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Post harvest nutrient availability as influenced by live mulching and nitrogen management practices in maize – groundnut sequence

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Abstract
An investigation 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 post-harvest nutrient availability in maize – groundnut sequence. Live mulching with annual legumes (sesbania or sunhemp or cowpea) significantly influenced post-harvest nutrient availability. Live mulching with sesbania recorded significantly higher soil available N after harvest of preceding maize as well as succeeding groundnut whereas live mulching with sunhemp recorded significantly higher P_2O_5 and K_2O being on par with cowpea live mulching than no mulching. Similarly, application of 75 per cent of RDN through urea + 25 per cent of RDN through FYM or PM recorded significantly higher soil available N, P_2O_5 and K_2O after harvest of preceding maize as well as succeeding groundnut than100 per cent RDN through urea and control during both the years.

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

Introduction
Maize is cultivated over an area of 9.38 M ha in India with a production of 28.75 M t and productivity of 3065 kg ha^{-1}. In Andhra Pradesh, it is cultivated in an area of 3.36 lakh hectares with a production of 2.32 M t and productivity of 6912 kg ha^{-1} (Ministry of Agriculture and Farmers Welfare, GoI, 2018). Maize is widely spaced crop and it’s canopy closes in about more than a month, during which time, there will be more weed competition, loss of soil moisture and nutrients from the bare soil. Herbicides have become most frequently used weed control strategy in maize, besides being costly, the negative shades of which include deteriorated environment and contaminated food (Coble, 1994) [3]. Live mulching of *in situ* grown annual legumes under rainfed conditions is a useful practice for controlling weed growth and conserving moisture as well as nutrients through production of ample quantity of nitrogen rich biomass for incorporation under present non-chemical sustainable agriculture strategy in maize.

Maize being an exhaustive crop, water and nitrogen are the most critical inputs required to achieve the high yield potential of modern corn varieties. But reliance on use of N fertilizer over longer period results in decline of soil physical properties, chemical properties, soil health and crop productivity (Hepperly *et al.*, 2009) [4]. On the other hand, using only organic manures maximum yield level of maize cannot be achieved because of their low nutrient content but judicious combination of chemical fertilizers along with various organic sources is capable to improve soil quality and higher maize productivity on long term basis.

Legumes in maize based cropping systems are considered to be better alternatives for securing nitrogen economy and increasing yield of maize besides higher net returns of the system. Groundnut (*Arachis hypogaea* L.) known for its oilseed, food and animal feed is an important annual legume suitable and involved in crop rotation in Southern Agro - Climatic Zone of Andhra Pradesh. Hence, groundnut is used as succeeding crop to study the residual effect of the treatments applied to *kharif* maize.

Considering these facts and to generate more information on the their availability for both the crops in response to live mulching and nitrogen supply through organic sources, the study was carried out on “Post harvest nutrient availability as influenced by live mulching and nitrogen management practices in maize – groundnut sequence”.

Materials and Methods

The experiment was carried out at the instructional farm of S.V.Agricultural College, Tirupati, Andhra Pradesh during two consecutive *kharif* and *rabi* seasons of 2015 and 2016. The texture of the soil was sandy loam, 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

Among the intercropped annual legumes in maize, significantly higher dry matter production, phosphorus and potassium accumulation were recorded by 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. Similarly, sesbania recorded significantly higher nitrogen accumulation (57.7 kg ha^{-1}) in the biomass followed by sunhemp (52.2 kg ha^{-1}).

Post harvest soil nutrient status after *kharif* maize

Post harvest nutrient status was significantly influenced by both live mulching and nitrogen management practices applied in maize and were presented in Table 1.

Soil available nitrogen

Significantly higher soil available nitrogen was registered in live mulching with sesbania (M_2) and was followed by live mulching with sunhemp (M_3) being comparable to live mulching with cowpea (M_4). However, treatment with no mulching (M_1) recorded the lowest available nitrogen in the soil after maize harvest during both the years of study as well as in pooled mean. This might be owing to higher atmospheric nitrogen fixation by sesbania and its rapid translocation in to the above ground parts resulting in higher nitrogen content (3.55, 3.61 and 3.58 per cent during 2015, 2016 and pooled mean, respectively) in the biomass. Further, slow decomposition and mineralization of its biomass might have increased the mobility of nitrogen leading to increased soil available nitrogen after maize harvest. Similar results were found in sesbania live mulching by Meelu and Morris (1988) [16] and in sunhemp live mulching by Edje and Mabuza (2014) [5].

Among the nitrogen management practices, application of 75 per cent of RDN through urea + 25 per cent of N through FYM (N_2) recorded significantly higher soil available nitrogen and application of no nitrogen (N_1) registered the lowest available nitrogen in the soil after maize harvest during both the years of study as well as in pooled mean. This might be owing to the slow decomposition and subsequent release of nitrogen trapped in organic matter through the process of aminization, ammonification, and oxidative deaminisation brought about by microbially mediated enzyme systems which are active in PM and FYM, thus contributing more of soluble N (Choudhary and Kumar, 2013) [2]. Combining organic and inorganic sources of nutrients increases synchrony and reduces nitrogen losses by converting inorganic nitrogen into organic forms increasing its availability at later stages was also noticed by Sharma *et al*. (2010) [19]. Similarly, inorganic fertilizers cause immediate release of nutrients, which will be utilized by the crop or may be lost into the environment through leaching or denitrification process hence, low available nitrogen in the treatment with 100% RDN through urea. These results are in conformity with the findings of Manjhi *et al*. (2014) [15] and Kalappanavar and Gali (2019) [11].

Soil available phosphorus

Live mulching with cowpea (M_4) and live mulching with sunhemp (M_3) comparable with each other and recorded significantly higher soil available P_2O_5 than live mulching with sesbania (M_2) during both the years and in pooled mean after maize harvest. Further, sole maize with no mulching (M_1) registered the lowest soil available P_2O_5. It could be due to higher phosphorus content in cowpea (0.37, 0.39 and 0.38 during 2015, 2016 and pooled mean, respectively) and sunhemp biomass (0.22, 0.26 and 0.24 during 2015, 2016 and pooled mean, respectively) coupled with higher biomass production might have resulted in greater accumulation of phosphorus (More, 2003 and Yogesh, 2013) [18, 22]. The availability of accumulated phosphorus might have been increased due to accelerated mineralization by the organic acids resulted from the decomposition of green manure (Ismail, 2013) [8].

With regard to nitrogen management practices, application of 75 per cent of RDN through urea + 25 per cent of N through PM (N_3) which was however, comparable with application of 75 per cent of RDN through urea + 25 per cent of N through FYM (N_2) recorded significantly higher soil available P_2O_5 while, application of no nitrogen (N_1) registered the lowest available P_2O_5 in the soil after maize harvest during both the years of study as well as in pooled mean. This might be due to the fact that irrespective of higher P content in PM and FYM (Kalhapure *et al*., 2014) [12], they might have also improved the population of phosphate solubilizing microorganisms (Gupta, 2014) [6], the activity of which enhanced the mineralization of soil phosphorus coupled with high phosphatase activity which hydrolyze the soil organic phosphorous and split phosphorous from organic residues are the reasons for higher available P_2O_5 in the soil (Choudhary and Kumar, 2013 and Jadhav *et al*., 2017) [2, 9]. Increase in P_2O_5 availability in the soil with the addition of organic manures like PM or FYM or sheep manure was also observed by Jat *et al*. (2012) [10], Kumar (2015) [14] and Kalappanavar and Gali (2019) [11].

Soil available potassium

During both the years of study as well as in pooled mean, live mulching of sunhemp (M_3) being comparable to live mulching with cowpea (M_4) recorded significantly higher soil available K_2O after maize harvest while no mulching (M_1) registered the lowest soil available K_2O. Higher K_2O availability could be due to higher potassium content in sunhemp (1.57, 1.51 and 1.54 during 2015, 2016 and pooled mean, respectively) and cowpea (1.32, 1.29 and 1.31 during 2015, 2016 and pooled mean, respectively) biomass coupled with higher biomass production might have resulted in greater accumulation of potassium in the soil (More, 2003 and Dahmardeh *et al*., 2010) [18].

During both the years of study as well as in pooled mean, application of 75 per cent of RDN through urea + 25 per cent of N through PM (N_3) being comparable with the application of 75 per cent of RDN through urea + 25 per cent of N through FYM (N_2) recorded significantly higher soil available K_2O. It was also found that application of no nitrogen (N_1) registered the lowest available K_2O in the soil after maize harvest. It might be due to the fact that higher potassium content in PM and FYM (Kalhapure *et al*., 2014) [12] and release of organic acids and other microbial products (Badiyala and Chopra, 2011) which might have improved availability of both native as well as added potassium through transformation of solid phase to soluble complex (Tetrawal *et al*. 2011). These results are in consonance with those of Manjhi *et al*. (2014) [15] and Kumar (2015) [14].

Residual effect

Application of live mulching and nitrogen management practices in preceding maize showed significant influence on post harvest nutrient availability after groundnut harvest (Table 2).

Post harvest soil nutrient status after *rabi* groundnut

Residual effect of live mulching

The residual effect of live mulching with sesbania (M_2) in preceding maize recorded significantly higher soil available nitrogen after succeeding groundnut harvest and no mulching (M_1) recorded the lowest available nitrogen in the soil during both the years of study as well as in pooled mean. This might be due to higher N accumulation and higher biomass addition by sesbania which might have lead to formation of organo-mineral complexes and thus ensured prolonged N availability through residual effects (Sharma *et al*., 2010) [19]. These results are in conformity with the findings of Jat *et al*. (2012) [10] and Kaushal *et al*. (2015) [13].

Live mulching with sunhemp (M_3) which was however, comparable to live mulching with cowpea (M_4) recorded significantly higher soil available P_2O_5 and K_2O after groundnut harvest while, the treatment with no mulching (M_1) recorded the lowest soil available P_2O_5 and K_2O during both the years of study. Addition of higher biomass and higher phosphorus and potassium contents in sunhemp and cowpea might have increased their availability in the soil. These results corroborate the findings of Subbaiah (2011) [20] and Jat *et al*. (2012) [10].

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) recorded significantly higher soil available nitrogen and application of no nitrogen (N_1) registered the lowest available nitrogen in the soil after groundnut harvest. The higher availability of nitrogen after groundnut harvest with substitution of 25 per cent of N through FYM or PM in preceding maize might be owing to continuous and slow release of nutrients from FYM or PM and accumulated soil organic matter as reported by Amanullah *et al*. (2006). With repeated additions of FYM or PM to the soil, the N mineralization from highly persistent organic materials encompassed the accumulated effect of all previous season's additions, which in turn increased the available nitrogen content compared to other treatments. These results are supported by the findings of Subbaiah (2011) [20] and Gupta *et al*., 2014) [6].

Application of 75 per cent of RDN through urea + 25 per cent of N through PM (N_3) recorded significantly higher soil available P_2O_5 and K_2O followed by the application of 75 per cent of RDN through urea + 25 per cent of N through FYM (N_2) while, application of no nitrogen (N_1) registered the lowest available P_2O_5 and K_2O in the soil after groundnut harvest during both the years of study as well as in pooled mean. This might be due to the fact that presence of higher phosphorus and potassium contents in PM and FYM. Slow decomposition of these organic manures resulting in the production of organic acids thus increased the nutrient availability through enhanced soil biological activities and release of nutrients from insoluble metal phosphates and from the exchange sites. The increase in soil available K_2O is also ascribed to the reduction in potassium fixation and release of potassium due to interaction of organic and inorganic sources of nutrients. Similar results were noticed by Subbaiah (2011) [20].

Table 1: Influence of live mulching and nitrogen management practices in maize on post-harvest soil available N, P_2O_5 and K_2O (kg ha^{-1})

Treatments	N			P_2O_5			K_2O		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Live mulching (M)									
M_1: No mulching	114.7	117.5	116.1	27.2	32.8	30.0	163.7	174.0	168.8
M_2: Mulching with Sesbania	143.2	163.8	153.5	29.9	35.8	32.9	169.2	184.9	177.1
M_3: Mulching with Sunhemp	135.6	151.4	143.5	31.7	39.6	35.7	179.1	192.3	185.7
M_4: Mulching with Cowpea	134.4	146.8	140.6	33.9	37.7	35.8	173.2	189.3	181.2
S.Em.±	3.02	2.07	1.35	0.68	0.79	0.44	2.09	3.04	1.23
CD (P=0.05)	10.4	7.2	4.7	2.3	2.7	1.5	7.2	10.5	4.3
Nitrogen management practices (N)									
N_1: No nitrogen	105.8	119.1	112.5	24.6	27.6	26.1	161.0	174.7	167.8
N_2: 75% RDN + 25% N through FYM	145.4	161.6	153.5	32.7	39.6	36.2	174.0	188.9	181.4
N_3: 75% RDN + 25% N through PM	140.5	151.9	146.2	34.7	41.3	38.0	183.1	194.7	188.9
N_4: 100% RDN	136.2	146.9	141.6	30.7	37.5	34.1	167.1	182.3	174.7
S.Em.±	2.51	2.89	2.33	0.70	0.85	0.63	3.40	3.75	1.65
CD (P=0.05)	7.3	8.4	6.8	2.0	2.5	1.8	9.9	11.0	4.8
Interaction (M x N)									
M at N									
S.Em±	5.00	5.80	4.25	1.39	1.67	1.17	6.25	7.18	3.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N at M									
S.Em±	5.12	5.87	2.71	1.36	1.57	0.87	4.17	6.08	2.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

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

Table 2: Soil available N, P_2O_5 and K_2O (kg ha^{-1}) after groundnut harvest as influenced by live mulching and nitrogen management practices imposed to *kharif* maize

Treatments	N			P_2O_5			K_2O		
	2015	2016	Pooled	2015	2016	Pooled	2015	2016	Pooled
Live mulching (M)									
M_1: No mulching	95.8	94.8	95.3	22.5	23.4	23.0	142.1	150.5	146.3
M_2: Mulching with Sesbania	109.2	121.6	115.4	25.0	29.2	27.1	149.8	170.8	160.3
M_3: Mulching with Sunhemp	104.3	115.6	110.0	28.1	32.8	30.4	156.0	176.4	166.2
M_4: Mulching with Cowpea	106.1	118.1	112.1	26.6	31.1	28.8	152.3	174.6	163.4
S.Em.±	0.92	2.14	0.94	0.47	0.54	0.33	1.75	1.91	1.70
CD (P=0.05)	3.2	7.4	3.2	1.6	1.9	1.1	6.0	6.6	5.9
Nitrogen management practices (N)									
N_1: No nitrogen	89.8	94.7	92.3	20.3	22.0	23.0	139.3	157.7	148.5
N_2: 75% RDN + 25% N through FYM	113.6	125.4	119.5	27.4	31.9	27.1	156.3	172.6	164.5
N_3: 75% RDN + 25% N through PM	109.3	119.8	114.6	28.8	33.4	30.4	157.7	177.6	167.7
N_4: 100% RDN*	102.7	110.2	106.5	25.6	29.1	28.8	146.8	164.4	155.6
S.Em.±	1.27	1.24	0.71	0.47	0.65	0.33	1.95	1.94	1.68
CD (P=0.05)	3.7	3.6	2.1	1.4	1.9	1.1	5.7	5.7	4.9
Interaction (M x N)									
M at N									
S.Em±	3.56	2.52	1.55	0.94	1.25	0.91	4.11	3.86	3.37
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N at M									
S.Em±	3.68	2.15	1.87	0.95	1.08	0.65	3.72	3.81	3.39
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

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 post harvest nutrient availability over longer period than sole maize. Among the annual legumes sunhemp was found to be superior in preceding maize as well as in succeeding groundnut. 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 post harvest nutrient availability than 100 per cent RDN through urea and control in preceding maize as well as in succeeding groundnut.

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