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Effect of Inclusion of Legumes in Cropping System and their Residue Incorporation on the Yield of Maize

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ABSTRACT

Background: Maize (*Zea mays* L.) is one of the important cereal crops of world. Its multiple uses in food industry made it most demanded crop, but the productivity in India is still low. Inclusion of legumes in the cropping system can help in restoring soil fertility in incredible ways hence, enhancing the crop productivity.

Methods: A field experiment was conducted at B. A. College of Agriculture, AAU, Anand during summer-*kharif* seasons of years 2017 and 2018 to examine the impact of legume crop residue and nitrogen levels on maize crop. Experiment comprised of three legume crops grown in summer season *viz.,* green gram, groundnut and cluster bean, two residue management treatments *viz.,* residue removal and incorporation and three nitrogen levels in *kharif* maize *viz.,* 100%, 75% and 50% recommended dose of nitrogen.

Result: Cluster bean-maize cropping system followed by groundnut-maize cropping system observed for the highest improvement in growth parameters, yield attribute and grain and straw yield. Residue incorporation of summer legumes and full dose of nitrogen in maize was found significant for increasing growth and yield parameters and grain yield of maize. Study indicate that residue incorporation had positive effects on maize growth and yield, however incorporation was not able to reduce the nitrogen requirement through chemical means.

Key words: Cropping system, Legume, Maize, Nitrogen, Residue management.

INTRODUCTION

Maize (*Zea mays* L.) crop considered as “Queen of cereals” due to its versatile uses in food industry. It is the second most widely grown crop in the world and cultivated in tropics, sub-tropics to temperate climate. In India, it is cultivated in 9.20 m ha with the production of 27.80 m tonnes and 2965 kg ha^{-1} productivity (Anonymous., 2020a), however in Gujarat, it is cultivated on 0.40 m ha area with production of 0.80 m tonnes and productivity 2170 kg ha^{-1} (Anonymous., 2020b). As the demand of maize is increasing globally due to its multiple uses, there is a need to enhance its productivity. In the soil, organic matter content is highly related with the fertility of soil due to its contribution in improving soil’s physical, chemical and biological properties. Intensive cropping and tillage system resulted in substantial decrease in soil organic matter levels. Legumes are well known to add significant amount of organic carbon and atmospheric N fixed in the soil by more amount of leaf litter fall and root residue as compare to cereals. Therefore, there is need to assess legume crops in crop sequences as an alternate source for improvement of soil health and N supply in crop sequences.

Cheaper organic source which is abundantly available should be explored to satisfy the nutrient requirement of high yielding crops. The use of alternative organic inputs such as leguminous crop residues could be an option for maintaining soil fertility and sustain crop yields (Zoumane *et al.,* 2000). Crop residues not only supplies all the major and micro nutrients, but also acts as a soil conditioner, improves the physical, chemical and biological properties (Mandal *et al*., 2004).

Diversification of cropping systems by incorporating short duration legume crops in the cereal based cropping sequence may be helpful in regaining the soil health. Legume crop residues can serve good source of plant nutrients and readily available energy for soil microbes because of their high nutrient content, low lignin content and easy decomposition as compare to cereal residue. The contribution of legume residues on productivity of the succeeding maize and their nitrogen economy is not thoroughly investigated. Hence, the present study was carried out with the objective to study the effect of different legume crop and their residue management with different nitrogen levels on growth and yield of maize crop.

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MATERIALS AND METHODS

A field experiment was conducted at B.A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India during summer-*kharif* seasons of years 2017 and 2018. The experimental field had an even topography with a gentle slope having good drainage and loamy sand in texture. The

soil of the experimental field at 0-15 cm depth was low in organic carbon (0.34%) and available N (141.1 kg ha^{-1}), medium in available P_2O_5 (36.2 kg ha^{-1}) and K_2O (226.8 kg ha^{-1}) and slightly alkaline in reaction (pH-8.24, EC-0.18).

Experiment details

The experiment was laid in strip-split plot design with four replications. Three legume crops were grown in summer season and designated in vertical strips *viz.*, green gram (C_1), groundnut (C_2) and cluster bean (C_3). Each legume crop strip had been sub-divided into two horizontal strips, for residue management treatments *viz.,* residue removal (R_0) and residue incorporation (R_1); which further split into three intersectional sub plots designated with three nitrogen levels in succeeding *kharif* maize *viz.,* 100% RDN (N_1), 75% RDN (N_2) and 50% RDN (N_3). The gross plot size was 3.6 m × 5 m and net plot size was 2.4 m × 4 m. green gram, groundnut and cluster bean were grown in summer season of both the years. All legumes in summer season received equal amounts of nutrients *i.e*., 20 kg N and 40 kg P_2O_5 per ha as basal dose. Sowing of legumes were done in February during both years. Harvesting of green gram was done in first fortnight of May and cluster bean and groundnut were harvested in first week of June. Maize *var.* GAWMH 2 was sown as main *kharif* crop and all the treatments were conferred upon it during both the years. The recommended dose of fertilizer for maize crop was 150-65-00 NPK, kg ha^{-1} which given as per treatment.

Residue management

Residue yield was obtained by subtracting the grain yield of legumes of each net plot from their respective total dry biomass (above ground) and computed on hectare basis. Nutrient (N, P and K) content of residue of legumes were estimated by as per the procedures described in Jackson (1973). After incorporation of residue in soil one irrigation was given for proper decomposition. The biomass was allowed to decompose for about 20 days in the field.

Data recording

Five plants were selected and tagged at random from each net plot to record observations on various growth characters at different stages of maize. Five cobs were randomly selected from the net plot produce of maize and used for studying various yield parameters. Grain and straw yield from net plot converted to kg ha^{-1} basis. Harvest index (HI) calculated as the ratio of economic yield to the total biological yield. Seed index calculated by counting and weighing 100 grains of maize grains from composite sample of the produce of the net plot.

Statistical analysis

The statistical analysis of the data of the *kharif* maize were performed in strip-split plot design as per the procedure described by Cochran and Cox (1957). Cropping systems, residue management and nitrogen management data were subjected to an ANOVA and means were compared using t-test, with α= 0.05 level.

RESULTS AND DISCUSSION

Among the three summer legumes, cluster bean produced the highest amount of total residue (haulm+pod residue) followed by groundnut. The nutrient content of cluster bean residue was also found higher which resulted in highest amount of nutrient addition to the soil (76.34 kg ha^{-1} N, 19.42 kg ha^{-1} P and 42.01 kg ha^{-1} K) followed by groundnut crop when residue was incorporated (Table 1).

Effect on succeeding maize

Effect of cropping systems

Growth parameters

Two-year study revealed that plant height of maize at harvest was not affected due to different cropping systems however, significantly higher leaf area at 60 DAS (3505 cm^2), chlorophyll content at 60 DAS (24.18) and dry matter production at 60 DAS and at harvest (5659 and 14187 kg ha^{-1}, respectively) was observed with cluster bean-maize cropping sequence. Groundnut-maize (C_2) cropping sequence gave comparable results with cluster bean-maize (C_3) for leaf area and chlorophyll content (Table 2).

Yield parameters

Cropping systems had significant influence on various yield attributes and grain and straw yields of maize. Cluster bean-maize (C_3) sequence provided significantly the highest cob

Table 1: Yield and nutrient content of summer legume residue and nutrient addition (kg ha^{-1}) in the soil through crop residues incorporation. (Average data of two years).

Crop		Residue yield (kg ha^{-1})	Nutrient content (%)			Addition of nutrients (kg ha^{-1})		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
Green gram	Haulm	2424	1.71	0.16	0.78	41.40	8.88	22.76
	Pod residue	234	1.88	0.17	0.44	4.41	0.89	1.24
	Total	2658	3.59	0.33	1.22	45.81	9.76	23.99
Groundnut	Haulm	3297	1.74	0.21	0.92	57.24	15.99	36.47
	Pod residue	536	1.51	0.12	0.95	8.11	1.45	6.14
	Total	3833	3.25	0.33	1.87	65.36	17.43	42.61
Cluster bean	Haulm	3619	1.79	0.20	0.84	64.86	16.66	36.48
	Pod residue	803	1.43	0.15	0.57	11.49	2.76	5.53
	Total	4422	3.22	0.35	1.41	76.34	19.42	42.01

Table 2: Different growth and yield parameters and grain and straw yield of *kharif* maize as influenced by different treatments (Pool data of two years).

Treatment	Plant height at harvest (cm)	Leaf area 60 DAS (cm^2)	Chlorophyll at 60 DAS (SPAD value)	Dry matter production (kg ha^{-1}) 60 DAS	At harvest	Cob length (cm)	Cob girth (cm)	Number of grains per cob	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	Seed index (g)
Cropping systems (C)												
C_1 : Green gram- Maize	170.8	3250	22.86	5213	13054	15.26	14.45	377.8	2934	5051	36.66	21.65
C_2 : Groundnut- Maize	173.2	3410	23.85	5469	13518	16.13	14.69	391.5	3114	5294	36.95	22.58
C_3 : Cluster bean- Maize	176.2	3505	24.18	5659	14187	16.80	14.78	412.2	3253	5525	36.97	23.47
SEm±	2.0	52	0.28	64	152	0.22	0.19	5.0	38.83	63.99	0.30	0.24
CD at 5%	NS	160	0.86	198	468	0.67	NS	15.3	120	197	NS	0.73
CV %	8.21	10.62	8.14	8.18	7.74	9.34	8.88	8.74	8.68	8.38	5.68	7.25
Residue management (R)												
R_0: Residue removal	169.0	3279	23.06	5306	13234	15.59	14.31	377.8	2899	5018	36.58	21.92
R_1 : Residue incorporation	177.8	3498	24.20	5588	13939	16.53	14.98	409.9	3301	5562	37.14	23.21
SEm±	1.3	34	0.17	43	107	0.13	0.13	3.4	27	47	0.29	0.18
CD at 5 %	4.5	118	0.60	149	370	0.44	0.44	11.8	94	161	NS	0.63
CV %	6.31	8.51	6.21	6.71	6.67	6.71	7.45	7.35	7.41	7.46	6.78	6.85
Nitrogen management in maize (N)												
N_1: 100% RDN	181.6	3556	25.22	6064	14537	17.95	15.62	451.5	3693	6138	37.48	25.70
N_2: 75% RDN	174.2	3402	23.80	5413	13438	15.89	14.54	392.9	3038	5265	36.60	21.89
N_3: 50% RDN	164.4	3207	21.88	4864	12784	14.35	13.76	337.1	2570	4467	36.50	20.11
SEm±	1.0	25	0.14	25	40	0.17	0.13	10.9	27	50	0.27	0.27
CD at 5%	2.8	70	0.40	71	112	0.47	0.76	66.6	77	141	0.76	1.65
CV %	5.37	6.92	5.45	5.72	5.39	5.89	5.78	6.51	5.54	6.15	6.09	5.46

length (16.80 cm) over rest of the sequences however, cob girth of maize was unaffected (Table 2). Cluster bean-maize (C_3) sequence recorded significantly the highest number of grains per cob (412.2), seed index (23.47 g), grain yield (3253 kg ha^{-1}) and straw yield of maize (5525 kg ha^{-1}) as compare to rest of the sequences. Harvest index remained unchanged in all sequences (Table 2).

The positive results of growing preceding legumes on maize growth and yield might be due to increased nitrogen and other nutrients availability in the soil for growing maize. The difference in growth and yield of maize observed between preceding legumes might be due to their different carry over capacity of nitrogen for the succeeding maize crop. Adeleke and Haruna (2012), Ammaji (2014) and Ali *et al.* (2015) also reported similar effect of different preceding legume crops on succeeding maize.

Effect of residue management

Growth parameters

Incorporation of legume residues (R_1) significantly enhanced plant height of maize at harvest (177.8 cm), leaf area at 60 DAS (3498 cm^2), chlorophyll content at 60 DAS (24.20) and dry matter production of maize at 60 DAS and at harvest (5469 and 13939 kg ha^{-1}, respectively) as compare to residue removal (Table 2).

Yield parameters

Similar to growth parameters residue incorporation of different legumes on maize significantly benefitted the yield parameters *i.e.* cob length of maize (16.53 cm), cob girth of maize (14.98 cm) number of grains per cob of maize (409.9), seed index (23.21 g), grain yield (3301 kg ha^{-1}) and straw yield of maize (5562 kg ha^{-1}) as compare to residue removal. However, it failed to influence harvest index of the crop (Table 2).

The findings are in corroboration with the reports of Ammaji (2014), Rajkumara *et al.* (2014) and Ali *et al.* (2015) and it might be due to improved mineralization and of high amount of accumulated nitrogen in the legume residue which was returned to the soil slowly throughout the crop growing period. Addition of organic matter in form of crop residues also boosted availability of other nutrients which might have resulted in better crop growth of maize.

Effect of nitrogen management in maize

Growth parameters

Results indicated that full dose of nitrogen in maize significantly increased plant height at harvest (181.6 cm), leaf area at 60 DAS (3556 cm^2), chlorophyll content at 60 DAS (25.22) and dry matter production at 60 DAS and at harvest (6065 and 14537 kg ha^{-1}, respectively) (Table 2).

Yield parameters

Full dose of nitrogen (100%) in maize significantly influenced cob length (17.95 cm), cob girth (15.62 cm), number of grains per cob (451.5), grain yield (3693 kg ha^{-1}), straw yield (6138 kg ha^{-1}), harvest index (37.48) and seed index (25.70 g) of maize (Table 2).

Improved growth parameters with full dose of N might be due to role of nitrogen in increasing cell division, cell elongation and chlorophyll formation. Similar findings reported by Rekha (2014) and Singh *et al.* (2015).

Relation between growth and yield parameters

Study of relation between different parameters while experimentation is important. Beneficial effect of different treatments on growth of crop, will ultimately result to positive effect on yield parameters and yield of crop. Linear regressions between different maize growth parameters and grain yield and yield parameters and grain yield presented in Fig 1 and Fig 2. Fig 1 shows that maize growth parameters effectively

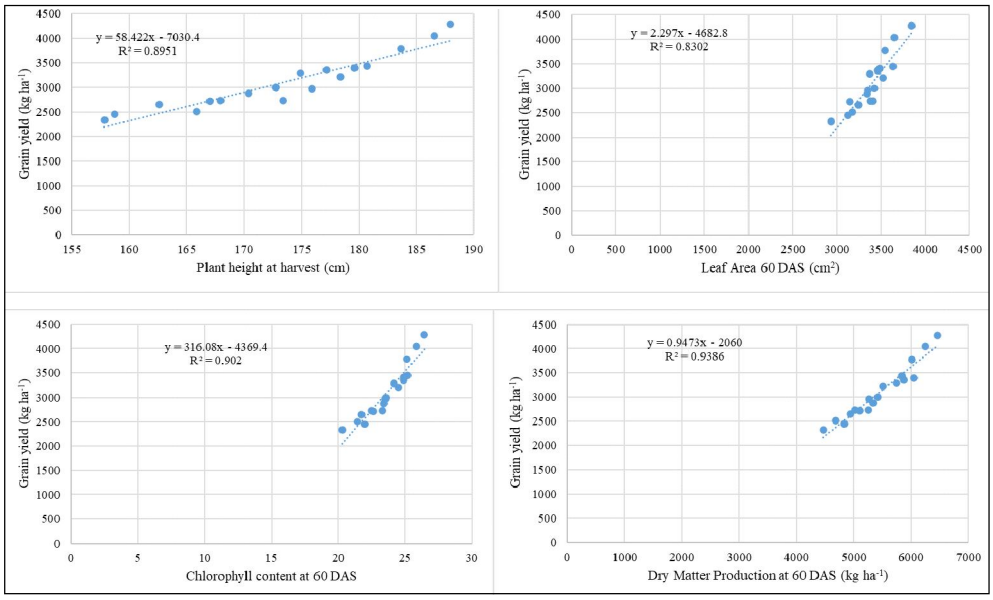

Fig 1: Linear regression between different growth parameters and grain yield of maize.

contribute to the maize grain yield. Plant height at harvest and leaf area at 60 DAS contributes 89% and 83% to grain yield of maize respectively. Moreover, the influence of the chlorophyll content and dry matter production at 60 DAS on the grain yield of maize is greater than plant height and leaf area (90% and 93% respectively). Fig 2 shows that maize grain yield is highly dependent to different yield parameters of maize. Number of grains per cob, cob length, seed index and cob girth strongly influence grain yield of maize with regression coefficients of 0.97, 0.95, 0.94 and 0.92 respectively.

Interaction effect

It was observed that the interaction between residue management and nitrogen management in maize (R x N) found significant, in case of grain yield of maize. The data revealed that residue incorporation of legumes with application of 100% RDN (R_1N_1) resulted in significantly the highest grain yield of maize (4035 kg ha^{-1}) than rest of combinations (Fig 3). Even residue incorporation significantly increases grain yield of maize at all levels of nitrogen. It increased grain yield by 20%, 11% and 7% as compare to residue removal at 100%, 75% and 50% recommended dose of nitrogen application.

Study of all three-factor interaction *i.e.* crping systems, residue management and nitrogen management in maize (C × R × N) revealed that in the second year (2018) interaction was found significant, in case of grain yield of maize. Cluster bean-maize cropping system with residue

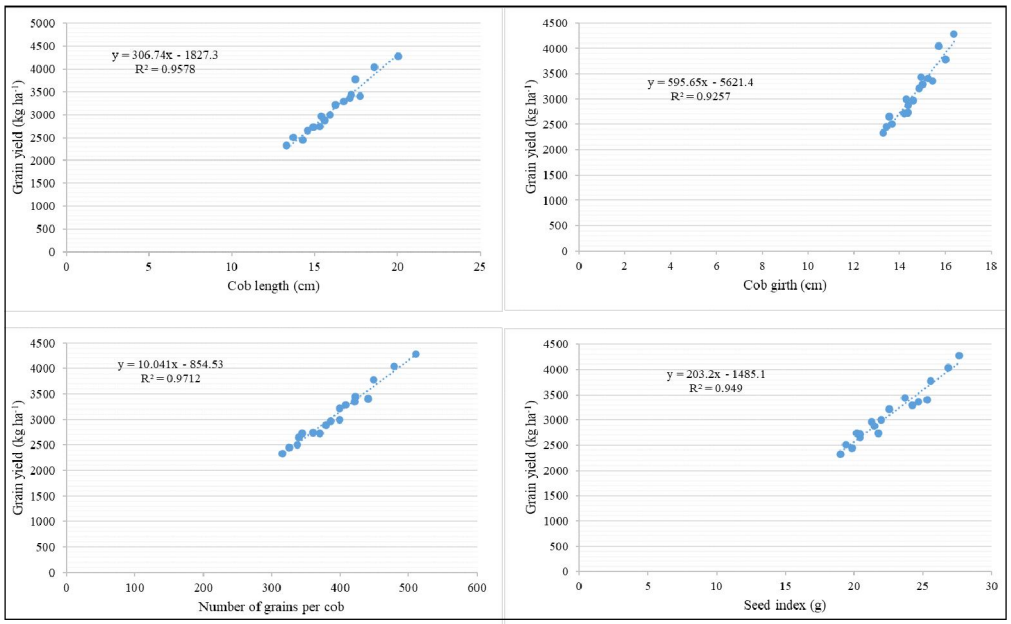

Fig 2: Linear regression between different yield parameters and grain yield of maize.

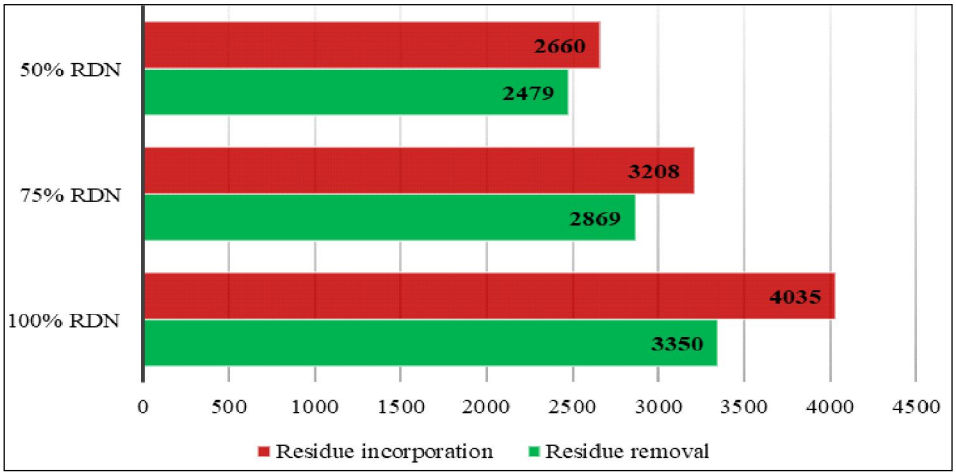

Fig 3: Grain yield (kg ha^{-1}) of maize as influenced by interaction effect of residue management and nitrogen management in maize (R × N) (Pool data of two years).

Fig 4: Grain yield (kg ha^{-1}) of maize as influenced by interaction effect of cropping systems, residue management and nitrogen management in maize (C × R × N) in the year 2018.

incorporation and 100% RDN ($C_3R_1N_1$) recorded significantly higher grain yield of maize (4492 kg ha^{-1}), followed by groundnut-maize cropping system with similar treatment combination ($C_2R_1N_1$) (4130 kg ha^{-1}) (Fig 4).

Residue incorporation of cluster bean and groundnut with 75% RDN application in maize gave comparable results with residue removal with 100% RDN application for grain yield. This indicates 25% saving of fertilizer nitrogen application with residue incorporation of legume crops like cluster bean and groundnut. Further residue incorporation of cluster bean at 100% RDN application improve 25% yield increase over residue removal with similar nitrogen application level. However, the interaction was found significant only in second year it means more repetition of research needed for consistent result.

CONCLUSION

On the basis of results of two years of experimentation with cropping system, residue and nitrogen management, it can be concluded that cluster bean-maize cropping system found to be the best system followed by groundnut-maize cropping system which provided the highest improvement in growth parameters, yield attribute and grain and straw yield of maize. Residue incorporation of summer legumes proved beneficial in improving growth and yield parameters and grain and straw yield that indicated its potential to use as an alternative of organic manure. Study of correlation and regression between growth and yield parameters revealed strong positive relations between growth and yield parameter and maize grain yield. Combined application of residue and nitrogenous fertilizers had positive effects on maize grain yield, however incorporation was not able to reduce the nitrogen requirement through chemical means. Effect of crop residues applied for a short period cannot be assessed as it takes long time to build up organic matter content in the soil and meet the nutrient requirement of crops in a sequence. So long term experimentation is needed to examine the potential of these treatments with respect to reducing nitrogen fertilizer requirement.

Conflict of interest: None.

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