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Residual Effects of Red Gram [*Cajanus cajan* (L.) Millsp.] on Growth, Yield and Quality of Fodder Maize (*Zea mays* L.)

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ABSTRACT

Background: Bio-recycling of crop residues is contemplated as an environment friendly soil enrichment and conservation practice that sustains agricultural productivity in the long run. Legume residues are privileged by the unique nitrogen fixing capacity and rhizospheric properties that enhance soil fertility, thereby reducing the need for chemical nutrient inputs. The present study was conducted to evaluate the residual effect of red gram on fodder maize cultivated as succeeding crop in the southern laterites of Thiruvananthapuram district, Kerala, India.

Methods: The field experiment to assess the effect of red gram residue incorporation on the growth and yield of fodder maize was carried out in the Instructional Farm, College of Agriculture, Vellayani, Kerala during June - August 2019. Fodder maize (African tall) was sown in the plots after incorporation of crop residues of red gram varieties (APK 1 and Vamban (Rg) 3) grown under different planting geometry (40 cm × 20 cm and 60 cm × 30 cm) and NPK doses (40:80:40, 30:60:30 and 20:40:20 kg NPK ha^{-1}) and compared with the package of practices recommendation and in randomized block design (RBD) replicated thrice.

Result: Significantly higher quantities of red gram residues were realised and incorporated in the treatments involving a planting geometry of 40 cm × 20 cm and an NPK dose of 40:80:40 kg NPK ha^{-1} in both varieties used, Vamban (Rg) 3 and APK 1 (T_7 and T_1). Nutrient contents in the residues and decomposition in T_1 and T_7 resulted in the maximum additions in soil, available N, P and K status and dehydrogenase activity. Evaluation of the residual effects of the legume on fodder maize revealed the significantly highest growth and yields in maize raised with chemical fertilizers as per package recommendation and, among the residue incorporated treatments, maximum plant height and fodder yields were recorded in the treatment in which residues of Vamban (Rg) 3 raised at 40 cm × 20 cm spacing and fertilised with 40:80:40 kg NPK ha^{-1} were incorporated, on par with variety APK 1 raised under same management practice. The green fodder yield with residue incorporation was 80-90 per cent that under chemical fertilizer managed treatment. Among the quality parameters, crude protein (9.30%) was the highest with chemical fertilizer application while carbohydrate content (66.23%) was the lowest.

Key words: Fodder, Maize, Quality, Residue, Red gram, Variety, Yield.

INTRODUCTION

Crop residues generated after harvest of the economic produce are critical organic inputs available for recycling. It is estimated that the average annual out turn of crop residues in agricultural fields amounts to 683 million tonnes in the country (TERI, 2020). Incorporation of the crop residues in soil is primarily a means to maintain soil organic matter that results in enhanced biological activity, physical properties and nutrient availability (Antil and Narwal, 2007). Among the agricultural residues, leguminous residues have greater nitrogen benefits and addition in soil reduces the need for mineral N fertilizer application by farmers (Svubure *et al.,* 2010). Keeping this in view, an experiment was undertaken to assess the effect of incorporation of red gram residues raised under different agronomic practices on fodder maize cultivated as succeeding crop in the southern laterites of Thiruvananthapuram district, Kerala.

MATERIALS AND METHODS

The field experiment was conducted in the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala located in the agroecological unit 8 (Southern laterites) during June to August 2019. The site is located at 8°30' N latitude and 76°54' E longitude at an altitude of 29 m above mean sea level. The soil of the experimental site is sandy clay loam belonging to the order Ultisols. The experiment on fodder maize was laid out in RBD in 3 replications with 13 treatments and compared with absolute control. The residues of red gram grown under the treatment combinations of variety, spacing and NPK doses, T_1: APK 1 + 40 cm × 20 cm + 40:80:40 kg NPK ha^{-1}, T_2: APK 1 + 40 cm × 20 cm + 30:60:30 kg NPK ha^{-1}, T_3: APK 1 + 40 cm × 20 cm

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+ 20:40:20 kg NPK ha^{-1}, T_4: APK 1 + 60 cm × 30 cm + 40:80:40 kg NPK ha^{-1}, T_5: APK 1 + 60 cm × 30 cm + 30:60:30 kg NPK ha^{-1}, T_6: APK 1 + 60 cm × 30 cm + 20:40:20 kg NPK ha^{-1}, T_7: Vamban (Rg) 3 + 40 cm × 20 cm + 40:80:40 kg NPK ha^{-1}, T_8: Vamban (Rg) 3 + 40 cm × 20 cm + 30:60:30 kg NPK ha^{-1}, T_9: Vamban (Rg) 3 + 40 cm × 20 cm + 20:40:20 kg NPK ha^{-1}, T_{10}: Vamban (Rg) 3 + 60 cm x 30 cm + 40:80:40 kg NPK ha^{-1}, T_{11}: Vamban (Rg) 3 + 60 cm × 30 cm + 30:60:30 kg NPK ha^{-1}, T_{12}: Vamban (Rg) 3 + 60 cm × 30 cm + 20:40:20 kg NPK ha^{-1} were used for the experiment. The package of practices recommendation of fodder maize (10 t ha^{-1} FYM and 120:60:40 kg NPK ha^{-1}) was taken as T_{13} and an absolute control (without nutrient application), as C.

After the harvest of red gram, crop residues were incorporated in the respective plots. Quantity of residues generated in each treatment was recorded and the amount of nutrients added in the soil by crop residues computed based on the nutrient contents in the residues. The soil dehydrogenase activity was monitored at 20 days interval and the soil chemical properties in each treatment plot were assessed both before and after the experiment as per standard analytical procedures. With the onset of south west monsoon, seeds of fodder maize variety "African tall" (@ 60 kg ha^{-1}) were sown in each plot at a spacing of 30 cm × 15 cm. Nutrients were applied in treatment T_{13} alone, basal dose of FYM @ 10 t ha^{-1} and NPK dose of 120:60:40 kg NPK ha^{-1} using urea, rajphos and muriate of potash as nutrient sources. The crop was harvested for fodder @ 60 DAS and observations on plant height and green fodder yields were recorded. Green fodder samples were dried to compute the dry fodder yields. Fodder quality in terms of protein and carbohydrate content were estimated as per standard procedures. The data were statistically analysed using the F-test (Gomez and Gomez, 1984) and critical differences were computed when treatment effects were found to be significant for comparison.

RESULTS AND DISCUSSION

Quantum of residues produced and nutrient additions

The quantity of residues generated with the different agronomic practices adopted in the two varieties of red gram and the nutrients (N, P and K) accretion possible based on the nutrient contents in the residues are presented in Table 1. The amount of residues produced were significantly the highest (4.83 t ha^{-1}) in T_7 ($v_2s_1n_1$, Vamban (Rg) 3 + 40 cm × 20 cm + 40:80:40 kg NPK ha^{-1}), which was at par with that in treatment T_1 ($v_1s_1n_1$, APK 1 + 40 cm × 20 cm + 40:80:40 kg NPK ha^{-1}). Vamban (Rg) and APK 1 are short duration varieties (100 - 105, 95 - 105 days, respectively) with a yield potential ranging from 0.94 to 1.04 t ha^{-1}. It is reasoned that the better growth and biomass production with the closer spacing and the highest nutrient dose that ensured an adequate supply of the major nutrients were responsible for the superior dry matter production and hence residues available for incorporation. The higher plant population (12 plants m^{-2}) in the closer spacing of 40 cm × 20 cm ensured higher quantum of residues compared to the wider spacing (60 cm × 30 cm). Considering the nutrient contents in the residues, the nutrient accretions possible are estimated to range from 46.58 to 101.19 for N, 4.50 to 16.34 for P and 16.72 to 35.16 for K kg ha^{-1}.

Effect residue incorporation on soil properties

Dehydrogenase activity in soil is considered as an indication of the soil microbial activity (Gu *et al.,* 2009). Monitoring the dehydrogenase activity during decomposition revealed an increase, irrespective of the treatments (Table 2) and the values were maximum at 60 DAI. The treatment T_1 ($v_1s_1n_1$) resulted in significantly the highest dehydrogenase activity at all stages of estimation, the value being 30.13 µ TPF g^{-1} soil 24 hr^{-1} at 60 DAI, on par with the treatment T_7 ($v_2s_1n_1$), 30.12 µ TPF g^{-1} soil 24 hr^{-1}.

Table 1: Nutrient additions through red gram residues in the soil.

Treatments	Quantity of residues (t ha^{-1})	Nutrient content (%)			Nutrients added (kg ha^{-1})		
		N	P	K	N	P	K
T_1	4.75	2.02	0.34	0.61	95.71	16.34	28.79
T_2	4.60	2.02	0.30	0.60	92.92	13.80	27.60
T_3	4.48	1.90	0.27	0.60	85.12	12.28	26.92
T_4	3.05	1.85	0.39	0.62	56.43	11.89	18.85
T_5	2.75	1.68	0.29	0.61	46.20	8.19	16.72
T_6	2.70	2.07	0.18	0.71	55.89	4.97	19.25
T_7	4.83	2.09	0.32	0.73	101.19	15.36	35.16
T_8	4.68	1.99	0.25	0.63	92.89	11.61	29.48
T_9	4.42	2.00	0.20	0.58	88.40	8.84	25.72
T_{10}	3.05	1.74	0.33	0.66	53.07	10.00	20.01
T_{11}	2.65	2.29	0.35	0.77	60.69	9.17	20.46
T_{12}	2.25	2.07	0.20	0.74	46.58	4.50	16.74

The soil chemical properties at the start of the experiment are depicted in Table 3. Perusal of the data reveal that the treatment T_1 recorded the significantly highest organic carbon and available N before sowing and T_7 resulted the significantly highest P and K. The treatment T_1 was at par with T_7. The results indicate that residue incorporation has significant effect on soil chemical properties. The mineralisation of crop residues results in increased NPK availability in soil (Abiven and Recous, 2007).

Growth and yield of fodder maize

The variations in plant height and fodder yield are presented in Table 4. Plants were significantly superior in height (198.00 cm), in T_{13}, (POP-100 per cent nutrient application), indicating the stimulative effect of the readily available nutrients from the chemical fertilizer sources. The shortest plants (156.33 cm) were observed in the absolute control plot in which nether residues nor manures were applied. Green fodder yields followed a similar trend as plant height. The highest green fodder yield and dry fodder yield was observed in POP recommendation (37. 25 and 12.07 t ha^{-1} respectively) and the lowest in absolute control plot (19.67 and 6.13 t ha^{-1} respectively). Among the residue incorporated treatments, T_7 (Vamban (Rg) 3 + 40 cm × 20 cm + 40:80:40 kg NPK ha^{-1}) resulted in significantly tallest plants (183.78 cm), highest green (33.61 t ha^{-1}) and dry (11.37 t ha^{-1}) fodder yield on par with treatment T_1 (APK 1 + 40 cm × 20 cm + 40:80:40 kg NPK ha^{-1}). The yields were 70.86 and 85.48 per cent higher than the absolute control.

Fodder maize in the control plants were the shortest and yields were the lowest bringing to focus that maize being a heavy feeder realizes green yields in accordance with the nutrient absorbed by the crop. Application of fertilizers (T_{13}) coupled with the soil contribution could assure the timely nutrient demand of the crop and hence ensured proper growth and yields. Although the soil nutrient status was lower (Table 3), the nutrients from the chemical fertilizers could supply the nutrient requirement of the crop. On the other hand, in the residue incorporated plots, maize grew on the nutrients added to the soil via the residues and the ease in availability was governed by the mineralisation and activity of soil microorganisms. The release of N through the N fixation and degeneration of root nodules also enhances the N status in soil. The variation in the performance among treatments involving residue incorporation may be ascribed to the quantum of residues generated in red gram and N fixed due to the treatment imposed during its cultivation and the subsequent decomposition. The initial soil nutrient status

Table 2: Effect of residue incorporation on dehydrogenase activity at 20 days interval.

Treatments	Dehydrogenase activity (µ TPF g^{-1} soil 24 hr^{-1})		
	20 *DAI	40 DAI	60 DAI
T_1 : $v_1s_1n_1$	22.84	26.10	30.13
T_2 : $v_1s_1n_2$	22.41	24.38	29.17
T_3 : $v_1s_1n_3$	20.92	23.80	28.79
T_4 : $v_1s_2n_1$	20.35	22.65	29.75
T_5 : $v_1s_2n_2$	20.33	22.07	27.06
T_6 : $v_1s_2n_3$	19.60	20.73	26.68
T_7 : $v_2s_1n_1$	21.69	25.91	30.12
T_8 : $v_2s_1n_2$	21.11	24.95	28.79
T_9 : $v_2s_1n_3$	19.96	24.76	27.83
T_{10} : $v_2s_2n_1$	19.19	22.46	29.37
T_{11} : $v_2s_2n_2$	19.00	21.50	28.41
T_{12} : $v_2s_2n_3$	18.43	21.11	27.64
SEm±	0.21	0.01	0.01
CD (0.05)	0.627	0.016	0.017

*Days after residue incorporation.

Table 3: Changes in soil nutrient status with fodder cultivation.

Treatments	Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Initial	After harvest	Initial	After harvest	Initial	After harvest	Initial	After harvest
T_1: $v_1s_1n_1$	1.58	1.63	225.26	152.94	133.85	113.08	333.45	243.33
T_2: $v_1s_1n_2$	1.53	1.60	223.40	153.13	127.14	111.16	325.48	241.74
T_3: $v_1s_1n_3$	1.50	1.50	218.99	144.50	125.02	108.92	312.99	235.40
T_4: $v_1s_2n_1$	1.47	1.52	219.86	158.68	129.95	113.88	319.36	252.14
T_5: $v_1s_2n_2$	1.45	1.49	215.48	149.85	130.85	112.09	311.45	246.76
T_6: $v_1s_2n_3$	1.41	1.44	211.69	140.33	130.15	107.22	309.34	239.67
T_7: $v_2s_1n_1$	1.57	1.64	223.57	166.30	134.76	111.42	338.24	248.86
T_8: $v_2s_1n_2$	1.54	1.62	219.00	148.05	132.82	108.37	305.23	245.17
T_9: $v_2s_1n_3$	1.51	1.60	218.99	162.08	122.54	100.92	314.78	239.69
T_{10}: $v_2s_2n_1$	1.50	1.54	220.63	168.67	125.55	114.92	335.49	275.48
T_{11}: $v_2s_2n_2$	1.46	1.50	212.72	153.08	127.36	113.20	328.01	251.52
T_{12}: $v_2s_2n_3$	1.41	1.47	209.40	147.63	127.79	102.82	311.49	249.15
T_{13}: PoP	1.37	1.42	178.50	123.18	102.34	85.78	300.28	222.86
SEm±	0.003	0.004	0.08	0.09	0.39	0.73	0.14	0.75
CD (0.05)	0.009	0.013	0.234	0.254	1.151	2.140	0.407	2.199
Absolute Control - C	1.35	1.40	176.70	110.71	100.50	82.67	300.40	214.67

Table 4: Effect of treatments on plant height, yield and quality parameters of fodder maize.

Treatments	Plant height (cm)	Green fodder yield (t ha^{-1})	Dry fodder yield (t ha^{-1})	Protein content (%)	Total carbohydrate (%)
T_1	181.92	32.85	11.08	8.60	68.72
T_2	179.50	32.40	10.95	7.38	71.53
T_3	179.17	32.21	10.71	7.31	74.67
T_4	180.83	30.21	10.87	7.65	70.01
T_5	173.25	28.81	9.92	7.25	73.18
T_6	170.00	28.86	9.82	7.23	77.33
T_7	183.78	33.61	11.37	8.75	69.07
T_8	181.55	32.11	10.52	8.10	72.20
T_9	173.22	31.66	10.74	7.63	76.69
T_{10}	174.08	31.15	10.68	7.86	71.65
T_{11}	168.75	31.08	10.59	7.60	74.61
T_{12}	175.46	29.39	9.91	7.22	77.50
T_{13}: PoP	198.00	37.25	12.07	9.30	66.23
SEm±	3.06	0.35	0.14	0.16	0.24
CD (0.05)	8.974	1.036	0.419	0.479	0.689
Absolute Control - C	156.33	19.67	6.13	6.83	78.53

(Table 3) is a reflection of the treatment effects in red gram and it is evident that T_7 recorded the comparatively highest available N, significantly highest P and K that contributed to the better performance of the maize crop in this treatment. These results are in conformity with the findings of Arif *et al.* (2011).

Quality parameters

It is evident from the data in Table 4 that the protein content was significantly the highest in the treatment T_{13}, where nutrients were given externally as chemical fertilizers. Among the different residue incorporated treatments, T_7 resulted in highest protein content, which was at par with treatment T_1. The absolute control treatment recorded highest carbohydrate content (78.53%) and the significantly lowest was in T_{13} (66.23%). Among the residue incorporated treatments, T_{12} resulted in highest carbohydrate content (77.50%) and the treatment T_1 resulted the lowest (68.72%).

The differences in the amount of protein and carbohydrate were due to difference in N availability (Khan *et al.,* 2014). Increased N availability through chemical fertilizer application and absorption by fodder maize under POP recommended treatment would have caused the higher protein content. In residue incorporation, the plausible reason would be the mineralization of crop residues in soil, resulting in nutrient transformations and their mobility into the plant system for a longer period. Similar results have been reported by Bakht *et al.* (2009) and Almaz *et al.* (2017).

The higher N status in plants would have encouraged catabolism of carbohydrates leading to the lower carbohydrate content in these treatments. Maize in the non manured plants were deprived of N as evidenced by the lowered protein contents resulting in a higher carbohydrate status. These results are in conformity with findings of Patel (2014) and Buso *et al.* (2016). Considering the quality, maize plants were nutritionally better with residue incorporation than fertilizer application.

Changes in soil nutrient status

The soil available NPK was found to decline from the status before fodder maize cultivation (Table 3). Perusal of the data revealed that the maximum content was recorded in treatment T_{10} (168.67, 114.92 and 275.48 kg N, P and K ha^{-1} respectively). The values were the lowest in the treatments T_6, T_9 and T_3 for available N, P and K respectively. The decline noticed in soil NPK status is undoubtedly due to the utilization by the crop for its growth and metabolic activities. Maize crop requires an adequate supply of nutrients particularly N, P and K for its optimum growth and yield (Agba and Long, 2005). Being a soil exhaustive crop, fodder maize can exploit the inherent fertility of the soil to meet its demands and this would have depleted the nutrient status. However, the fertility status in soil with residue incorporation could support the maize crop for satisfactory yields.

The residual effect of the red gram legume and fertilizer treatments in fodder maize was apparent from the results of the study. The direct effect of the legume coupled with the decomposition dynamics of the incorporated residues could raise the fertility status of the soil resulting in fodder yields, nearly 80-90 per cent that realized under the package of practice recommendation illustrating the scope for reducing the external nutrient inputs in the succeeding crops of red gram cultivation, in a cropping sequence.

CONCLUSION

The study brings to focus the residual effect of red gram with respect to residue incorporation and its potential for supporting growth and yields in the nutrient exhaustive maize crop. The yields realized were only 10.83 and 6.16 per cent lower indicating that with residue incorporation substantial portion of the chemical fertilizer needed for maize can be reduced. Among the treatments imposed in red gram, the residues realized with the variety Vamban (Rg) 3 or APK 1 planted at 40 cm x 20 cm and fertilized with 40:80:40 kg NPK ha^{-1} was found to be superior. Taking into account the cost of chemical fertilizers and need for eco-friendly practices, red gram residues can be effectively utilized in cropping systems. Residue incorporation practice can save Rs 16720 ha^{-1} (cost of FYM and chemical fertilizers) compared to PoP recommendation.

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