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Research Article

Nutrient Dynamics in Maize (Zea Mays L.) as Influenced by Cumulative Effect of Crop Residue Incorporation and Nitrogen Management

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Abstract

Field experiments were conducted for two consecutive years to assess the productivity, resource use efficiency and nitrogen dynamics in maize as influenced by cumulative effect of legume crops, crop residue incorporation and nitrogen fertilization in legume maize sequence. The experiment was laid out in split- split plot design with three legumes, as main plot treatments during the *kharif* season and two residue management practices as sub plot treatments and four nitrogen levels as sub- sub plot treatments to maize. The growth parameters of maize were significantly high when cowpea was taken as a preceding crop. Residue incorporation has resulted in improvement in yield attributing characters compared to residue removal. Application of nitrogen @ 300 kg ha^{-1} was found to be significantly superior to 75 and 150 kg N ha^{-1} and comparable with 225 kg ha^{-1}. Higher kernel and Stover yields were also obtained when cowpea was grown as a preceding crop to maize. Nitrogen uptake of maize was significantly influenced by all the treatments at all the stages of crop growth. N uptake by maize increased with the advancement in the age of the crop during both the years of investigation. Nitrogen uptake at maturity by grain and stover of maize is (68.1 and 29.4 kg ha^{-1}) in first year and (78.0 kg ha^{-1} and 30.9 kgha^{-1}) in second year when cowpea grown as a preceding crop to maize. Legume residue incorporation has increased the total uptake of nitrogen by grain and stover during both the years compared to the residue removal treatments. Improvement in N uptake by grain and stover was observed up to 300 kg ka^{-1}. The total uptake by grain and stover with 300 kg ha^{-1} was 113.4 kg ha^{-} and 124.5 kg ha^{-1} in first and second year, respectively. The available NPK after the harvest of maize crop was highest with cow pea as preceding crop to maize and residue incorporation.

Keywords: Maize, Nitrogen levels, N uptake, Crop residues, Yield

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Introduction

Maize (*Zea mays* L) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 % (782 m t) in the global grain production. In India, maize is the third most important food crops after rice and wheat. Maize in India, contributes nearly 9 % in the national food basket. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries etc. Maize is cultivated both in temperate and tropical regions of the world. The full yield potential of maize crop can be exploited through adoption of hybrids with better nitrogen management practices. Further, maize is a heavy feeder of nutrients, especially nitrogen, the deficiency of which limits the growth and yield of the crops. Over dependence on chemical fertilizers alone would lead to gradual decline in organic matter content and native fertility status of the soil, which in turn, reflects on productivity. legume crop residues after the harvest of the economic part are the good source of plant nutrients and serves as readily available energy for soil microbes because of their relatively high nutrient content, low lignin content and easy decomposition. Therefore, a strategy of integrated use of nitrogen through fertilizers in combination with cheaper sources of organic matter which is abundantly available should be tried to satisfy the higher nitrogen requirement of the maize crop to produce higher quantity and quality yield of maize without impairing the soils health.

Since, crop residues after the harvest of the economic yield can be profitably utilized as organic manure for the succeeding crop instead of using the residues for non-agricultural purposes. The information on the contribution of legume crops as well as their residues for the succeeding cereal in the sequence and the nutrient dynamics is quite scarce therefore the present investigation was under taken to study the response of maize to legume crops residue management practices and nitrogen levels.

Materials and Methods

Field trials were conducted for two consecutive years at Agricultural College Farm, Aswaraopet, Khammam dist. Telangana state during *kharif* and *rabi* seasons for two consecutive years. The soil of the experimental site was sandy clay in texture, slightly alkaline in reaction (P^H 7.8), low in available nitrogen, 148 kg ha^{-1}), medium in available phosphorus (33 kg ha^{-1}) and high available K (256 kg ha^{-1}). The experiment was laid out in split- split plot design and the treatments were replicated thrice with three legumes, viz., cowpea, (M_1) field bean (M_2) and green gram (M_3) as main plot treatments taken up during the *kharif* season and two residue management practices viz., residue removal (I_0) and residue incorporation (I_1) as sub- plot treatments and four nitrogen levels 75 kg ha^{-1} (N_1), 150 kg ha^{-1} (N_2), 225 kg ha^{-1} (N_3) and 300 kg ha^{-1} (N_4) as sub- sub plot treatments to maize.

The trial was repeated in a separate field in the second year. During two years of study Co-4, HA-3, MGG-295 varieties of cowpea, field bean and green gram respectively, were raised as *kharif* legumes while 30-V-92 a popular maize hybrid was grown during *rabi*. Legume crops are taken up in the *kharif* season, during both the years of study, in half of the plot residues are removed while in the another half the plot residues are incorporated in the of the plot after harvesting the economic yield. The residue was allowed to decompose in the field for one month thereafter field was thoroughly ploughed to sow the succeeding maize. The maize crop test variety 30 V92 was sown by adopting a spacing of 60 cm X 20 cm for the two successive seasons. Nitrogen was applied in the farm of urea as per the treatments in three splits viz., ¼ th at the time of sowing, ½ at knee-high stage and the remaining ¼ at tasselling stage. A common dose of 60 kg P_2O_5 and 50 kg K_2O was applied in the form of single super phosphate and muriate of potash at the time of sowing.

Bio metrical observations like plant height, dry matter production recorded at 20 days interval from 30 DAS to maturity. Post harvest observations like number of grains per cob, Test weight, Grain yield and stover yield was recorded and the plant samples were analysed for N (Modified Microkjeldhal method [1]. The nutrient uptake by grain and was calculated by making use of the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) X Dry matter accumulation kg ha}^{-1}}{100}$$

Results and Discussion

Plant height

Plant height of maize significantly influenced by *Kharif* legume crops, residue management practices and nitrogen levels during both the years of study. Among different *Kharif* crops tested, cowpea as preceding crop to maize has resulted in significantly taller plants of maize compared to other legume crops included in the study during the first year. However, during the second year, though cowpea as a preceding crop resulted in maximum plant height of maize, it remained statistically at par with field bean as a preceding crop. Incorporation of crop residues of all the legumes has resulted in significant increase in plant height of maize compared to their removal during both the years of study. Legume crop residue incorporation has resulted in 7 per cent increase in height of maize over its removal in first the year, while residue management treatments were comparable during the second year.

During the two years of study, cowpea as a preceding crop favored the succeeding maize to grow taller plants which indicated the advantage of legume effect on the succeed cereal in sequence. The positive response of cereals following legume have been attributed largely to the enhanced availability of nitrogen to the cereal crop grown after a legume. Legumes with low harvest indices have the greater potential for enhancing the soil fertility which might have resulted in the increased plant height of maize subsequently. Similar findings were also reported by [2], [3] and [4].

There was a corresponding increase in plant height with the increase in dose of nitrogen up to the highest level tried. Each succeeding level was found to be significantly superior to the preceding level in first year, while, during second year, application of N @150 & 225 kg ha^{-1} and 225 & 300 kg ha^{-1} were comparable with each other. The maximum plant height of 200 and 204 cm was recorded with 300 kg ha^{-1}during first and second years respectively.

Drymatter Production (kgha^{-1})

Drymatter production of *rabi* maize was significantly influenced by *Kharif* legume crops, residue management practices and nitrogen levels. Cowpea as a preceding legume to maize has accumulated maximum amount of dry matter 10854 kg $ha^{-1}$and 1100 kg ha^{-1} in first and second years of investigation respectively. Which was significantly superior to greengram and remained at par with field bean during both the years of investigation. The superiority of cowpea-maize sequence compared to other sequences might be due to the improvement in soil N status subsequent to the legumes due to the biological nitrogen fixation of the legumes. Further it is evident that there is a variation among the legumes in accumulation of N and its availability to the succeeding crops can be seen among the legume crops. These results are in accordance with the findings of [5] and [6]. Incorporation of crop residues significantly influenced the drymatter accumulation over the removal during both the years. The per cent increase in drymatter with residue incorporation is 7 per cent during both the years compared to the residue removal. Irrespective of the stage of the crop and year of experimentation, incorporation of crop residue has resulted in significant improvement in drymatter accumulation. since, legume residues have a narrow C: N ratio which was in the range of mineralization thus the mineralized N and the fertilized N might have been are equally available to the succeeding crop resulting in prolonged availability due to the reduced losses and fermentation of mineral complexes which was clearly evident in the residue incorporation treatments. Increased application of N fertilizer resulted in with linear increase of dry matter accumulation of maize up to the highest level tried. Judicious supply of nitrogen is known to enhance chlorophyll content, which in turn, increase photosynthetic activity and hence, rate of accumulation of dry matter was increased. [7] and [8].

Number of cobs per plant

Number of cobs per plant produced by *rabi* maize was significantly affected by residue management practices and nitrogen levels, whereas, the preceding legume crops did not exert significant influence on the number of cobs per plant during both the years of study. Irrespective of the year of study, residue incorporation resulted in significant improvement in cob number per plant. Likewise, number of cobs per plant also increased with increase in the level of nitrogen application. The highest number of cobs per plant was recorded at 300 kg N ha^{-1} (1.72 and 1.77) in the first and the second year, respectively.

Number of kernels per cob

Number of kernels per cob was significantly influenced by *kharif* legumes, residue management practices and nitrogen levels in both the years. The highest kernel number per cob of 320 and 325 were recorded during first and second years, respectively, with cowpea as a preceding crop to maize and was significantly superior to other two preceding legume crops. The residue incorporation or non-incorporation had no significant effect on kernel number per cob during both the years. The number of kernels per cob increased significantly with increase in level of N application. The increase in kernel number per cob due to preceding legumes, residue management practices and nitrogen levels might be due to more dry matter accumulation in the respective treatments leading to extension of grain filling period along with effective translocation of photosynthates to sink, which might have resulted in significant improvement in yield attributes of maize.

Test Weight

The 100 kernel weight was significantly influenced by *kharif* legume crops, residue management practices and nitrogen levels during both the years. Among the *kharif* legumes, cowpea proceeded to maize recorded maximum test weight of 27.8 g and 29.1 g during the first and the second year respectively, and was found to be significantly superior to green gram-maize sequence. Residue incorporation has resulted in significant increase in test weight compared to the removal during both the years of study. The per cent increase in test weight due to incorporation of residue was 8.8 per cent and 6.4 per cent in first and second year, respectively. The superior performance of maize when grown as a subsequent crop to cowpea might be due to higher biomass accumulation of cowpea resulted in the build up of soil organic carbon, which in turn improved the soil physicochemical properties, which might have translated into superior growth of yield components compared to other legumes.

Significant improvement in yield components with the incorporation over non incorporation of legume residue might be attributed to the nodulated roots and the above ground residues after the harvest of seed represent the potentially viable source of nitrogen for the soil microbes when these residues were incorporated into the soil. The increase in soil microbial population with residue incorporation was better evident in the present investigation. This might have increased the nutrient availability to the succeeding maize in sequence. These results are in conformity with the findings of [9] [10], [11] and [12].

Kernel yield (kgha^{-1})

Kernel yield of maize was the affected by *kharif* legume crops, residue management practices and nitrogen levels during the both the year of experimentation However, the interactions of these factors were found to be non-significant. Among different *kharif* legume crops tested, cowpea preceded to maize resulted in the highest kernel yield of 6092 kg ha^{-1} and 6317 kg ha^{-1} during the first and the second year of study, respectively, while the kernel yield of maize with field bean and green gram as preceding crops were comparable during both the years of study.

Residue incorporation resulted in significant increase in kernel yield of succeeding maize during both the years. The per cent increase in kernel yield of maize due to residue incorporation was 6 and 7 per cent during the first and second year, respectively, over no incorporation. Increase in the level of nitrogen significantly increased the kernel yield of maize. Application of 225 kg N ha^{-1} and 300 kg N ha^{-1} increased the kernel yield by 48.3 and 54.7 per cent, respectively over 75 kg N ha^{-1}.

The superior performance of maize when grown as a subsequent crop to cowpea might be due to higher biomass accumulation of cowpea resulted in the buildup of soil organic carbon, which in turn improved the soil physico-chemical properties, which might have translated into superior growth and yield.

Significant improvement in yield components with the incorporation over non incorporation of legume residue might be attributed to the nodulated roots and the above ground residues after the harvest of seed represent the potentially viable source of nitrogen for the soil microbes when these residues were incorporated into the soil.

Figure 1 A view of different legume crops grown during Kharif season at Agricultural College, Aswaraopet, Telangana state

Figure 2 An overall view of legume crops during *Kharif* 2011 and 2012

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Figure 3 General view of experiment of maize during 2011 – 12 and 2012 – 13

Figure 4 A view of difference in length, number and kernels per cob across the treatments

Irrespective of the legume crops preceded in the sequence, yield components of maize increased significantly with increase in the level of nitrogen. The beneficial role of nitrogen in enhancing the yield attributes of maize irrespective of the crops taken in sequence in different soils and regions was reported by many researchers like [13], [14] and [15] the present findings are in accordance with the above results.

Nitrogen uptake

Nitrogen uptake of maize measured at maturity was significantly influenced by legume crops, residue management practices and nitrogen levels. In general, N uptake by maize increased with the advancement in the age of the crop during both the years of investigation. Among the legumes proceeding to maize, cowpea has registered the highest uptake of nitrogen by maize, which was significantly superior to green gram and field bean as preceding crops.

Incorporation of crop residues has resulted in increase in uptake of nitrogen during both the years under investigation. Nitrogen uptake at maturity by grain and stover of maize is (68.1 and 29.4 kg ha^{-1}) in the first year and (78.0 kg ha^{-1} and 30.9 $kgha^{-1}$) in the second year when cowpea grown as a preceding crop to maize. While maize preceded by green gram recorded lowest uptake of 87 kg ha^{-1} and 98 kg ha^{-1} in first and second year, respectively. Legume residue incorporation has increased the total uptake of nitrogen by grain and stover during both the years compared to the residue removal treatments.

Table 1 Yield and yield attributes and nutrient uptake of maize as influenced by cumulative effect of crop residue incorporation and nitrogen management

Treatment	Plant height (Cm)	Drymatter Production (g)	No.of grains /cob	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Plant height (Cm)	Drymatter Production (kg ha-1)	No.of grains /cob	Test weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
	First year						**Second year**					
Legume crops												
Cowpea	191	10854	320	27.8	6092	6880	193	11000	325	29.1	6317	7098
Field bean	184	10370	307	27.5	5646	6750	188	11541	313	26.7	5864	6992
Greengram	181	10084	300	27.0	5417	6679	185	10536	302	28.3	5683	6921
SEm+	2.39	131.6	2.20	0.16	116.7	187.1	2.24	112.4	2.68	0.11	93.2	113.7
CD (P=0.05)	9.38	516.9	6.67	0.62	458.5	NS	8.82	441	10.5	0.45	560	NS
Residue management Practices												
Residue Removal	179	10072	304	26.1	5532	6621	182	10372	309	27.8	5742	6895
Residue incorporation	192	10800	344	28.4	5884	6918	195	11116	318	29.6	6167	7112
SEm+	1.42	150.8	3.78	0.16	95.0	46.65	2.66	133	1.38	0.07	100.6	68.6
CD (P=0.05)	4.93	432.6	NS	0.56	329.0	161.4	9.23	510	NS	0.27	348.2	237.6
Nitrogen Levels												
75 kg ha^{-1}	167	9446	234	26.0	4379	5342	170	9696	234	27.1	5565	5220
150 kg ha^{-1}	181	10215	284	27.2	5257	6425	184	10517	284	28.3	5571	6631
225 kg ha^{-1}	192	10813	364	28.1	6435	7463	195	11133	364	29.4	6608	7778
300 kg ha^{-1}	200	11270	371	28.4	6762	7848	204	11631	371	29.8	7073	8084
SEm$\pm$	2.39	150.8	2.96	0.14	186.4	126.9	2.24	221	2.96	0.14	195.3	138.9
CD (P=0.05)	9.38	432.6	8.50	0.41	534.7	364.2	8.82	720	8.50	0.41	560.1	398.6

Table 2 Nitrogen uptake (kg ha^{-1}) of maize at harvest as influenced by legume crops, residue management practices and nitrogen levels during the period under investigation

Treatment	First year					Second year				
	Grain		Stover		Total (kg ha^{-1})	Grain		Stover		Total (kg ha^{-1})
	N content (%)	Uptake (kg ha^{-1})	N content (%)	Uptake (kg ha^{-1})		N content (%)	Uptake (kg ha^{-1})	N content (%)	Uptake (kg ha^{-1})	
Legume Crops (LC)										
Cow pea	1.12	68.19	0.42	29.49	97.68	1.23	78.01	0.39	30.99	109.00
Field bean	1.11	63.29	0.37	27.85	91.14	1.22	72.18	0.38	29.54	101.72
Greengram	1.12	60.53	0.35	26.81	87.34	1.22	70.07	0.36	28.49	98.56
SE m$\pm$		1.31		0.78			1.14		0.46	
CD (0.05)		5.15		3			4.4		1.8	
CV (%)		19.1		24.2			18.2		20.5	
Residue Management Practices (RMP)										
Residue removal (I_1)	1.11	62.09	0.39	26.8	88.89	1.21	70.76	0.46	26.8	99.41
Residue incorporation (I_2)	1.12	66.12	0.41	29.23	95.35	1.23	76.08	0.49	29.23	106.78
SE m$\pm$		1.06		0.19			1.24		0.19	
CD (0.05)		3.6		0.6			4.2		0.6	
CV (%)		21.2		20.3			15.4		20.5	
Nitrogen Levels ((NL)										
75 kg N ha^{-1}	1.11	48.75	0.38	19.95	68.7	1.2	55.85	0.39	21.18	77.03
150 kg N ha^{-1}	1.12	58.96	0.39	25.39	84.35	1.21	68.61	0.41	26.86	93.47
225 kg N ha^{-1}	1.13	72.52	0.4	31.64	104.16	1.22	81.75	0.42	33.59	115.3
300 kg N ha^{-1}	1.13	76.18	0.41	35.22	111.4	1.23	87.47	0.44	37.07	124.54
SE m$\pm$		2.09		0.52			2.4		0.58	
CD (0.05)		5.9		1.4			6.91		1.6	
CV (%)		15.2		11.5			14.2		12.5	

Significant improvement in N uptake by grain and stover was observed up to 300 kg ka^{-1}. The total uptake by grain and stover with 300 kg ha^{-1} was 111.4 kg ha^{-1} in the first year and 124.5 kg ha^{-1} in the second year, respectively. The improvement in uptake of nitrogen by maize preceded by legumes suggests that mineralized N was utilized efficiently by the crop plants for their growth. Higher uptake of N by maize due to incorporation of legume crop residues might be due to better availability of nitrogen in soil after their decomposition and consequent increase in dry matter production. Several researchers like [16], [17], [18] and [19] observed significant increase in N uptake of maize with incorporation of crop residues.

Higher uptake of nitrogen with the increase in nitrogen levels can be attributed to increase in nitrogen content in dry matter coupled with increased dry matter accumulation. These findings are in accordance with [20], [21] and [22]

Conclusions

The following conclusions can be drawn from the experimental data Among the different legume crops cowpea found to be the best legume crop with high dry matter accumulation. The influence of different legumes in terms of growth parameters and yields was more with cowpea- maize sequence with incorporation of crop residues. Incorporation of legume crop residues was found to be beneficial in improving the soil physical properties and yields of the crops. Application of nitrogen @ 225 kg ha^{-1} in combination with was found to be economical.

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