International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(1): 3493-3497

Received: 01-10-2020
Accepted: 12-12-2020

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Effect of kharif legumes on nutrient uptake by Rabi maize

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DOI: https://doi.org/10.22271/chemi.2021.v9.i1aw.11775

Abstract
In this current study, the treatments consisted of three legumes, *viz*., groundnut (C_1), cowpea (C_2) and cluster bean (C_3) as main plot treatments taken up during the *kharif* season and two residue management practices *viz*., residue incorporation (I_1) and no residue incorporation (I_2) as sub-plot treatments and four nitrogen levels 75% RDN (N_1), 100% RDN (N_2), 125% RDN (N_3) and 150% RDN (N_4) as sub-sub plot treatments to maize as 120 kg N ha^{-1} being the recommended dose during *rabi* in Odisha. Significantly higher N, P, K uptake by maize was observed with incorporation of legume crop residues in the first and second year of study at all the growth stages when compared with no residue incorporation. Significant improvement in the nutrient uptake by maize was observed at various growth periods, with increase in the level of nitrogen application and highest uptake was recorded with application of 180 kg N ha^{-1} and found significantly superior to other nitrogen levels.

Keywords: Maize, nutrient uptake, residue incorporation, nitrogen levels, yield

Introduction

Indian agriculture has made tremendous progress during the past few decades. Among the various food crops, cereals have been the main focus of this progress and have been the keepings of the transformation of Indian agriculture from security to surplus. Among various cereal crops, maize (*Zea mays* L.) is one of the most predominant one. The possibility of horizontal expansion by putting more land under cultivation being remote, future augmentation in production would have achieved vertically through enhancing productivity of individual crops. Intercropping is a widely-used system where multiple different crops (usually two or three) are produced from a parcel of land each year to produce higher yields and to suppress weed, disease, and pest incidences (Li *et al*. 2001; Liu *et al*. 2017) [16, 17]. Intercropping is often an efficient land use and sustainable agricultural practice. The maize-soybean relay intercropping system could promote efficient use of crop and soil nutrients, regulate the nitrogen cycle of soil, and significantly increase the rate of nitrogen fertilizer utilization in maize and soybean in the southwestern region of China. This intercropping strategy could effectively utilize heat and light resources, increase the grain yield, and potentially improve the land equivalent ratio as high as 2.2 (Yang *et al*. 2017; Du *et al*. 2018) [16, 17, 34]. Soil microbes can regulate soil microecology, prolong the material recycling pathway of mineral elements, and promote the diversification of nutrients (Cardinale *et al*. 2006; Enwall *et al*. 2007) [8, 11]. A shift of soil community structure has been correlated with changes in soil total nitrogen, organic matter, available phosphorus, and soil pH (Yin *et al*. 2015) [35]. Fan *et al*. (2012) [12, 34, 35] suggested that the interspecies competition of maize-based intercropping could change the soil nitrification rate due to changes in the soil bacterial community, thus affecting the soil nitrogen absorption. Previous studies have focused on nutrient uptake, light energy utilization, and crop yield in intercropping systems. But while intercropping can affect the soil bacterial community, and a shift in the soil bacterial community may be important for nutrient uptake, little is known about the interaction of crop nutrient uptake, soil properties, and soil bacterial communities in maize-soybean relay intercropping system. Our aim was to investigate whether the different planting patterns had impact on soil properties and bacterial communities, and more importantly, whether changes in soil properties and bacterial communities can promote plant nutrient uptake.

Material and Methods

The experimental site was situated at an altitude of 25.9 m above mean sea level, 20^0 15'N latitude, $85^o52'$ E longitude. It is situated at about 64 km away from the Bay of Bengal within the East and South Eastern Coastal Plain Agro climatic Zone of Odisha and falls under the East Coastal Plains and Hills Zone of the humid tropics of India. The climate of Bhubaneswar was characterized by hot, moist and sub-humid climate with hot summer and mild winter. Nearly 76 per cent of the annual rainfall is received by south west monsoon between June to September. The experiment was laid out in a split-split plot design and the treatments were replicated thrice. The three *kharif* crops were sown as the main plots and the two residue management practices were assigned to sub-plots and the four nitrogen (N) levels were allotted to the sub-sub-plot treatments for growing the maize crop during the *rabi* season. To study the uptake of different nutrients (N, P and K), five numbers of plant samples collected from each treatment plot for determination of dry matter at the time of harvest were used for chemical analysis to estimate the nutrient content and uptake by crops. The samples were shade dried for 48 hours and later kept in hot air oven at 70°C for 48 hours to get a constant weight. Then they were processed for final grinding, passed through a 2 mm sieve and were analysed for the estimation of nitrogen, phosphorus and potash contents. Half a gram powdered sample was predigested with 5 ml of concentrated nitric acid (NHO_3) over night. Further, predigested sample was treated with diacid (nitric acid: Perchloric acid in the ratio 10:4) mixture (HNO_3: $HClO_4$) and kept on sand both for digestion till snow white solid residue was obtained. After complete digestion precipitate was dissolved in 6NHCl and transferred to the hundred ml volumetric flask through whatman No.42 filter paper and finally the volume of extract was made to 100 ml with double distilled water and preserved for further analysis of P and K (Jackson, 1973).

Powdered sample (0.5 g) was digested with concentrated H_2SO_4 in presence of digestion mixture ($CuSO_4$ + K_2SO_4 + selenium powder on 200:10:1) till the digested sample give clear bluish green colour. The digested sample was further diluted carefully with distilled water to a known volume. Then a known amount of aliquot was transferred to a distillation unit (Micro KJeldahl-apparatus) and liberated ammonia was trapped in boric acid containing mixed indication. Later it was titrated against standard H_2SO_4 and the amount of ammonia liberated was estimated in the form of nitrogen. Phosphorus in plant digested sample was determined by vanadomolybdo-phosphoric yellow colour method, by using spectrophotometer at 470 nm. The potassium content in the digested sample was determined by flame photometer after making appropriate dilution.

The nutrient content in grain and straw obtained from plant analysis was multiplied with the component of plant to get the nutrient uptake in kg ha^{-1}. The uptake of nutrients was estimated by the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{yield (kg ha}^{-1}\text{) on oven dry basis}}{100}$$

Result and Discussion

Nitrogen uptake

Nitrogen uptake by maize was significantly influenced by the preceding legume crops and the improvement in N uptake might be due to efficient utilization of mineralized N by the crop plants for their growth owing to increased microbial activity (Table-1). Increased uptake of nitrogen by cowpea-maize sequence might be due to higher nitrogen fixation and also extraction of self-fixed nitrogen. The incorporation of crop residues resulted in higher N uptake which might be attributed to better availability of nitrogen in soil after their decomposition and consequent increase in dry matter production. These results corroborated the findings of researchers like Jeranyama *et al*. (2000), Chamanlal and Dalip Singh (2007) [9], Sujatha *et al*. (2008) [29] and Bharati (2010).

Also it was observed that with increase in nitrogen levels, the uptake of nitrogen by maize increased which may be attributed to increase in nitrogen content in dry matter and increased dry matter accumulation. Similar findings were reported by Kar *et al.* (2006) [14], Ramu and Reddy (2007) [24, 25], Bindhavi *et al.* (2008), Malla Reddy *et al.* (2010) [19] and Mercy *et al*. (2012) [21].

Phosphorus uptake

The phosphorus uptake by maize at different growth stages and at harvest was found to follow an increasing trend (Table-2). The total uptake of phosphorus by kernel and stover of maize was significantly more with cowpea as a preceding crop compared to other legumes during investigation period. The P uptake was also more with residue incorporation over no incorporation. The uptake of P was improved with increasing levels of N. This might be due to the rhizospheric effect of preceding legumes which improved the P availability in the legume-maize sequence. Also the increased P uptake at higher N levels might be due to more available N which also helps in phosphorus uptake from soil. The variation among different factors with respect to P uptake may be due to increase in dry matter production coupled with per cent increase in nutrient content in dry matter that might have contributed for the increased uptake of P. Similar findings were established by researchers like Brar *et al.* (2006) [7], Tripathy and Hazra (2002) [33], Meena *et al.* (2007) [20], Bharati *et al.* (2010) and Rao (2012) [26].

Potassium uptake

Uptake of potassium recorded at different growth stages and harvest of maize had shown increased trend. The variations among different treatments with regard to K uptake might be due to higher dry matter accumulation coupled with per cent increase in K nutrient content in the dry matter resulting in the increased K uptake in respective treatments (Table-3).These findings corroborated the results obtained by Tanimu *et al.* (2007) [31] Yusuf *et al.* (2009b) [36, 37] and Bharati (2010).

Kernel yield

Kernel yield of maize was significantly influenced by legume crops, residue incorporation and nitrogen levels during both the years of experimentation (Table 1). However, the interaction of these factors was found to be non-significant.

The highest kernel yield of 7175 and 7324 kg ha^{-1} was recorded with cowpea as preceding crop which was comparable with that of cluster bean-maize sequence with 7070 and 7096 kg ha^{-1} during the first and second year of study.

Residue incorporation of legume crops resulted in significant increase in kernel yield of maize during both the years. More kernel yield was registered to the tune of 2.4 and 2.3 per cent with legume residue incorporation over no residue incorporation during 2014-15 and 2015-16, respectively. The kernel yield was found to be significantly increased with the increase in the level of nitrogen application. Application of

180 kg N ha^{-1} was found to increase the kernel yield by 5.0 per cent over 90 kg N ha^{-1} during both the years of study and registered superiority over other levels of nitrogen application.

The kernel yield was highest with cowpea grown as preceding crop which may be attributed to higher biomass production and nutrient uptake. The increase in the population of microbes subsequent to legume harvest as well as due to residue incorporation. This might have resulted in increased solubilization of all the nutrients for absorption leading to increased dry matter production and enhanced yield attributes like cob length, number of kernels per cob, kernel weight which finally gave higher kernel yield compared to other crops in sequence. The preceding legumes had a positive effect on maize yield which might be due to mineralization of decomposing legume roots in the soil, which can increase the N availability to the associated crop (Evans *et al*., 2001) and also may be due to non-N rotational effects where there might have been increased availability of nutrients other than N through increased soil microbial activity, deep ploughing and secretion of root exudates. These results are in agreement with the findings of Palm *et al.* (2001) [22], Sidhu *et al.* (2003) [28], Baghal (2005), Agyare *et al*. (2006) [2], Yusuf *et al*. (2009) [36, 37] and Arif *et al*. (2011) [3].

The beneficial effects and positive response of higher nitrogen application on kernel yield could be attributed to more vigorous growth by accumulating more dry matter and increase in various yield attributes. This might have enabled the plants to absorb more soil nutrients and prepare more photosynthates and translocate them to the sink which was finally reflected in kernel yield. Similar findings were established and reported by different researchers like Ramulu *et al*. (2006) [24], Patel *et al*. (2008) [23], Suryavanshi *et al*. (2008) [30], Kumar (2009) [15], Lingaraju *et al*. (2010) [18, 29], Thimmappa *et al*. (2012) [32] and Adhikary and Adhikary (2013) [1].

Table 1: Nitrogen uptake (kg ha^{-1}) of maize at different growth stages as influenced by legume crops, residue incorporation and nitrogen levels

Treatments	2014-15				2015-16				2014-15		2015-16		2014-15	2015-16
	N Uptake (kg ha^{-1})				N Uptake (kg ha^{-1})				Kerenel				Kernel Yield (kgha^{-1})	
	30 DAS	50 DAS	70 DAS	90 DAS	30 DAS	50 DAS	70 DAS	90 DAS	N Content (%)	N Uptake (kgha^{-1})	N Content (%)	N Uptake (kgha^{-1})		
Legume Crops (C)														
Groundnut (C_1)	10.5	45.9	80.2	101.4	11.6	50.1	86.9	110.9	1.12	77.9	1.12	77.9	6958	7050
Cowpea (C_2)	12.1	52.5	91.6	112.8	12.9	55.6	96.8	119.8	1.15	83.2	1.15	83.2	7175	7324
Cluster bean (C_3)	11.2	47.4	84.8	105.9	12.3	52.2	92.2	115.8	1.13	80.5	1.13	80.5	7070	7096
S.Em±	0.26	0.74	0.50	0.40	0.21	0.42	0.52	0.48		0.71		0.71	38.1	44.2
CD (*P*=0.05)	NS	2.9	2.0	1.6	0.6	1.3	1.6	1.6		2.8		2.8	149	173
Residue Incorporation (I)														
With residue (I_1)	11.8	50.7	87.9	109.6	12.8	54.7	94.6	118.6	1.14	82.4	1.14	82.4	7149	7239
Without residue(I_2)	10.7	46.5	83.1	103.7	11.8	50.5	89.4	112.3	1.12	79.2	1.12	79.2	6987	7074
S.Em±	0.09	0.44	0.39	0.53	0.12	0.46	0.43	0.54		0.92		0.92	39.1	31.8
CD (*P*=0.05)	0.3	1.3	1.2	1.6	0.4	1.4	1.3	1.6		2.8		2.8	120	97
Nitrogen Levels (N)														
75%RDN (N_1)	10.2	45.5	86.2	101.0	11.2	49.1	92.3	109.1	1.12	77.2	77.2	0.32	6895	6991
100% RDN (N_2)	11.1	47.9	82.5	105.5	12.2	51.7	88.5	113.9	1.14	79.9	79.9	0.34	7013	7101
125% RDN (N_3)	11.6	49.6	85.3	108.8	12.6	53.5	91.4	117.2	1.15	81.8	81.8	0.35	7116	7193
150% RDN (N_4)	12.1	51.3	88.1	111.6	13.2	55.9	95.8	121.7	1.16	84.1	84.1	0.37	7246	7341
S.Em±	0.21	0.47	1.06	1.22	0.28	0.52	0.88	1.16		1.26	1.26		68.6	69.1
CD (*P*=0.05)	0.6	1.3	3.0	3.5	0.9	1.6	2.6	3.5		3.6	3.6		196	198

Table 2: Phosphorus uptake (kg ha^{-1}) of maize at different growth stages as influenced by legume crops, residue incorporation and nitrogen levels

Treatments	2014-15				2015-16				2014-15				2015-16			
	P Uptake (kg ha^{-1}) (14-15)				P Uptake (kg ha^{-1}) (15-16)				Kernel		Stover		Kernel		Stover	
	30 DAS	50 DAS	70 DAS	90 DAS	30 DAS	50 DAS	70 DAS	90 DAS	P Content (%)	P uptake (kgha^{-1})	P Content (%)	P Uptake (kgha^{-1})	P Content (%)	P Uptake (kgha^{-1})	P Content (%)	P Uptake (kgha^{-1})
Legume Crops (C)																
Groundnut (C_1)	2.3	10.2	17.4	22.5	2.4	10.2	17.5	22.7	0.19	13.0	0.12	10.7	0.21	14.8	0.10	10.9
Cowpea (C_2)	2.6	11.5	19.8	24.9	2.5	10.9	18.8	23.6	0.21	15.1	0.13	12.2	0.21	15.3	0.11	12.2
Cluster bean (C_3)	2.5	10.8	19.1	24.3	2.5	10.4	18.2	23.2	0.21	14.8	0.13	11.8	0.20	14.1	0.11	11.9
S.Em±	0.02	0.04	0.08	0.07	0.04	0.07	0.12	0.13		0.07		0.04		0.08		0.04
CD (*P*=0.05)	0.1	0.2	0.3	0.3	0.1	0.2	0.4	0.4		0.3		0.2		0.2		0.1
Residue Incorporation (I)																
With residue (I_1)	2.6	11.3	19.3	25.5	2.6	11.1	18.8	24.1	0.21	15.2	0.12	12.1	0.23	16.6	0.13	12.3
Without residue (I_2)	2.2	9.5	16.7	22.4	2.3	9.9	17.4	22.2	0.19	13.3	0.11	11.1	0.22	15.5	0.12	11.1
S.Em±	0.01	0.06	0.08	0.09	0.03	0.08	1.06	1.10		0.13		0.08		0.12		0.09
CD (*P*=0.05)	0.1	0.2	0.2	0.3	0.1	0.2	3.2	3.4		0.4		0.2		0.4		0.3
Nitrogen Levels (N)																
75% RDN (N_1)	2.1	9.4	17.9	21.3	2.1	9.6	17.9	21.5	0.18	12.9	0.12	10.4	0.19	13.2	0.10	11.0
100% RDN (N_2)	2.3	10.3	18.8	23.0	2.2	9.8	16.8	21.8	0.19	13.8	0.13	11.5	0.20	14.2	0.10	11.1

125% RDN (N_3)	2.6	11.2	19.6	24.8	2.5	10.7	18.2	23.7	0.20	14.7	0.13	11.7	0.21	15.1	0.11	12.2
150% RDN (N_4)	2.8	12.1	20.8	26.6	2.7	11.6	19.8	25.5	0.21	15.7	0.14	12.7	0.22	16.1	0.11	12.5
S.Em±	0.04	0.11	0.12	0.16	0.05	0.15	0.20	0.23		0.21		0.15		0.20		0.16
CD (P=0.05)	0.1	0.3	0.35	0.5	0.1	0.4	0.6	0.7		0.6		0.4		0.5		0.5

Table 3: Potassium uptake (kg ha-1) of maize at different growth stages as influenced by legume crops, residue incorporation and nitrogen levels during 2014-15

Treatments	2014-15				2015-16				2014-15				2015-16			
	K Uptake (kg ha^{-1})				K Uptake (kg ha^{-1})				Grain		Stover		Grain		Stover	
	30 DAS	50 DAS	70 DAS	90 DAS	30 DAS	50 DAS	70 DAS	90 DAS	K Content (%)	K Uptake ($kgha^{-1}$)	K Content (%)	K Uptake ($kgha^{-1}$)	K Content (%)	K Uptake ($kgha^{-1}$)	K Content (%)	K Uptake ($kgha^{-1}$)
Legume Crops (C)																
Groundnut (C_1)	11.5	50.3	86.1	111.3	12.1	51.3	87.3	113.8	0.38	26.4	1.19	107.1	0.39	27.4	1.21	111.7
Cowpea (C_2)	12.6	55.2	94.6	118.6	13.3	56.3	96.3	121.3	0.41	29.4	1.21	114.2	0.42	30.7	1.22	117.3
Cluster bean (C_3)	12.1	51.2	89.8	114.5	12.7	52.7	91.6	117.2	0.39	27.5	1.20	109.7	0.4	28.3	1.21	112.4
S.Em±	0.08	0.08	0.66	0.44	0.12	0.15	0.63	0.67		0.43		0.42		0.38		0.41
CD (P=0.05)	0.3	0.3	2.6	1.7	0.4	0.4	1.9	2.1		1.7		1.7		1.2		1.2
Residue Incorporation (I)																
With residue (I_1)	12.5	54.1	92.0	117.1	13.1	55.3	93.8	119.8	0.39	28.8	1.21	112.1	0.41	29.8	1.22	116.1
Without residue(I_2)	11.5	50.4	88.3	112.5	12.2	51.6	89.7	115.1	0.37	26.7	1.19	108.6	0.39	27.8	1.20	111.5
S.Em±	0.11	0.32	0.56	0.35	0.13	0.40	0.73	0.64		0.32		0.30		0.30		0.25
CD (P=0.05)	0.3	1.0	NS	1.1	0.4	1.2	2.2	1.9		1.0		0.9		0.9		0.7
Nitrogen Levels (N)																
75%RDN (N_1)	11.1	49.2	91.3	109.2	11.6	50.3	92.7	111.8	0.37	25.6	1.19	107.2	0.38	26.9	1.20	109.3
100% RDN (N_2)	11.7	51.1	86.1	112.5	12.4	52.3	87.6	115.2	0.38	26.7	1.20	109.7	0.39	28.0	1.21	111.9
125% RDN (N_3)	12.4	53.4	90.1	117.3	13.0	54.7	91.6	119.9	0.41	29.2	1.21	111.1	0.41	29.8	1.23	115.2
150% RDN (N_4)	13.0	55.3	93.2	120.2	13.6	56.5	94.9	122.8	0.42	30.5	1.22	113.5	0.42	30.8	1.24	118.9
S.Em±	0.12	0.60	0.77	0.83	0.18	0.73	0.84	0.92		0.65		0.68		0.60		0.60
CD (P=0.05)	0.4	1.7	2.2	2.5	0.6	2.2	2.5	2.8		1.9		1.9		2.2		2.1

Conclusion

Incorporation of legume crop residues was found to be beneficial in improving the soil physical and biological properties and yields of the crops. The highest kernel yield (7175 kg ha^{-1} and 7324 kg ha^{-1}) of maize was recorded with cowpea as preceding crop during 2014-15 and 2015-16 and the yields obtained with cluster bean and groundnut were comparable and remained at par. Application of 180 kg N ha^{-1} has resulted in highest kernel yield of 7246 kg ha^{-1} and 7341 kg ha^{-1} during 2014-15 and 2015-16, respectively and found superior over other lower levels. Nutrient (N, P and K) uptake of maize recorded at different intervals also followed similar trend, where cowpea as preceding crop to maize recorded the highest uptake of N, P and K followed by cluster bean. Incorporation of legume residues was found to be significantly superior over no residue incorporation in the uptake of nutrients at all the stages of crop growth. Higher uptakes of all the nutrients were recorded with nitrogen application of 180 kg ha^{-1}, which was found to be significantly superior to the lower levels.

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