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Effect of different tillage, nutrient management practices and foliar sprays on Post-harvest soil available nutrient status of redgram [*Cajanus cajan* (L.)]

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Abstract
A field experiment was conducted during two consecutive *kharif* seasons of 2019-20 and 2020-21 to study the influence of tillage, nutrient levels and foliar sprays on post harvest soil nutrient status of redgram on sandy loam soil which was low in available nitrogen, medium in available phosphorus and available potassium. The experiment was conducted in a split split plot design, consisting of three tillage practices in main plots, three nutrient levels in sub plots and three foliar sprays in sub sub plots. Higher available nitrogen, phosphorus and potassium was recorded with vertical tillage with subsoiler upto 60 cm deep at 1 m interval with application of 125% RDF and with foliar application of KNO_3 1% twice with 15 days interval at 50 per cent flowering stage.

Keywords: Tillage, nutrient levels, foliar sprays and post harvest available nutrients

Introduction
Pulses play an important role in Indian agriculture and source of protein for the poor as well as for the vegetarians which constitute major population of the country. Pulses mainly include chickpea, pigeonpea, lentil, mungbean, urdbean and fieldpea. The split grains of pulses called dal are excellent source of high quality protein, essential amino and fatty acids, fibers, minerals, vitamins and help address obesity, diabetes besides fixing atmospheric nitrogen up to 200 kg ha^{-1} (Anonymous, 2010) [3]. Redgram (*Cajanus cajan* L.) is one of the important pulse crops of India and ranks second after chickpea in area and production. In India redgram was grown over an area of 4.45 million hectares with production of 3.83 million tonnes and 937 kg ha^{-1} productivity (Anonymous, 2019-20) [2]. In Andhra Pradesh, redgram is grown under rainfed conditions to an extent of 2.43 lakh hectares with an annual production of 1.19 lakh tonnes and productivity of 486 kg ha^{-1} (Annual Report, 2019-20).

Tillage, nutrient management is also described as the technique of using optimum effective dose of sufficient and balanced fertilizers in combination with foliar sprays to make nutrients more available and most effective for maintaining high yields without exposing soil native nutrients and polluting the environment. Furthermore, many benefits can also be gained from using integrated tillage and nutrient management practices can act as the driving forces, able to support the plans to improving post harvest soil fertility. Vertical tillage with subsoiler, which loosens the subsoil without inverting, it is aimed at stimulating greater and faster penetration of roots at increasing the availability of nutrients and moisture to plants. (Reeves and Mullins, 1995 and Tursic *et al*., 1998) [13, 17]. Nutrient management practices may be improve nitrogen, phosphorous and potassium availability in soil due to higher nutrient doses which enhances mineralization and availability of nutrients as well as they increase root nodules formations on roots and soil microbial activity.

Usually, the farmer's fertilizer programs focus solely on soil applied NPK, without plans for foliar application, however recent studies had shown the foliar fertilization enhance yield and soil fertility (Gowthami & Rama, 2014 and Chaturvedi *et al*., 2012) [6, 4]. Synchronised flowering in pulses altered the source-sink relationship due to rapid translocation of nutrients from leaves to the developing pods. Additional nutrition through foliar feeding play a vital role in pulse production by stimulating root development, nodulation, energy transformation, metabolic processes and pod setting. It is also recognized that supplementary foliar fertilization during crop growth can improve the mineral status of plants (Sarkar and Mallik, 2009) [14].

This is necessary to find the appropriate land configuration and techno-economic nutrient management package for redgram production under prevailing conditions. Hence, keeping all these points in view, the present investigation is planned entitled with effect of different tillage, nutrient management practices and foliar sprays on post harvest soil available nutrient status of redgram.

Materials and Methods

A field experiment was conducted at S. V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh during two consecutive *kharif* seasons of 2019-20 and 2020-21 to study the effect of different tillage, nutrient management practices and foliar sprays on post harvest soil nutrient status of redgram. The soil of the experimental field was sandy loam in texture, low in available N, medium in available P and available K. Redgram variety LRG-52 was used for experimentation. The experiment was laid in split-split design with three tillage practices (T_1: Conventional tillage with tractor drawn cultivator, T_2: Ploughing with duck foot cultivator upto a depth of 30 cm and T_3: Vertical tillage with subsoiler upto 60 cm deep at 1.0 m interval) in main plots, three nutrient levels (N_1: 75% RDF, N_2: 100% RDF (20-50-00 kg ha^{-1}) and N_3: 125% RDF) in subplots and three foliar sprays (F_1: Control (No spray) F_2: Borax 0.1% F_3: KNO_3 1%) in sub-sub plots. Three nutrient levels were applied to sub plots as per the prescribed treatments assigned. Entire quantities of N, P_2O_5 and K_2O were applied in the form of urea, singe super phosphate and muriate of potash respectively by placement method at the time of sowing and first foliar spray of Borax 0.1% and KNO_3 1% was done at 50 per cent flowering stage and second spray at 15 days after the first spray. The post harvest representative soil sample after harvesting were collected from the root zone depth at 0-20, 20-40, and 40-60 cm from each plot and composite samples were prepared following the existing procedure for chemical analysis. The sample was air dried, powdered, sieved through 2 mm sieve and used for analysis of nitrogen, phosphorus and potassium. Available nitrogen was estimated by alkaline potassium permanganate method as advised by Subbiah and Asija (1956) [16] and expressed in kg ha^{-1}. Available phosphorous was estimated by using the method suggested by Olsen *et al.* (1954) [11] and expressed in kg ha^{-1}. Available potassium was estimated by flame photometer (Jackson, 1973) [7] from the extract of neutral normal ammonium acetate and expressed in kg ha^{-1}.

Results And Discussion

The available nitrogen, phosphorous and potassium status in soil was estimated after harvesting of redgram crop was affected significantly by different tillage and nutrient management practices, whereas foliar sprays failed to influence the post harvest available nutrients during both the years of study inclusive of pooled mean (Table 1, 2 and 2). There was no significant interaction between tillage, nutrient management practices and foliar sprays in influencing post harvest availability of nutrients in soil after redgram.

Soil Available Nitrogen

Soil available nitrogen at 0-20 cm depth

The soil available nitrogen was maximum with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3), which was significantly higher than that ploughing with duck foot cultivator upto a depth of 30 cm (T_2). Conventional tillage with tractor drawn cultivator (T_1) recorded significantly lower soil available nitrogen during both the years of investigation and pooled mean.

Among different nutrient management practices studied, application of 125% RDF (N_3) registered higher soil available nitrogen which was significantly superior to 100% RDF (N_2) and 75% RDF (N_1). The difference between latter two treatments was significant. The soil available nitrogen was recorded lower with lower nutrient dose of 75% RDF (N_1) during both the years of study and in pooled mean.

Foliar application of KNO_3 1% (F_3), borax 0.1% (F_2) twice with 15 days interval at 50 per cent flowering stage and control (No spray) (F_1), failed to exert significant influence on soil available nitrogen during the two years of investigation as well as their interaction.

Soil available nitrogen at 20-40 cm depth

During both the years of study, the highest soil available nitrogen was recorded with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) and significantly superior to ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) which recorded lower soil available nitrogen.

Successive increase in fertilizer dose from 75% RDF to 125% RDF progressively increased the soil available nitrogen with significant disparity among one another. Application of 125% RDF (N_3) recorded significantly highest soil available nitrogen followed by 100% RDF (N_2) and 75% RDF (N_1) in the order of descent.

Foliar sprays failed to exert significant influence on soil available nitrogen during the two years of investigation, however higher soil available nitrogen was with foliar application of KNO_3 1% (F_3) twice with 15 days interval at 50 per cent flowering stage followed by borax 0.1% (F_2) and control (No spray) (F_1).

Soil available nitrogen at 40-60 cm depth

With regards to tillage practices, vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) recorded higher soil available nitrogen which was significantly superior to ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) during both the years of study and in pooled mean.

Application of 125% RDF (N_3) recorded significantly higher soil available nitrogen which was significantly superior to 100% RDF (N_2) and 75% RDF (N_1). The latter two treatments were comparable with each other.

Foliar sprays twice with 15 days interval at 50 per cent flowering stage was no significant effect on soil available nitrogen during both the years of investigation. However, foliar application of KNO_3 1% (F_3) twice with 15 days interval at 50 per cent flowering stage was recorded higher soil available nitrogen followed by borax 0.1% (F_2) and control (No spray) (F_1).

Soil Available Phosphorus

Soil available phosphorus at 0-20 cm depth

Vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) recorded higher soil available phosphorus followed by ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) with significant disparity between any two of the three tillage practices in the order of descent.

The maximum soil available phosphorus was noticed with application of 125% RDF (N_3) which was on par with 100% RDF (N_2) and significantly superior to 75% RDF (N_1). The latter two treatments were comparable during first year of study, whereas during second year the difference between the two nutrient doses was statistically significant.

Foliar sprays failed to exert significant influence on soil available phosphorus during the two years of investigation, however higher soil available phosphorus was with foliar application of KNO_3 1% (F_3) twice with 15 days interval at 50 per cent flowering stage followed by borax 0.1% (F_2) and control (No spray) (F_1).

Soil available phosphorus at 20-40 cm depth

Soil available phosphorus was higher with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) followed by ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) with significant disparity between any two of the three tillage practices in the order of descent.

In the different nutrient management practices tried, higher soil available phosphorus was registered with application of 125% RDF (N_3) which was significantly superior to 100% RDF (N_2) and 75% RDF (N_1) in the order of descent and the difference between the latter two nutrient management practices was comparable during both the years of study.

Foliar sprays failed to exert significant influence on soil available phosphorus during the two years of investigation, but higher soil available phosphorus with foliar application of KNO_3 1% (F_3) twice with 15 days interval at 50 per cent flowering stage followed by borax 0.1% (F_2) and control (No spray) (F_1).

Soil available phosphorus at 40-60 cm depth

Vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) recorded higher soil available phosphorus followed by ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) with significant disparity between any two of the three tillage practices in the order of descent.

The maximum soil available phosphorus was noticed with application of 125% RDF (N_3) which was on par with 100% RDF (N_2) and significantly superior to 75% RDF (N_1). The latter two treatments were comparable during both the year of study as well as in pooled mean.

Foliar sprays could not exert significant influence on soil available phosphorus during both the years of investigation, but higher soil available phosphorus was with foliar application of KNO_3 1% (F_3) twice with 15 days interval at 50 per cent flowering stage followed by borax 0.1% (F_2) and control (No spray) (F_1).

Soil Available Potassium

Tillage, nutrient management practices and foliar sprays as well as their interaction could not exert significant influence on soil available potassium at different soil depths during both the years as well in pooled mean.

Soil available potassium at 0-20, 20-40 and 40-60 cm depths

Soil available potassium was maximum with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (T_3) followed by ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) with no significant disparity among the treatments during both the years of study as well as in pooled mean.

Higher soil available potassium at different depths was observed with 125% RDF (N_3) followed by 100% RDF (N_2) and 75% RDF (N_1) with no significant disparity among the nutrient management practices that were studied for the two years of investigation and pooled mean.

Foliar sprays twice with 15 days interval at 50 per cent flowering stage has shown non significant effect on soil available potassium at different depths, but higher soil available potassium was registered with foliar application of KNO_3 1% (F_3) followed by foliar application of borax 0.1% (F_2) and Control (No spray) (F_1) during both the years of study inclusive of pooled mean.

Among the tillage practices studied during both the years of experiment, maximum availability of soil nitrogen, phosphorous and potassium at different soil depths after harvest of redgram was recorded with vertical tillage with subsoiler upto 60 cm depth at 1 m interval (T_3). This might be due to higher root activity of redgram and favourable soil moisture conditions that increased the microbial activity and mineralisation of nutrients would have led to increased availability of nutrients in vertical tillage compared to deep ploughing and conventional tillage. Similar results were reported by Kumar *et al*. (2013a) [9] and Priya (2017) [12].

Maximum nitrogen, phosphorus and potassium availability in soil after harvest of redgram was obtained with 125% RDF (N_3) application might be due to more amount of nitrogen, phosphorus and potassium applied to soil. These results are in agreement with the findings of Nagamani (2015) [10], Priya (2017) [12], Sekhon *et al*. (2018) [15] and Dalai *et al*. (2019) [5].

Minimum amount of nitrogen, phosphorous and potassium availability was measured with 75% RDF (N_1) where less fertilizers were applied which was significantly lower than with rest of the nutrient management practices tried, due to less availability of nutrients for the plants during two years of study (Priya, 2017 and Nagamani, 2017) [12].

Foliar application of nutrients twice with 15 days interval at 50 per cent flowering stage has shown non significant effect on availability of soil nitrogen, phosphorus and potassium during both the years of study, however higher soil available nitrogen, phosphorus and potassium was registered with foliar application of KNO_3 1% (F_3) at 50 per cent flowering stage may be attributed to the increased nodule count which was responsible for increased nitrogen fixation and readily available nitrate supply from foliar application of KNO_3 which resulted in lower uptake of nitrogen and potassium from soil which inturn increases the soil available nitrogen and potassium. These results are in conformity with the earlier findings of Krishna and Kaleeswari (2018) [8].

Table 1: Post harvest soil available nitrogen (kg ha^{-1}) as influenced by tillage and nutrient management practices of redgram during 2019-20 and 2020-21

Treatments	0-20 cm		Pooled	20-40 cm		Pooled	40-60 cm		Pooled
	2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
Main plots: Tillage practices (T)									
T_1- Conventional tillage with tractor drawn cultivator	144	153	148	93	98	96	80	84	82
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	150	163	156	95	102	98	84	88	86
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	158	176	167	112	121	117	105	111	108
S.Em ±	1.6	3.0	2.3	2.2	2.4	2.3	3.0	3.1	3.0
CD (P= 0.05)	6	12	9	9	9	9	12	12	12
Sub plots: Nutrient management practices (N)									
N_1- 75% RDF	143	154	149	92	97	94	83	87	85
N_2- 100% RDF	151	162	157	99	104	102	89	93	91
N_3- 125% RDF	157	176	166	109	120	115	98	103	100
S.Em ±	1.3	2.3	1.8	2.4	2.6	2.5	2.2	2.3	2.2
CD (P = 0.05)	4	7	6	8	8	8	7	7	7
Sub sub plots: Foliar sprays (F)									
F_1- Control	149	163	156	98	105	102	88	92	90
F_2- Borax - 0.1%	151	164	157	100	107	104	90	94	92
F_3- KNO_3 - 1.0%	152	165	159	101	109	105	92	96	94
S.Em ±	0.8	0.6	0.7	0.7	0.9	0.8	0.7	0.9	0.8
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
T x N									
S.Em ±	2.2	3.9	3.1	4.2	4.5	4.3	3.8	4.0	3.9
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x F									
S.Em ±	1.1	0.6	0.9	0.9	1.0	1.0	0.7	0.7	0.7
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x F									
S.Em ±	1.1	0.6	0.9	0.9	1.0	1.0	0.7	0.7	0.7
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N x F									
S.Em ±	1.9	1.1	1.5	1.6	1.8	1.7	1.2	1.2	1.2
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Post harvest soil available phosphorus (P_2O_5) (kg ha^{-1}) as influenced by tillage and nutrient management practices of redgram during 2019-20 and 2020-21

Treatments	0-20 cm		Pooled	20-40 cm		Pooled	40-60 cm		Pooled
	2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
Main plots: Tillage practices (T)									
T_1- Conventional tillage with tractor drawn cultivator	37.5	41.3	39.4	33.8	37.2	35.5	29.1	32.0	30.6
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	42.3	47.9	45.1	38.1	43.1	40.6	32.8	36.0	34.4
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	48.7	55.3	52.0	43.8	49.7	46.8	37.7	41.4	39.6
S.Em ±	1.16	1.28	1.22	1.04	1.15	1.10	0.90	0.99	0.95
CD (P= 0.05)	4.6	5.0	4.8	4.1	4.5	4.3	3.5	3.9	3.7
Sub plots: Nutrient management practices (N)									
N_1- 75% RDF	38.1	41.9	40.0	34.3	37.7	36.0	29.5	32.4	31.0
N_2- 100% RDF	42.6	48.0	45.3	38.4	43.2	40.8	33.0	36.3	34.7
N_3- 125% RDF	47.8	54.6	51.2	43.0	49.2	46.1	37.0	40.7	38.9
S.Em ±	1.77	2.00	1.89	1.59	1.80	1.70	1.37	1.51	1.44
CD (P = 0.05)	5.5	6.2	5.9	4.9	5.6	5.3	4.2	4.6	4.4
Sub sub plots: Foliar sprays (F)									
F_1- Control	43.0	48.3	45.7	38.7	43.5	41.1	33.3	36.6	35.0
F_2- Borax - 0.1%	43.6	49.0	46.3	39.3	44.1	41.7	33.8	37.1	35.5
F_3- KNO_3 - 1.0%	41.9	47.1	44.5	37.7	42.4	40.1	32.4	35.7	34.1
S.Em ±	1.26	1.46	1.36	1.13	1.31	1.22	0.98	1.07	1.03
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
T x N									
S.Em ±	3.06	3.46	3.26	2.75	3.12	2.94	2.37	2.60	2.49
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x F									
S.Em ±	2.18	2.52	2.35	1.96	2.27	2.12	1.69	1.85	1.77
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x F									
S.Em±	2.18	2.52	2.35	1.96	2.27	2.12	1.69	1.85	1.77

CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N x F									
S.Em ±	3.78	4.37	4.08	3.40	3.94	3.67	2.92	3.22	3.07
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Post harvest soil available potassium (K_2O) (kg ha^{-1}) as influenced by tillage and nutrient management practices of redgram during 2019-20 and 2020-21

Treatments	0-20 cm			20-40 cm			40-60 cm		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main plots: Tillage practices (T)									
T_1- Conventional tillage with tractor drawn cultivator	189	137	163	170	130	150	156	121	139
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	194	147	171	175	139	157	161	130	146
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	198	154	176	178	146	162	164	136	150
S.Em ±	3.6	3.7	3.7	3.3	3.5	3.4	3.0	3.3	3.2
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub plots: Nutrient management practices (N)									
N_1- 75% RDF	190	138	164	171	131	151	157	122	140
N_2- 100% RDF	193	148	171	174	140	157	160	131	146
N_3- 125% RDF	198	152	175	179	144	162	164	134	149
S.Em ±	3.6	3.8	3.7	3.3	3.6	3.5	3.0	3.3	3.2
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Sub sub plots: Foliar sprays (F)									
F_1- Control	191	145	168	172	137	155	158	128	143
F_2- Borax - 0.1%	193	146	170	174	138	156	160	129	145
F_3- KNO_3 - 1.0%	197	147	172	177	140	159	163	130	147
S.Em ±	0.8	1.6	1.2	0.9	1.5	1.2	0.8	1.4	1.1
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
T x N									
S.Em ±	6.3	6.5	6.4	5.6	6.2	5.9	5.2	5.7	5.5
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x F									
S.Em ±	0.9	2.7	1.8	2.8	2.6	2.7	2.5	2.4	2.5
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x F									
S.Em ±	0.9	2.7	1.8	2.8	2.6	2.7	2.5	2.4	2.5
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N x F									
S.Em ±	1.5	4.8	3.2	1.1	4.5	2.8	1.3	4.2	2.8
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

From the present investigation it can be concluded that crop with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) with application of 125% RDF (N_3) and foliar application of KNO_3-1% (F_3) twice at 50 per cent flowering stage of redgram resulted in higher post harvest availability of nutrients under the prevailing condition.

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