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Nutrient uptake as influenced by live mulching and nitrogen management practices in maize-groundnut sequence

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Abstract
A field experiment was carried out during two consecutive *kharif* and *rabi* seasons of 2015 and 2016 on sandy loam soils of dryland farm of S.V. Agricultural College, Tirupati, Andhra Pradesh. The experiment was laid out in a split plot design with three replications to study the direct and residual effect of live mulching and nitrogen management practices on nutrient uptake. The treatment with no mulching *i.e.* sole maize and treatment live mulching with sunhemp recorded higher total N uptake, nitrogen use efficiency (NUE), higher total P and K uptake at harvest in maize during 2015 and 2016, respectively. Among the nitrogen management practices, substitution of 25 per cent of RDN through either poultry manure (PM) or FYM along with 75 per cent RDN through urea recorded higher total N uptake, NUE, total P and K uptake by maize at harvest than control. Residual effect of live mulching of sesbania and substitution of 25 per cent of RDN through either PM or FYM showed higher total N, P and K uptake by groundnut, respectively.

Keywords: Maize, groundnut, live mulching, RDN, Poultry manure (PM), FYM, nutrient uptake, residual effect

Introduction

Maize is cultivated over an area of 9.38 M ha with a productivity of 3065 kg ha^{-1} in India. In Andhra Pradesh, it is cultivated in an area of 3.36 lakh hectares with a productivity of 6912 kg ha^{-1} (Ministry of Agriculture and Farmers Welfare, GoI, 2018). Maize being a widely spaced crop there will be more weed growth, loss of nutrients and moisture from the soil before it covers the inter row space. Generally herbicides are most frequently used for weed control in maize the negative effects of which include polluted soil environment and contaminated food (Coble, 1994) [3]. Live mulching of *in situ* grown annual legumes in rainfed situations is a useful practice for controlling weeds and reducing loss of moisture as well as nutrients through production of feasible quantity of rich biomass for incorporation under present low chemical sustainable agriculture strategy in maize.

For maize being a highly nutrient responsive crop, water and nitrogen are the critical inputs to acquire the potential yield of modern corn hybrids. However, use of N fertilizer over a longer period results in deterioration of soil health and crop productivity (Hepperly *et al*., 2009) [6]. While, using only organic manures potential yield level of maize cannot be reached because of their low nutrient content and slow releasing nature. Hence, judicious combination of chemical fertilizers along with suitable organic sources is capable to improve soil physico chemical properties and achieve sustainable yield.

Introducing legumes in cereal based cropping systems was known for securing nitrogen economy and increasing yield as well as improving the economy of the system. Groundnut (*Arachis hypogaea* L.) is an important annual legume suitable and involved in crop rotation in sandy loams of Southern Agro - Climatic Zone of A. P. Hence, it was used to study the residual effect of the treatments applied to *kharif* maize as succeeding crop.

In view of the above facts and to generate ample information on direct and residual effect of live mulching and nitrogen supply through organic sources on the nutrient uptake by both the crops, the present study was carried out.

Materials and Methods

The study was conducted at the dryland instructional farm of S.V.Agricultural College, Tirupati, Andhra Pradesh during two consecutive *kharif* and *rabi* seasons of 2015 and 2016. "The soil was sandy loam in texture, neutral in reaction" (pH-6.83), low in organic carbon (0.24%) and available nitrogen (89 kg ha^{-1}) and medium in available phosphorus (24.0 kg ha^{-1}) and available potassium (174.0 kg ha^{-1}). The bulk density of the soil is 1.26 Mg m^{-3} with field capacity 14.4% and permanent wilting point 4.4%. Further, 878.4 mm of rainfall was received during the crop period 2015-16 and 618.3 mm was received during the crop period 2016-17.

The experiment was laid out in split plot design comprising four live mulching practices *viz*., no mulching (M_1), live mulching with sesbania (M_2), live mulching with sunhemp (M_3) and live mulching with cowpea (M_4) "as main plot treatments and four nitrogen management practices" *viz*., no nitrogen (N_1), application of 75% RDN + 25% N through FYM (N_2), application of 75% RDN + 25% N through Poultry Manure (PM) (N_3) and application of 100% RDN (N_4) as sub plot treatments. Two rows of live mulch crop with 20 cm inter row spacing was raised between the maize crop rows and were cut and spread between the same rows at 40 DAS. Recommended dose of fertilizers followed for maize in the experiment was 200-60-50 kg N, P_2O_5 and K_2O ha^{-1}. Organic manures equivalent to 25 per cent RDN were applied two weeks before sowing of maize in the treatments N_2 and N_3. Common dose of P (Single super phosphate) and K (Muriate of potash) was applied to all the treatments and the 75% RDN through urea was applied in three splits at the time of sowing, knee height stage and at flowering stage as per the treatments. Sowing of maize (DHM-117) was done during *kharif* season at a spacing of 60 cm × 20 cm. Groundnut (*var*. Dharani) was sown during *rabi* season at a spacing of 22.5 cm × 10 cm without applying any nutrients in the undisturbed layout of the *kharif* season. Oven dried plant samples collected for dry matter estimation were finely powdered and used for nutrient analysis. N, P and K contents in plant samples were analyzed by micro-kjeldhal, vanado-molybdate and flame photometer methods, respectively. N, P and K uptake by the crops at harvest were calculated by multiplying the nutrient content (expressed in percentage) with the respective weights of dry matter of the crop at the different stages and expressed as kg ha^{-1}. After harvest of the crops in every season soil samples were collected at a depth of 0-30 cm from all the treatments and were analysed for available nitrogen by Alkaline permanganate method, phosphorus by Olsen's method and potassium by Flame photometry, respectively. The data recorded during the course of study were statistically analyzed and presented.

Results and Discussion

Higher dry matter production, P and K accumulation were recorded by the sunnhemp (2.45 t ha^{-1}, 6.0 kg ha^{-1} and 38.7 kg ha^{-1}, respectively) and cowpea (1.73 t ha^{-1}, 6.6 kg ha^{-1} and 22.5 kg ha^{-1}, respectively) than sesbania among the annual legumes used for live mulching in maize. Similarly, sesbania recorded significantly higher nitrogen accumulation (57.7 kg ha^{-1}) in the biomass followed by sunhemp (52.2 kg ha^{-1}).

Nutrient (N, P and K) uptake in *kharif* maize

Effect of live mulching

Total nitrogen uptake at periodical intervals, nitrogen use efficiency (NUE), total P and K uptake at harvest in maize were significantly influenced by the live mulching options and nitrogen management practices during both the years of study as well as in pooled mean and presented in Table 1 and Table 2.

During 2015 as well as in pooled mean treatment with no mulching *i.e* sole maize (M_1) recorded significantly higher nitrogen uptake at 25, 50, 75 DAS and at harvest, higher NUE, higher total P and total K uptake at harvest than the other treatments. It might be attributed to adequate availability of N, P and K nutrients throughout the crop growth in absence of competition due to intercropped annual legumes at early stages. This might have enhanced the vegetative growth which ultimately increased N, P and K uptake and it's concentration in total biomass of the plants (Jat *et al*., 2012) [7]. Higher biological yield and higher N, P and K content in the total biomass may be ascribed as the main pertinent reason for higher uptake of nutrients (Manjhi *et al*., 2014) [16].

Live mulching with sunhemp (M_3) recorded the lowest nitrogen uptake at 25, 50, 75 DAS and at harvest, lower NUE, lower total P and total K uptake at harvest during 2015. Lower uptake of N, P and K might be attributed to the fact that in the presence of adequate to excessive N, legumes switch nitrogen fixation and use the readily available soil N and decreased N fixation resulting in competition for soil N, P and K with maize (Jeranyama *et al*., 2000) [8]. It might also be due to lower sink demand in live mulched treatments which produced lower biological yield than in sole maize (Dustin *et al*., 2012) [4].

During 2016, live mulching with sunhemp (M_3) recorded higher nitrogen uptake at 25, 50, 75 DAS and at harvest, higher NUE, higher total P and total K uptake at harvest than the other treatments. It might be due to higher biomass addition during first year coupled with legume effect of preceding groundnut which might have been resulted in higher nutrient availability, increased biological yield and ultimately higher concentration of N, P and K in the biomass of maize. These results are in conformity with the findings of Chaterjee *et al*. (2017) and Kumawat *et al*. (2018) [13].

Similarly, live mulching with sesbania (M_2) recorded the lowest nitrogen uptake at 25, 50, 75 DAS and at harvest, lower NUE, lower total P and total K uptake at harvest during 2016 as well as in pooled mean. It might be due to higher mining of nutrients and lower biomass addition by sesbania compared to other treatments. N, P and K contribution of legumes is highly variable and comes from desiccation and decomposition of legume plant parts. It mainly depends on species of legumes, dry matter production and N, P and K concentration in the legumes along with indigenous soil N and time of arresting the growth of legumes (Kipling and Reeves, 2005) [10].

Effect of nitrogen management practices

Among the nitrogen management practices, application of 75 per cent of RDN through urea + 25 per cent of N through PM (N_3) recorded significantly higher total N uptake at 25, 50, 75 DAS and at harvest, higher NUE, higher total P and K uptake at harvest. Application of no nitrogen (N_1) registered significantly the lowest total N uptake at 25, 50, 75 DAS and at harvest, lower NUE, lower total P and K uptake at harvest. However, application of 75 per cent of RDN through urea + 25 per cent of N through FYM (N_2) and application of 100 per cent of RDN through urea (N_4) remained statistically on par.

Increase of N, P, and K uptake and higher NUE by maize with the application of 75 per cent of RDN through urea + 25 per cent of N through PM or FYM was attributed to proportionate increase in dry matter production and increase in total biological yield which ultimately increased the total uptake of nutrients (Subbaiah *et al*., 2014) [24]. Application of organic and inorganic sources of nitrogen in maize recorded higher N, P and K uptake which might be due to easy decomposition and synchronized release (Jat *et al*., 2012) [7] and balanced supply of all nutrients to plants at all the stages of crop growth (Paramasivan *et al*. 2011) [20]. These results are in consistent with the findings of Kumar (2015) [12] and Kumawat *et al*. (2018) [13].

Interaction effect of live mulching and nitrogen management practices

Significant interaction of live mulching and nitrogen management practices was found on NUE in pooled mean (Table 3). Treatment combinations involving no live mulching (M_1) along with all the nitrogen management practices recorded higher NUE than the other treatments among which no live mulching along with application of 75 per cent of RDN through urea + 25 per cent of N through PM (M_1N_3) recorded significantly higher NUE and treatment combination live mulching with sesbania along with application of 100 per cent of RDN through urea (M_2N_4) recorded significantly lower NUE. The highest nitrogen use efficiency in sole maize along with substitution of 25 per cent of N through PM or FYM might be attributed to the fact that absence of competition for resources in sole maize and improved physico-chemical properties of the soil with the application of organic nutrient sources. It might have further resulted in adequate availability of nitrogen for longer time providing opportunity to higher uptake of nitrogen, higher biomass production and higher grain yield per unit nitrogen applied than other treatment combinations. These results are in consonance with those of Jeranyama *et al*. (2000) [8], Jat *et al*. (2012) [7], Choudhary and Kumar (2013) [2], Kalhapure *et al*. (2014) [9] and Kumar (2015) [12].

Residual effect

Application of live mulching and nitrogen management practices in preceding maize showed significant influence on nutrient uptake (Table 4 and Table 5) by the succeeding groundnut.

Nutrient uptake in *rabi* groundnut

Residual effect of live mulching

The highest total N, P and K uptake by groundnut was observed in the treatment live mulching with sesbania (M_2) being on par with live mulching of cowpea (M_4) in preceding maize. It was also noticed that no mulching (M_1) recorded the lowest total N, P and K uptake in groundnut during both the years as well as in pooled mean. Increase in total N, P and K uptake was more pronounced in succeeding crop than in companion maize crop might be due to the fact that annual legumes were spread as mulch in maize while their incorporation was done after maize harvest (Singh *et al*., (2011) [22], and it was further attributed to the higher yields of groundnut following application of the mulching materials which led to greater N, P and K uptake (Sharma *et al*., 2010). Kleinhenz *et al*. (1997) [11] and Jeranyama *et al*. (2000) [8] observed higher N uptake in succeeding crop when cowpea and sunhemp intercropped in previous maize due to slow but sustained mineralization of soil organic N which was improved by the addition of higher biomass. Similar findings were reported by Manan *et al*. (2013) [15].

Residual effect of nitrogen management practices

Among the nitrogen management practices, application of 75 per cent of RDN through urea + 25 per cent of N through FYM (N_2) followed by application of 75 per cent of RDN through urea + 25 per cent of N through PM (N_3) in preceding maize recorded higher total N, P and K uptake by the groundnut while, application of no nitrogen (N_1) recorded significantly lower total N, P and K uptake. More N, P and K uptake with the substitution of + 25 per cent of N through FYM or PM might be due to higher nutrient contents in them and influence of soil microorganisms in increasing the availability of nutrients (Mukharjee, 2014) [19] in succeeding crop. Further, better root establishment, resulting in higher absorption of N, P and K to feed and sustain in increased growth lead to higher pod and haulm yield. The N, P and K uptake is the function of yield and N, P and K concentration and yield is more deciding factor for higher N, P and K uptake (Meena *et al*. (2011) [17]. Madhavi (2007) [14] also recorded higher N, P and K uptake by groundnut under residual fertility of application of FYM or PM along with inorganic sources of nutrients.

Significant interaction between the live mulching options and nitrogen management practices was observed in pooled mean of K uptake. The treatment combination live mulching with sesbania along with application of 75 per cent of RDN through urea + 25 per cent of N through FYM (M_2N_2) recorded significantly higher K uptake by groundnut. Further, treatments with no live mulching (M) in combination with all the nitrogen management practices comparable with each other recorded the lowest K uptake among which application of no mulching and no nitrogen (M_1N_1) was the least. Higher K uptake in groundnut under the combination of live mulching of annual legumes along with the conjunctive application of organic (FYM of PM) and inorganic sources of nitrogen in preceding maize might be due to higher K content in the applied manures and their increased availability in the soil resulting in higher pod and haulm yields. Significant interaction between the live mulching options and nitrogen management practices on nutrient uptake was also observed by Jeranyama *et al*. (2000) [8] and Kipling *et al*. (2005) [10].

Table 1: Nitrogen uptake (kg ha^{-1}) by maize as influenced by live mulching and nitrogen management practices during *kharif* season

Treatments	25 DAS			50 DAS			75 DAS			At Harvest		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Live mulching (M)												
M_1: No mulching	20.8	18.1	19.4	62.5	57.3	59.9	79.4	81.7	80.5	118.5	102.7	106.8
M_2: Mulching with Sesbania	15.1	15.6	15.4	49.5	40.4	44.9	64.3	58.8	61.5	92.8	80.2	86.5
M_3: Mulching with Sunhemp	13.0	20.2	16.6	39.5	61.1	50.3	58.8	89.0	73.9	86.9	108.9	97.9
M_4: Mulching with Cowpea	16.9	17.1	17.0	53.8	52.3	53.0	69.3	72.0	70.7	102.1	96.3	97.3
S.Em.±	0.34	0.39	0.27	1.55	0.93	0.73	2.23	2.05	1.44	2.44	4.03	2.22
CD (P=0.05)	1.2	1.4	1.0	5.4	3.2	2.5	7.7	7.1	5.0	8.5	14.0	7.7
Nitrogen management practices (N)												

N_1: No nitrogen	10.5	12.2	11.4	30.4	29.4	29.9	40.6	44.7	42.6	58.5	56.1	57.3
N_2: 75% RDN + 25% N through FYM	18.0	19.0	18.5	59.7	61.2	60.5	78.5	85.1	81.8	112.5	109.7	109.2
N_3: 75% RDN + 25% N through PM	19.7	20.7	20.2	64.6	64.7	64.6	83.5	94.0	88.8	123.5	120.2	120.0
N_4: 100% RDN*	17.6	19.1	18.4	50.6	55.8	53.2	69.1	77.8	73.4	105.7	102.1	102.0
S.Em.±	0.42	0.43	0.29	1.57	1.56	1.12	2.14	2.61	1.59	2.98	3.39	2.26
CD (P=0.05)	1.2	1.3	0.8	4.6	4.6	3.3	6.2	7.6	4.6	8.7	9.9	6.6
Interaction (M x N)												
M at N												
S.Em±	0.80	0.85	0.57	3.12	3.80	2.07	4.32	4.97	3.11	5.71	7.12	4.50
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N at M												
S.Em±	0.68	0.78	0.55	3.10	3.76	1.47	4.45	4.10	2.87	4.88	8.07	4.44
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*100% RDN = 200 kg N ha^{-1}

Table 2: Nitrogen use efficiency, total P and K uptake (kg ha^{-1}) by maize at harvest as influenced by live mulching and nitrogen management practices during *kharif* season

Treatments	NUE			P			K		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Live mulching (M)									
M_1: No mulching	21.9	19.7	20.8	25.8	21.8	23.8	103.6	106.4	105.0
M_2: Mulching with Sesbania	17.7	18.8	18.3	22.6	17.5	20.1	91.0	97.0	94.0
M_3: Mulching with Sunhemp	17.3	20.9	19.1	20.0	23.6	21.8	82.0	111.4	96.7
M_4: Mulching with Cowpea	18.8	19.6	19.2	23.4	20.0	21.7	94.6	101.9	98.2
S.Em.±	0.47	0.28	0.13	0.36	0.53	0.30	1.19	2.09	0.66
CD (P=0.05)	1.6	1.0	0.5	1.3	1.8	1.0	4.1	7.2	2.3
Nitrogen management practices (N)									
N_1: No nitrogen	0.0	0.0	0.0	17.2	12.8	15.0	38.7	44.2	41.4
N_2: 75% RDN + 25% N through FYM	25.2	26.1	25.7	23.5	23.4	23.5	111.0	123.4	117.2
N_3: 75% RDN + 25% N through PM	26.0	27.3	26.7	29.4	26.2	27.8	115.6	129.8	122.7
N_4: 100% RDN	24.5	25.6	25.0	21.7	20.5	21.1	105.8	119.3	112.5
S.Em.±	0.49	0.27	0.16	0.49	0.75	0.38	2.02	1.60	1.12
CD (P=0.05)	1.4	0.8	0.5	1.4	2.2	1.1	5.9	4.7	3.3
Interaction (M x N)									
M at N									
S.Em±	0.97	0.54	0.31	0.92	1.40	0.73	3.70	3.48	2.05
CD (P=0.05)	NS	NS	0.95	NS	NS	NS	NS	NS	NS
N at M									
S.Em±	0.93	0.56	0.27	0.72	1.06	0.60	2.79	4.18	1.32
CD (P=0.05)	NS	NS	0.99	NS	NS	NS	NS	NS	NS

Table 3: Interaction effect of live mulching and nitrogen management practices on NUE of maize in pooled mean

Treatments	N_1	N_2	N_3	N_4	Mean N
M_1	0.0	27.2	28.5	27.7	20.8
M_2	0.0	24.2	25.6	23.3	18.3
M_3	0.0	25.7	26.2	24.4	19.1
M_4	0.0	25.7	26.3	24.8	19.2
Mean M	0.0	25.7	26.7	25.0	
			S.Em.±	CD (P=0.05)	
Factor (M) at same level of N			0.31	0.95	
Factor (N) at same level of M			0.27	0.99	

Table 4: N, P and K uptake (kg ha^{-1}) by *rabi* groundnut as influenced by live mulching and nitrogen management practices imposed to *kharif* maize

Treatments	N			P			K		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Live mulching (M)									
M_1: No mulching	78.2	85.3	81.8	13.2	14.3	13.7	57.1	62.1	59.6
M_2: Mulching with Sesbania	93.3	101.7	97.5	16.3	18.0	17.1	68.4	74.3	71.3
M_3: Mulching with Sunhemp	86.6	92.7	89.6	14.8	16.6	15.7	62.2	65.1	63.7
M_4: Mulching with Cowpea	88.3	96.3	92.3	15.7	17.5	16.6	66.0	71.2	68.6
S.Em.±	1.66	2.12	1.14	0.23	0.22	0.36	1.81	1.10	1.19
CD (P=0.05)	5.7	7.3	4.0	0.8	0.8	1.3	6.3	3.8	4.1
Nitrogen management practices (N)									
N_1: No nitrogen	80.0	77.1	78.5	10.7	11.6	11.0	41.7	45.3	43.5
N_2: 75% RDN + 25% N through FYM	94.4	105.5	100.0	17.4	19.4	18.5	75.4	81.0	78.2
N_3: 75% RDN + 25% N through PM	88.3	98.4	93.4	16.9	18.4	17.7	72.1	77.4	74.7

N_4: 100% RDN	83.6	95.0	89.3	15.1	16.8	16.0	64.4	69.1	66.7
S.Em.±	1.64	1.43	0.98	0.23	0.26	0.30	1.50	1.37	1.05
CD (P=0.05)	4.8	4.2	2.9	0.7	0.8	0.9	4.4	4.0	3.1
Interaction (M x N)									
M at N									
S.Em±	3.28	3.27	2.04	0.45	052	0.63	3.16	2.62	2.17
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	6.8
N at M									
S.Em±	3.33	4.24	2.28	0.51	0.54	0.72	3.63	2.19	2.38
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	6.5

Table 5: Interaction effect of live mulching and nitrogen management practices on K uptake (kg ha^{-1}) by *rabi* groundnut

Treatments	N_1	N_2	N_3	N_4	Mean N
M_1	41.1	68.6	65.5	63.2	59.6
M_2	45.4	87.0	84.9	68.1	71.3
M_3	43.3	75.0	72.0	64.4	63.7
M_4	44.3	82.2	76.6	71.3	68.6
Mean M	43.5	78.2	74.7	66.7	
			S.Em.±		CD (P=0.05)
Factor (M) at same level of N			2.17		6.8
Factor (N) at same level of M			2.38		6.5

Conclusion

From the present investigation it was revealed that live mulching with annual legumes *viz.* sunhemp or cowpea or sesbania had significant direct and residual effect on nutrient uptake over longer period than sole maize. Among the annual legumes live mulching with sunhemp was found to be superior in preceding maize as well as in succeeding groundnut and recorded higher N, P and K uptake. Among the nitrogen management practices substitution of 25 per cent RDN through PM or FYM along with 75 per cent RDN through urea had significant influence on nutrient uptake than 100 per cent RDN through urea and control in preceding maize as well as in succeeding groundnut. Further, combination of sole maize along with the substitution of 25 per cent RDN through PM has higher nitrogen use efficiency in maize whereas, residual effect on nutrient uptake of groundnut was found to be higher with the interaction of live mulching of sesbania along with the substitution of 25 per cent RDN through FYM.

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