg K_2O ha^{-1} and 40 kg S ha^{-1} significantly increased the yield of berseem crop. Application of poultry drainage @ 3 tons/ha increased the number of primary branches per plant, plant height and yield with maximum formation of nodules on plants of green gram [29].

3.2 Mungbean Equivalent Yield and Land Equivalent Ratio

A perusal of data (Table 3) indicated that among the different intercropping systems, the sole planting of mungbean, being at par with 4:1 row ratio, recorded, significantly the highest mungbean equivalent yield, the which was 73.67, 19.15 and 12.49 per cent higher as compared to sole sesame, 2:1and 3:1 row ratios, respectively. The 4:1 row ratio also produced significantly higher equivalent yield by 66.47, 14.21 and 7.83 per cent as compared to sole sesame, 2:1 and

3:1 row ratios, respectively. Further reference to data showed a significant increase in mungbean equivalent yield due to the application of increasing levels of sulphur to 45 Kg ha^{-1}. Application of 45 kg S ha^{-1} represented an increase of 32.65, 16.73 and 5.95 per cent over control, 15 and 30 kg S ha^{-1}, respectively. Among the different intercropping systems, 4:1 row ratio recorded the significantly highest land equivalent ratio as compared to all other intercropping systems (Table 3) further indicated that increasing levels of sulphur, upto 45 kg ha^{-1} recorded the significantly highest land equivalent ratio as compared to control, 15 and 30 kg S ha^{-1} by 16.84, 8.82 and 3.74 per cent, respectively. Agricultural production in sufficient quantities in a sustainable way is today's greatest challenge. The sustainable way here means without deteriorating the soil health. In the current scenario, the cultivation of high yield varieties with synthetic fertilizer and agrochemicals helps to produce the required food demand from a growing population but in discriminate and imbalanced use of agrochemicals imparting negative effects on soil productivity, environmental health and food quality [30]. A significant effect of different intercropping systems on mungbean equivalent yield was observed (Table 3). The sole planting of mungbean remaining at par with 4:1 row ratio gave significantly the highest mungbean equivalent yield (MEY) as compared to sole sesame, 2:1 and 3:1 row ratios. The higher equivalent yield of mungbean under sole planting might be due to higher production per unit area of mungbean along with higher prices of produce. But the highest land equivalent ratio (LER) was found, under 4:1 row ratio as compared to 2:1, 3:1 row ratios and sole crops. [31] While studying the groundnut + sesame intercropping system at Akola, we have also reported that the maximum groundnut equivalent yield was obtained under the pure stand of groundnut. The higher LER under intercropping might be due to biological efficiency of the system in terms of yield per unit area.

3.3 Nutrient Concentration, Uptake and Quality Parameters of Mungbean

3.3.1 Nitrogen concentration in seed and straw

It is evident from data (Table 4) that the sole mungbean, being at par with 4:1 row ratio, gave the significantly highest nitrogen concentration in seed as compared to 2:1 and 3:1 row ratios. The increase in nitrogen concentration under sole mungbean was 10.17 and 5.19 per cent over 2:1 and 3:1 row ratios, respectively. The 4:1 row ratio, being at par with 3:1 row ratio, also increased the nitrogen concentration by 5.29 per cent over 2:1 row ratio. A further reference to data showed that increasing sulphur levels to 30 kg/ha significantly increased the nitrogen concentration in the seed of mungbean, indicating an increase of 12.22 and 5.66 per cent over control and 15 kg S ha^{-1}, respectively. The different intercropping systems did not affect the nitrogen concentration in straw of mungbean significantly. Application of sulphur up to 30 kg/ha significantly increased the nitrogen concentration in the straw of mungbean. The increase in nitrogen concentration due to 30 kg S ha^{-1} was 12.63 and 5.94 per cent over control and 15 kg, respectively. Application of 90 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} significantly increased the nutrient content and uptake of green gram [32].

3.3.2 Total uptake of nitrogen

A perusal of data (Table 4) indicated that all the intercropping systems were significantly different from each other so far as total nitrogen uptake by mungbean is concerned. The sole mungbean gave significantly the highest total nitrogen uptake, which was 81.05, 48.44 and 29.55 per cent more, as compared to 2:1, 3:1 and 4:1 row ratios, respectively. The total nitrogen uptake by mungbean under 4:1 row ratio was 39.75 and 14.57 per cent higher compared to 2:1 and 3:1 row ratios, respectively. A critical examination of data showed that increasing sulphur levels significantly increased the total uptake of nitrogen by mungbean. Application of 45 kg S ha^{-1} significantly enhanced the total nitrogen uptake, indicating an increase of 49.56, 26.66 and 10.84 per cent over control, 15 and 30 kg S ha^{-1}, respectively. A significant increase in nitrogen concentration in seed and sulphur concentration in seed and straw and protein content in seed of sole mungbean was recorded as compared to different intercropping systems. The higher total nitrogen and sulphur uptake under sole crops as compared to their intercropping systems was primarily due to increased seed yield under sole mungbean as compared to yield obtained under intercropping [3,29]. The recorded significantly higher uptake of total nitrogen by sole clusterbean and sesame [33].

Table 1. Cropping history of the experimental field

Years	*Kharif* Season	*Rabi* Season
2014-15	Pearl millet	Mustard
2015-16	Clusterbean	Fallow
2016-17	Guar	Cumin
2017-18	Mungbean+sesame*	Mustard

Table 2. Effect of intercropping systems and sulphur on yields and harvest index of mungbean

Treatments	Seed yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest index (%)
A. Intercropping systems			
Mungbean sole	1199	2578	31.73
Mungbean + sesame (2:1)	700	1565	30.88
Mungbean + sesame (3:1)	834	1801	31.54
Mungbean + sesame (4:1)	963	2032	32.11
SEm +	22	49	0.79
CD (*P=0.05*)	64	142	NS
B. Sulphur (S Kg ha^{-1})			
0	791	1786	30.60
15	890	1939	31.42
30	978	2074	32.01
45	1038	2177	32.23
SEm +	22	49	0.79
CD (*P=0.05*)	64	142	NS
NS=Non significant			

Table 3. Effect of intercropping systems and sulphur on mungbean equivalent yield (MEY) and land equivalent ratio (LER)

Treatments	MEY (Kg ha^{-1})	LER
A. Intercropping systems		
Mungbean sole	1207	1.01
Sesame sole	695	1.01
Mungbean + sesame (2:1)	1013	1.06
Mungbean + sesame (3:1)	1073	1.02
Mungbean + sesame (4:1)	1157	1.02
SEm +	21	0.02
CD (*P=0.05*)	60	0.05
B. Sulphur (S Kg ha^{-1})		
0	873	0.94
15	992	1.01
30	1093	1.06
45	1158	1.11
SEm +	19	0.01
CD (*P=0.05*)	54	0.04

3.4 Protein Content

The quality parameters such as protein content were significantly influenced by different intercropping systems (Table 4). The increase in protein content under sole mungbean was 10.17, 5.19 and 4.62 per cent as compared to 2:1, 3:1 and 4:1 row ratios, respectively. The 4:1 and 3:1 row ratios, being at par with each other, also increased the protein content in seed significantly by 5.30 and 4.73 per cent over 2:1 row ratio, respectively. Application of increasing levels of sulphur increased to 45 kg ha^{-1} significantly increased the protein content in the seed of mungbean. The protein content in seed with 45 kg S ha^{-1} registered an increase of 17.24, 10.40 and 4.49 per cent as compared to control, 15 and 30 kg S ha^{-1}, respectively. Application of 90 kg

K_2O ha^{-1} and 40 kg S ha^{-1} significantly increased the protein content and sulphur uptake of berseem [34,28]. Rhizobium 30g/pot produced significantly higher protein content and fenugreek yield than other Rhizobium treatment and control [35]. Application of 90 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} significantly increased the protein content and yield of green gram [36].

3.5 Sulphur Concentration in Seed and Straw

A reference to data in Table 5 indicated that among the different intercropping systems, the sole mungbean, being at par with 4:1 and 3:1 row ratios, recorded significantly the highest sulphur concentration in the seed of mungbean which was 9.77 per cent higher over 2:1 row ratio. The 4:1 and 3:1 row ratios being at par with each other also increased sulphur concentration in seed by 4.56 and 3.58 per cent as compared to 2:1 row ratio, respectively. The sulphur concentration increased significantly with increasing levels of sulphur. Application of 45 kg S ha^{-1} significantly increased the sulphur concentration in seed, indicating an increase of 31.87, 15.01 and 6.82 per cent over control, 15 and 30 kg S ha^{-1}, respectively. Among the different intercropping systems, the sole mungbean recorded the significantly highest sulphur concentration in the straw of mungbean. The sole mungbean recorded 9.65, 8.16 and 7.43 per cent higher sulphur concentration in straw as compared to 2:1, 3:1 and 4:1 row ratios, respectively. The 2:1, 3:1 and 4:1 row ratios were at par with each other in sulphur concentration in straw. Data (Table 5) further showed that increasing levels of sulphur up to 30 kg/ha significantly improved the sulphur concentration in straw. Application of 30 kg S ha^{-1} enhanced the sulphur concentration in straw by 24.41 and 8.96 per cent over control and 15 kg S ha^{-1}, respectively. Similarly [34,28] reported that application of 90 kg K_2O ha^{-1} and 40 kg S ha^{-1} significantly increased the sulphur content and sulphur uptake of berseem.

3.5.1 Total sulphur uptake

Data presented in Table 5 indicates that the significantly highest total sulphur uptake by mungbean is observed under sole mungbean as compared to all other intercropping systems. The sole mungbean gave 83.94, 51.61 and 33.00 per cent higher total sulphur uptake as compared to 2:1, 3:1 and 4:1 row ratios, respectively. The intercropping in 4:1 row ratio also recorded significantly higher sulphur uptake, registering an increase of 38.30 and 13.99 per cent over 2:1 and 3:1 row ratios, respectively. A study of data in Table 5 indicated that application of sulphur in increasing levels up to 45 kg ha^{-1} significantly increased the total sulphur uptake by mungbean. The application of 45 kg S ha^{-1} registered an increase of 67.28, 32.67 and 12.46 per cent over control, 15 and 30 kg S ha^{-1}, respectively. It was reported that 90 kg P_2O_5 ha^{-1} and 40 kg S ha^{-1} significantly increased the sulphur uptake of

Table 4. Effect of intercropping systems and sulphur on nitrogen concentration in seed and straw and total nitrogen uptake and protein content in seed of mungbean

Treatments	Nitrogen concentration (%)		Total N uptake	Protein
	Seed	Straw	(Kg ha^{-1})	content (%)
A. Intercropping systems				
Mungbean sole	3.868	1.200	77.63	24.17
Mungbean + sesame (2:1)	3.503	1.143	42.59	21.89
Mungbean + sesame (3:1)	3.673	1.162	52.08	22.95
Mungbean + sesame (4:1)	3.693	1.175	59.74	23.08
SEm +	0.063	0.023	1.70	0.37
CD (*P=0.05*)	0.182	0.065	4.90	1.06
B. Sulphur (S Kg ha^{-1})				
0	3.375	1.065	45.95	21.09
15	3.590	1.137	54.46	22.44
30	3.798	1.209	62.36	23.73
45	3.973	1.269	69.27	24.83
SEm +	0.063	0.023	1.70	0.37
CD (*P=0.05*)	0.182	0.065	4.90	1.06
NS=Non significant				

Table 5. Effect of intercropping systems and sulphur on sulphur concentration in seed and straw and total sulphur uptake of mungbean

Treatments	Sulphur concentration (%)		Total sulphur uptake (Kg ha^{-1})
	Seed	Straw	
A. Intercropping systems			
Mungbean sole	2.315	0.936	7.44
Mungbean + sesame (2:1)	2.733	1.029	3.98
Mungbean + sesame (3:1)	2.663	1.012	4.86
Mungbean + sesame (4:1)	2.643	1.006	5.54
SEm +	0.061	0.020	0.19
CD (*P=0.05*)	0.176	0.057	0.54
B. Sulphur (S Kg ha^{-1})			
0	1.963	0.863	3.94
15	2.535	0.963	5.05
30	2.843	1.052	6.02
45	3.013	1.105	6.80
SEm +	0.061	0.020	0.19
CD (*P=0.05*)	0.176	0.057	0.54

green gram crop [36]. Application of graded levels of sulphur from 0 to 45 kg S ha^{-1} significantly influenced the seed yield, total uptake of nitrogen and sulphur, protein content in seed of mungbean and oil content in seed of sesame over control. Similarly, results [37] observed significantly higher uptake of total nitrogen and sulphur by sole mungbean and sesame intercropping. The maximum values of sulphur uptake but sesame under rainy conditions with application of 60 kg P_2O_5+45kg sulphur ha^{-1}[38].

4. CONCLUSIONS

Developing countries like India need 377 million tonnes of food grain production by 2050 to feed the growing population. Hence, it needs to enhance the productivity of crops mainly in resource-secure areas. In this experiment, a different inter-cropping row was evaluated with graded application of S. Results showed that mungbean- sesame inter-cropping at 4:1 more enhanced the yield attributes in mungbean; whereas, mungbean-sesame 2:1 was more profitable in sesame. Application of S @ 45 kg ha^{-1} improved the quality, nutrient content, uptake and yield attributes of both crops. Such studies are very important to enhance the crop yield potential mostly in arid regions of Rajasthan.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Annual Report. Directorate of Economics & Statistics, Government of Andhra Pradesh; 2020-21.
2. Doutaniya RK, Ghilotia YK, Dotaniya CK, Lata M, Singh N, Reager ML, Balwan, Mohbe S. Influence of growth attributes and sulphur on mungbean (*Vigna radiate*L.) and sesame (*Sesamumindicum* L) intercropping of Rajasthan. International Journal of Agricultural Sciences. 2021;13 (4):10744-10746.
3. Doutaniya RK, Ghilotia YK, Dotaniya CK. Sulphur Levels with Intercropping System of Sesame and Mungbean. Research Book, Lap Lambert Academic Publisher, Germany, ISBN 13-978-6203927948 (eBook). 2021a;1- 120.
4. Dotaniya ML, Meena MD, Meena LK, Dotaniya CK., Ray PK. Soil health management for crop production. Technical Bulletin No. DRMR/SS/2022/1, ICAR-Directorate of Rapeseed-Mustard Research Sewar, Bharatpur. 2022; 57+vii

5. Dotaniya CK, Lakaria BL, Singh M, Sharma Y, Meena BP, Dotaniya ML, Biswas AK, Patra AK, Doutaniya RK. Long-term integrated nutrient management on potassium balance and uptake kinetics in maize– chickpea cropping system in a Vertisol. The Pharma Innovation Journal. 2022a;SP-11(1):1358-1362.
6. Meena RN, Ghilotia YK, Kumar S. Influence of planting pattern and sulphur levels on yield and quality of castor (*Ricinuscommunis*) under eastern Uttar Pradesh condition. Indian Journal of Agronomy. 2019;64 (2):69-73.
7. Chapman HD, Pratt PF. Methods of analysis for soils, plants and waters. University of California, Los Angeles. 1961;60-61:150-179.
8. Dotaniya CK, Lakaria BL, Sharma Y, Biswas AK, Meena BP, Reager ML, Yadav SR, Aher SB. Physiological parameter of Maize as Influenced by INM Modules under Maize-Chickpea Sequence in a Vertisol of Central India. International Journal of Current Microbiology and Applied Sciences. 2020;9(9):2745-2753.
9. Dotaniya ML, Meena VD, Basak BB, Meena RS. Potassium uptake by crops as well as microorganisms. In: Meena VS, Maurya BR, Verma JP, Meena RS (*Eds*.), Potassium solubilizing microorganisms for sustainable agriculture. Springer, India. 2016;267–280.
10. Rao MR, Singh M. Productivity and risk evaluation in contrasting intercropping systems Field Crop Research. 1990;23: 279–293.
11. Bandopadhyay SK, De R. Yield, nitrogen and WUE and soil fertility imperatives of sorghum based intercropping system with seed legumes. Fertilizer News. 1986; 31:15–30.
12. Ofari F, Stern WR. Cereal–legume intercropping systems Advances of Agronomy. 1987;41:41-90.
13. Paoline R, Caporali F, Campiglia E. Intercropping Part II Modification to the cultural environment Rivista de Agronomica. 1988;22:243–257.
14. Venkateswarlu U, Ahlawat IPS. Studies on weed management in pigeonpea based intercropping systems. Indian Journal of Agronomy. 1986;31:184–187.
15. Dotaniya CK, Lakaria BL, Sharma Y, Meena BP, Aher SB, Shirale AO, Gurav PP, Dotaniya ML, Biswas AK, Patra AK, Yadav SR, Reager ML, Sanwal RC, Doutaniya RK, Lata M. Performance of chickpea (*Cicerarietinum* L.) in maize-chickpea sequence under various integrated nutrient modules in a Vertisol of Central India. Plos One. 2022;17(2):e0262652.
16. Dotaniya CK, Lakaria BL, Aher SB, Subhash, Mohbe S, Doutaniya RK. Critical role of potassium in crop production. Agriculture and Food: E-Newsletter, Article ID: 314292. 2020;(9):89-92.
17. Greengram Outlook Report- January to May 2021; Agricultural Market Intelligence Centre, ANGRAU, Lam; 2021.
18. Doutaniya RK, Dotaniya CK, Ghilotia YK, Singh N, Balwan, Sanwal RC, Diwan P, Dautaniya H, Lata M, Singh K, Bhukhar OS, Mohbe S, Bairwa RK. Graded application of sulphur mediated yield attributes of sesame and mungbean grown in sandy soil. The Pharma Innovation Journal. 2022;SP-11(1), 1354-1357.
19. Meena MD, Ray PK, Dotaniya ML, Meena LK, Dotaniya CK. Soil and Water Analysis Techniques. Published by ICAR-Directorate of Rapeseed-Mustard Research Sewar., Bharatpur. 2020;120.
20. Jackson ML. Soil chemical analysis (*Edn*. 2) Prentice Hall of India Pvt Ltd , New Delhi 1973;69–182.
21. Kumar U, Mishra VN, Kumar N, Rathiya GR. Methods of Soil Analysis. Kalyani Publishers New Delhi. 2018;58-60.
22. Richards LA. Diagnosis and improvement of saline and alkaline soils., USDA Hand Book No 60 Oxford and IBH Publishing Company., New Delhi; 1954.
23. Walkley A, Black IA. An examination of degtjareff method for determinationing soils organic matter and a proposed modification of the chromic acid titration method. Soil Science, 1934;34:29-38.
24. Gomez KA, Gomez A. Statistical Procedures for Agricultural Research (2nd edition), John Willey and Sons, New York.1983;1-680.
25. Tripathi HN, Chand S, Tripathi AK. Biological and economical feasibility of chickpea (*Cicerarietinum*) + Indian mustard (*Brassica juncea*) cropping systems under varying levels of phosphorus. Indian Journal of Agronomy. 2005;50(1):31–34.
26. Dudhade DD, Deshmukh GP, Harer PN, Patil JV. Studies on intercropping of pulse crops with pigeonpea under rainfed condition. Legume Research. 2009;32(3): 215-217.

27. Dotaniya CK, Lata M, Singh N. Integrated nutrient management in fenugreek. Research book, lap lambert academic publisher, Research Book, Lap Lambert Academic Publisher, Germany, ISBN-13:978-3330080584 (eBook). 2017;1- 60.
28. Malvi V, Dotaniya CK Reager ML, Dixit HC Doutaniya RK, Mohbe S. Effect of potassium and sulphur on yield, quality and nutrient uptake of winter season berseem (*Trifolium Alexanderinum* L.) in central part of India. Journal Soils and Crops. 2021;31(1):25-31.
29. Mohbe S, Dotaniya CK, Reager ML, Doutaniya RK. Effect of organic manures on productivity of green gram (*Phaseolusradiata* L.) under rainfed condition. Summary XXI Biennial National Symposium of Indian Society of Agronomy. 24–26 October, 2018 at MPUAT., Udaipur., Rajasthan. 2018;520-521.
30. Dotaniya CK, Yashona DS, Aher SB, Rajput PS, Doutaniya RK, Lata M, Mohbe S. Crop performance and soil properties under organic nutrient management. International Journal of Current Microbiology and Applied Sciences. 2020a;9(04):1055-1065.
31. Dahantande BN, Turkhede AB, Kale MR, Suryavanshi BM. Study on intercropping of groundnut and sesame. PKV, Research Journal. 1995;9 (1):83-84.
32. Dharwe DS, Dixit HC, Dotaniya CK, Mohbe S, Doutaniya RK, Jamara P. Influences of phosphorus and sulphur on yield attributes of summer green gram (*Vigna radiate* L.). Journal of Pharmacognosy and Phytochemistry. 2018;7(2):147-149.
33. Meena SL, Shamsudheen M, Dayal D. Impact of row ratio and nutrient management on performance of clusterbean (*Cyamopsistetragonoloba*) +sesame (*Sesamumindicum*) intercropping system. Indian Journal of Agronomy. 2008;53(4):284–89.
34. Malvi V, Dotaniya CK, Dixit HC. Effect of potassium and sulphur on yield and quality of berseem (*Trifolium alexandrinum* L.). Annals of Plant and Soil Research. 2019;21(2):145-148.
35. Dotaniya CK, Niranjan RK, Kumar U, Lata M, Regar KL, Doutaniya RK, Mohbe S, Jadon P. Quality, yield and nutrient uptake of fenugreek as influenced by integrated nutrient management. International Journal of Plant, Soil Science. 2019;29(3): 1-7.
36. Dharwe DS, Dixit HC, Dotaniya CK, Khandagle A, Mohbe S, Doutaniya RK. Effect of phosphorus and sulphur on the yield and nutrient content of green gram International Journal of Chemical Studies. 2019;7(2):01-05.
37. Prajapat K, Shivran AC, Choudhary GL, Choudhary HR. Influence of planting pattern and sulphur on mungbean (*Vignaradiata*) and sesame (*Sesamumindicum*) intercropping under semi-arid region of Rajasthan Indian Journal of Agronomy,. 2012;57(1): 89-91.
38. Salame R, Mishra US, Mohbe S, Subhash, Dotaniya CK, Pahade V, Doutaniya RK, Wagadre D. Influence of Growth and Yield Attributes of Sesame (*Sesamumindicum* L.) by Sulphur and Phosphorus Different Combination Fertilizer Levels under the Rainfed Condition. Indian Journal of Pure and Applied Biosciences. 2020;8(4):115-124.

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