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Yield and Nutrient Uptake of Pigeonpea [*Cajanus cajan* (L.)] as Influenced by Tillage, Nutrient Levels and Foliar Sprays

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field investigation was conducted during two consecutive *kharif* seasons of 2019-20 and 2020-21 to study the effect of tillage, nutrient levels and foliar sprays on yield and nutrient uptake of redgram on sandy loam soil which was low in available nitrogen, medium in available phosphorus and available potassium. The research 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 seed yield and nutrient uptake of redgram 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; seed; stover yield and nutrient uptake.

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1. INTRODUCTION

Pulses occupy a unique position in Indian agriculture by virtue of the fact that they provide the rich source of vegetable protein and calories to the average Indian diet. Besides being rich source of protein, they maintain soil fertility through biological nitrogen fixation in soil and thus play a vital role in sustainable agriculture [1]. The pulses form an integral part of cropping system of the farmers all over the country, because they fit well in crop rotation and crop mixtures as well.

Redgram (*Cajanus cajan* L.) is one of the main pulse crops of India and ranks second after chickpea in area and production. Protein content (20-22 %) in redgram makes it an important source for supplementing the energy rich cereal diet, besides fixing atmospheric nitrogen up to 200 kg ha^{-1} [2]. 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. 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} [3].

In recent years it was found that due to ploughing at the same depth year after year or continuous use of tractor drawn implements for years together under conventional tillage systems usually caused sub-soil compaction resulting in hard pan formation. Tillage pans have high bulk densities, few macropores for roots to grow through mechanical impedance great enough to markedly reduce root growth rate which subsequently reduce nutrients and water uptake by the crop. Subsoil root development can often be increased if the tillage pan is fractured by a subsoiler [4].

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 [5-6].

Pigeonpea is an energy rich crop cultivated largely under energy starving situations and productivity is low due to inadequate fertilizer applications. As such, there is immense scope for augmenting its yield through balanced application of nutrients. There is a need to study whether there is any scope for improving its productivity with higher rates of nutrient application. Hence, its performance has been tested at three levels of nitrogen, phosphorus and potassium application in the present investigation.

Among the methods of fertilizer application, foliar nutrition is recognized as an important one, since foliar nutrients usually penetrate the leaf cuticle or stomata and enters the cells facilitating easy, rapid utilization and supplying nutrient instantly to crop [7]. Foliar nutrition with nitrogen (N) at later stage of crop growth delays the synthesis of abscisic acid and promotes cytokinin activity causes high chlorophyll retention and thereby photosynthetic activity in effective leaves for supply of current photosynthates to the grains resulting in higher yield [8].

Hence, development of an integrated approach with tillage, nutrient management practices and foliar sprays for redgram crop under rainfed conditions is a research priority. Hence, keeping all these points in view, the present investigation is planned.

2. 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 yield and nutrient uptake of pigeonpea. The soil of the experimental field was sandy clay loam in texture, low in available N, medium in available P and available K. Pigeonpea 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 by placement method at the time of sowing and first foliar spray of Borax - 0.1% and KNO_3 - 1.0 % was done at 50 % flowering stage and second spray at 15 days after the first spray. At harvest, seed and stover yields were recorded on a whole-plot basis after discarding border plants and were expressed as seed and stover yield in kg ha^{-1}.

Nitrogen, phosphorus and potassium contents in plants were analyzed by the standard procedure outlined by Jackson [9]. The uptake of nitrogen, phosphorus and potassium at harvest were calculated and expressed in kg ha^{-1}.

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

3. RESULTS AND DISCUSSION

3.1 Seed Yield

Data about effect of various tillage, nutrient management practices and foliar sprays significantly influenced the seed yield of redgram with unaltered trend during both the years as well as pooled (Table 1). The interaction between tillage practices and nutrient management practices was significant and other interactions were not statistically traceable, during both years of study.

Table 1. Seed and stover yield of redgram as influenced by tillage, nutrient management practices and foliar sprays during 2019-20 and 2020-21

Treatments	Seed yield (kg ha^{-1})		Pooled	Stover yield (kg ha^{-1})		Pooled
	2019-20	2020-21		2019-20	2020-21	
Main plots : Tillage practices (T) (3)						
T_1- Conventional tillage with tractor drawn cultivator	1210	1089	1149	8140	6919	7529
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	1358	1223	1290	8737	7427	8082
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	1614	1452	1533	9139	7768	8453
SEm±	46.1	41.5	43.8	182.8	155.4	169.1
CD (P= 0.05)	181	163	172	718	610	664
Sub plots : Nutrient management practices (N) (3)						
N_1- 75% RDF	1281	1153	1217	8072	6861	7467
N_2- 100% RDF	1346	1212	1279	8560	7276	7918
N_3- 125% RDF	1555	1399	1477	9384	7977	8680
SEm±	45.0	40.5	42.7	175.6	149.2	162.4
CD (P= 0.05)	139	125	132	541	460	500
Sub sub plots : Foliar sprays (F) (3)						
F_1- Control	1287	1158	1222	8218	6985	7602
F_2- Borax - 0.1%	1394	1254	1324	8591	7302	7947
F_3- KNO_3 - 1.0%	1502	1351	1426	9207	7826	8516
SEm±	35.2	31.6	33.4	142	120.9	131.6
CD (P= 0.05)	101	91	96	408	347	377
Interaction						
T x N						
SEm±	77.1	70.1	74.0	304.1	258.5	281.31
CD (P= 0.05)	240	216	228	936	796	NS
T x F						
SEm±	60.8	54.7	57.8	246	209.4	227.7
CD (P= 0.05)	NS	NS	NS		NS	NS
N x F						
SEm±	60.8	54.7	57.8	426	209.4	227.7
CD (P= 0.05)	NS	NS	NS		NS	NS
T x N x F						
SEm±	105.4	94.9	100.1	426	362.7	394.7
CD (P= 0.05)	NS	NS	NS	NS	NS	NS

During both the years of study, the highest seed yield of redgram 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). Lower seed yield was recorded with conventional tillage with tractor drawn cultivator (T_1).

Higher seed yield of redgram due to vertical tillage with subsoiler can be attributed to an improving the soil environment by favorable soil physical conditions such as changes in soil bulk density, penetration resistance, moisture content, root proliferation, available N reserves and increase in the quantum of nutrient absorption due to better root development, improving nitrogen accumulation and translocation, amount of N mobilization in stem and sheath reflected in better development and expression of growth and yield components, better portioning of photosynthates to developing pods which inturn resulted in higher seed yield under vertical tillage during the both years of investigation. The similar findings were reported by Priya et al. [10-12].

Lower seed yield due to conventional tillage practice was attributed to compacted layer was not loosened, the rooting of redgram was shallower resulting in lower moisture and nutrient uptake and a more rapid depletion of moisture in the rooting zone. These results are in agreement with findings of those Jordan et al. [13] and Barbosa et al. [14].

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

The highest seed yield with higher nutrient dose increased the supply of nutrients which inturn increased the multi role activities in plant and soil, rate of symbiotic N fixation, energy transformation and metabolic processes which resulted in maximum growth parameters, yield attributing characters and higher rate of photosynthesis helped in the production of new tissue and development of new shoot, greater accumulation of carbohydrates, protein and their translocation to the reproductive organs inturm resulted in greater translocation of photosynthates towards the sink development. The results are in close agreements with those of Singh et al. [15], Das et al. [16], Ware et al. [17], Tyagi and Singh [18], Nagamani et al. [19], Tekule et al. [20] and Ghule et al. [21].

Maximum seed yield of redgram was recorded with foliar application of KNO_3 1 % (F_3) twice with 15 days interval at 50 per cent flowering stage followed by foliar application of borax 0.1 % (F_2) and control (No spray) (F_1) in the order of descent, with significant disparity between any two of the three foliar sprays tested.

Highest seed yield with foliar application of KNO_3 1 % (F_3) might have resulted in transport of assimilates thereby better balanced supply with cation and anions of potassium, nitrate nitrogen respectively enhances the other nutrient availability at critical stages could have induced more flowering, reduction in flower shedding, delayed the synthesis of abscisic acid and promoted cytokinin activity causing higher chlorophyll retention in leaves leading to activation of enzymes responsible for carbohydrates redistribution and increased transportation of photosynthates from source to sink and in later stages, more assimilates are produced than used in growth and development, excess assimilates are diverted to storage compounds resulting increased seed yield of redgram. These results are in accordance with findings of Sarkar and Mallick, [22], Sarkar and Pal, [23], Shrikanth, [24] and Tripathy et al. [25], Vijayakumar et al. [26], Laishram et al. [27] and Ghule et al [21].

3.2 Stover Yield

Stover yield of redgram differed significantly due to tillage, nutrient management practices and foliar sprays with similar trend during both the years. Interaction between tillage and nutrient management practices was statistically measurable while, the other interactions had no significant influence on stover yield in both the years including pooled (Table 1).

Among the different tillage practices tried, maximum stover yield of redgram was registered with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) which was however comparable with ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and statistically superior to conventional tillage with tractor drawn cultivator (T_1). Lower stover yield of redgram was recorded with conventional tillage with tractor drawn cultivator (T_1) during both the years of study. The increase in stover yield might be owing to beneficial effect of subsoiling which results in better absorption of moisture, nutrient and that enhanced the vegetative growth interms of plant height, leaf area index and dry matter production resulting in increased stover yield. These results are in conformity with Kumar et al. [28] and Dalai et al. [29].

During both years of investigation, higher stover yield of redgram was noticed with application 125 % RDF (N_3), which was however comparable with 100 % RDF (N_2) and significantly superior to 75 % RDF (N_1). Lower stover yield of redgram was recorded with 75 % RDF (N_1). Difference between latter two nutrient management practices was non significant. Higher stover yield with higher nutrient dose could be attributed to increased availability of nutrients that enhanced the plant height and more drymatter production. These corroborates with the findings of Priya et al. [10], Tungoe et al. [30], Tyagi and Singh [18], Nagamani et al. [19], Devaraj et al. [31] and Ghule et al [21]. Lower stover yield of redgram was recorded with 75 % RDF (N_1) might be due to transient deficiency of nutrients causing reduced leaf area, dry matter and finally lower stover yield.

Foliar application of KNO_3 1 % (F_3) twice with 15 days interval at 50 per cent flowering stage was registered maximum stover yield of redgram and significantly superior to foliar application of borax 0.1 % (F_2) and control (No spray) (F_1). The latter two treatments were comparable with each other. Maximum stover yield with KNO_3 1 % (F_3) foliar spray might be due to better absorption, translocation of nutrients, consequent cellular functions and increased enzyme activities which were reflected in higher values of growth parameters which resulted in higher stover yield. These results are in conformity with Waraich et al. [32] Keerthi et al. [33] Vijayakumar et al. [26] and Laishram et al. [27].

3.3 Nutrient Uptake at Different Growth Stages of Redgram

Nutrient uptake of nitrogen, phosphorous and potassium was estimated at 30, 60, 90, 120 DAS and at harvest. Uptake of nutrients differed significantly due to tillage and nutrient management practices during both the years of study. (Table 4).

3.4 Nitrogen Uptake

Different tillage practices could not exert significant effect on nitrogen uptake at 30 DAS during both the years of study (Table. 2a and 2b). Significantly higher nitrogen uptake was registered with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) at 60, 90, 120 DAS and at harvest of redgram followed by ploughing with duck foot cultivator at a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) with significant disparity between each other. Lower nitrogen uptake was recorded with conventional tillage with tractor drawn cultivator (T_1).

Nutrient management practices could not exert significant effect on nitrogen uptake at 30 DAS. Application of 125 % RDF (N_3) registered higher nitrogen as compared with 100 % RDF (N_2) and 75 % RDF (N_1) at 60, 90, 120 DAS and at harvest during two years of investigation.

Foliar application of nutrients twice with 15 days interval at 50 per cent flowering stage exerted significant effect on nitrogen uptake of redgram at harvest during both the years of study. Foliar application of KNO_3 1 % (F_3) recorded maximum nitrogen uptake, followed by foliar application of borax 0.1 % (F_2) and control (no spray) (F_1) which was recorded lower nitrogen uptake.

3.5 Phosphorus Uptake

Phosphorus uptake of redgram significantly differed due to tillage, nutrient management practices and foliar sprays. Interaction between tillage and nutrient management practices alone was observed at 120 DAS and at harvest in both the years of experiment.

Vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3) recorded higher phosphorus uptake at 30. 60, 90, 120 DAS and at harvest of redgram followed by ploughing with duck foot cultivator upto a depth of 30 cm (T_2) and conventional tillage with tractor drawn cultivator (T_1) in the order of descent with significant disparity between any two of the three tillage practices during both the years study (Table. 3a and 3b).

With regards to nutrient management practices evaluated, higher phosphorus uptake was registered with application of 125 % RDF (N_3) followed by 100 % RDF (N_2) and 75 % RDF with significant disparity among one another at all crop growth stages of redgram during two years of experiment (Table. 3a and 3b).

Table 2(a). Nitrogen uptake (kg ha^{-1}) as influenced by tillage and nutrient management practices at different growth stages of redgram during 2019-20 and 2020-21

Treatments	30 DAS		Pooled	60 DAS		Pooled	90 DAS		Pooled
	2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
Main plots : Tillage practices (T) (3)									
T_1- Conventional tillage with tractor drawn cultivator	0.51	0.35	0.43	24.4	20.4	22.4	65.6	54.7	60.2
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	0.57	0.38	0.48	29.8	25.6	27.7	78.3	66.5	72.4
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	0.66	0.45	0.56	36.1	31.0	33.6	82.6	69.4	76.0
SEm±	0.030	0.012	0.021	1.25	1.07	1.16	2.29	1.8	2.05
CD (P= 0.05)	NS	NS	NS	4.9	4.2	4.6	9.0	7.2	8.1
Sub plots : Nutrient management practices (N) (3)									
N_1- 75% RDF	0.54	0.37	0.46	26.5	22.3	24.4	64.6	54.2	59.4
N_2- 100% RDF	0.58	0.39	0.49	29.7	25.3	27.5	75.1	63.2	69.2
N_3- 125% RDF	0.62	0.42	0.52	34.2	29.4	31.8	86.8	73.2	80.0
SEm±	0.021	0.013	0.017	0.97	0.84	0.91	1.82	1.5	1.66
CD (P= 0.05)	NS	NS	NS	3.0	2.0	2.5	5.6	4.6	5.1
Sub sub plots : Foliar sprays (F) (3)									
F_1- Control	0.57	0.37	0.47	29.4	25.0	27.2	73.8	62.2	68.0
F_2- Borax - 0.1%	0.57	0.39	0.48	30.2	25.8	28.0	75.1	63.2	69.2
F_3- KNO_3 - 1.0%	0.59	0.42	0.51	30.7	26.2	28.5	77.7	65.2	71.5
SEm±	0.014	0.013	0.014	0.737	0.64	0.69	2.02	1.65	1.84
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
T x N									
SEm±	0.036	0.023	0.030	1.67	1.45	1.56	3.15	2.57	2.86
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x F									
SEm±	0.025	0.022	0.024	1.27	1.01	1.14	3.50	2.86	3.18
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x F									
SEm±	0.025	0.022	0.024	1.27	1.01	1.14	3.50	2.86	3.18
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N x F									
SEm±	0.045	0.038	0.042	2.21	1.90	2.06	6.06	4.95	5.51
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2(b). Nitrogen uptake (kg ha^{-1}) as influenced by tillage, nutrient management practices and foliar sprays at different growth stages of redgram during 2019-20 and 2020

Treatments	120 DAS		Pooled	At harvest		Pooled
	2019-20	2020-21		2019-20	2020-21	
Main plots : Tillage practices (T) (3)						
T_1- Conventional tillage with tractor drawn cultivator	117	91	104	152	127	140
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	139	107	123	180	151	165
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	156	120	138	206	166	186
SEm±	5.8	4.5	5	7.5	6.2	6.9
CD (P= 0.05)	23	18	20	30	24	27
Sub plots : Nutrient management practices (N) (3)						
N_1- 75% RDF	112	86	99	143	126	134
N_2- 100% RDF	139	107	123	182	147	165
N_3- 125% RDF	161	124	143	213	172	192
SEm±	4.8	3.7	4	4.4	4.0	4.2
CD (P= 0.05)	15	11	13	14	12	13
Sub sub plots : Foliar sprays (F) (3)						
F_1- Control	135	104	120	168	137	151
F_2- Borax - 0.1%	138	106	122	179	148	164
F_3- KNO_3 - 1.0%	139	107	123	191	160	176
SEm±	3.0	2.3	3	4.0	2.8	3.4
CD (P= 0.05)	NS	NS	NS	11	8	10
Interaction						
T x N						
SEm±	8.2	6.3	7.2	7.5	6.9	7.2
CD (P= 0.05)	25	19	22	23	21	22
T x F						
SEm±	5.20	3.9	4.5	6.9	5.6	6.2
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
N x F						
SEm±	5.20	3.9	4.5	6.9	5.6	6.2
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
T x N x F						
SEm±	9.00	6.8	7.9	11.9	8.9	10.4
CD (P= 0.05)	NS	NS	NS	NS	NS	NS

Table 3(a). Phosphorus uptake (kg ha^{-1}) as influenced by tillage and nutrient management practices at different growth stages of redgram during 2019-20 and 2020-21

Treatments	30 DAS		Pooled	60 DAS		Pooled	90 DAS		Pooled
	2019-20	2020-21		2019-20	2020-21		2019-20	2020-21	
Main plots : Tillage practices (T) (3)									
T_1- Conventional tillage with tractor drawn cultivator	0.068	0.044	0.056	3.00	2.42	2.71	8.46	8.11	8.29
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	0.092	0.060	0.076	4.50	3.63	4.07	12.32	11.76	12.04
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	0.128	0.082	0.105	6.71	5.53	6.12	15.56	14.80	15.18
SEm±	0.0047	0.0032	0.0040	0.447	0.367	0.407	0.416	0.519	0.468
CD (P= 0.05)	0.018	0.013	0.016	1.75	1.44	1.60	1.63	2.04	1.84
Sub plots : Nutrient management practices (N) (3)									
N_1- 75% RDF	0.084	0.054	0.069	3.96	3.23	3.60	9.28	8.49	8.89
N_2- 100% RDF	0.096	0.062	0.079	4.79	3.91	4.35	12.15	11.63	11.89
N_3- 125% RDF	0.109	0.070	0.090	5.46	4.45	4.96	14.92	14.55	14.74
SEm±	0.0033	0.0022	0.0028	0.202	0.164	0.183	0.272	1.026	0.649
CD (P= 0.05)	0.010	0.007	0.009	0.62	0.51	0.57	0.84	3.16	2.00
Sub sub plots : Foliar sprays (F) (3)									
F_1- Control	0.096	0.059	0.078	4.61	3.76	4.19	11.87	11.35	11.61
F_2- Borax - 0.1%	0.096	0.062	0.079	4.70	3.83	4.27	12.00	11.44	11.72
F_3- KNO_3 - 1.0%	0.097	0.066	0.082	4.91	4.00	4.46	12.47	11.88	12.18
SEm±	0.0023	0.0014	0.0019	0.134	0.110	0.122	0.222	0.203	0.213
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction									
T x N									
SEm±	0.0057	0.037	0.021	0.349	0.284	0.317	1.606	1.776	1.691
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x F									
SEm±	0.0040	0.0034	0.004	0.231	0.189	0.210	0.337	0.350	0.343
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x F									
SEm±	0.0040	0.0034	0.004	0.231	0.189	0.210	0.337	0.350	0.343
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N x F									
SEm±	0.0069	0.0043	0.006	0.400	0.328	0.364	0.584	0.609	0.596
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3(b). Phosphorus uptake (kg ha^{-1}) as influenced by tillage, nutrient management practices and foliar sprays at different growth stages of redgram during 2019-20 and 2020

Treatments	120 DAS		Pooled	At harvest		Pooled
	2019-20	2020-21		2019-20	2020-21	
Main plots : Tillage practices (T) (3)						
T_1- Conventional tillage with tractor drawn cultivator	14.43	11.21	12.82	17.68	14.52	16.10
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	20.16	15.62	17.89	24.88	20.43	22.66
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	27.88	21.55	24.71	35.26	27.77	31.52
SEm±	2.145	1.702	1.924	2.301	1.742	2.021
CD (P= 0.05)	8.42	6.68	7.55	9.04	6.84	7.93
Sub plots : Nutrient management practices (N) (3)						
N_1- 75% RDF	14.95	11.61	13.28	17.89	15.44	16.67
N_2- 100% RDF	21.02	16.29	18.65	25.10	19.78	22.44
N_3- 125% RDF	26.49	20.49	23.49	34.83	27.49	31.16
SEm±	1.795	1.409	1.602	2.899	2.333	2.610
CD (P= 0.05)	5.53	4.34	4.94	8.93	7.19	8.04
Sub sub plots : Foliar sprays (F) (3)						
F_1- Control	20.59	15.95	18.27	25.73	20.34	23.03
F_2- Borax - 0.1%	20.79	16.09	18.43	25.94	20.81	23.38
F_3- KNO_3 - 1.0%	21.09	16.34	18.72	26.16	21.57	23.86
SEm±	0.336	0.254	0.295	0.37	0.304	0.286
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
Interaction						
T x N						
SEm±	3.112	2.433	2.773	5.022	4.040	4.521
CD (P= 0.05)	10.10	7.52	8.55	15.47	12.45	13.93
T x F						
SEm±	0.582	0.440	0.511	0.644	0.526	0.495
CD (P= 0.05)	NS	NS	NS		NS	NS
N x F						
SEm±	0.582	0.440	0.511	0.644	0.526	0.495
CD (P= 0.05)	NS	NS	NS		NS	NS
T x N x F						
SEm±	1.009	0.762	0.886	1.1157	0.911	0.858
CD (P= 0.05)	NS	NS	NS		NS	NS

Table 4(a). Potassium uptake (kg ha^{-1}) as influenced by tillage and nutrient management practices at different growth stages of redgram during 2019-20 and 2020-21

Treatments	30 DAS			60 DAS			90 DAS		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
Main plots : Tillage practices (T) (3)									
T_1- Conventional tillage with tractor drawn cultivator	0.50	0.35	0.43	22.1	18.2	20.2	63.7	54.84	59.27
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	0.57	0.40	0.49	27.1	22.3	24.7	77.9	66.29	72.10
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	0.66	0.46	0.56	33.0	27.1	30.1	83.1	70.67	76.89
SEm±	0.029	0.022	0.026	1.23	1.00	1.12	2.72	2.187	2.454
CD (P= 0.05)	NS	NS	NS	4.8	3.9	4.4	10.6	8.59	9.60
Sub plots : Nutrient management practices (N) (3)									
N_1- 75% RDF	0.54	0.36	0.45	24.1	19.8	22.0	64.2	55.19	59.70
N_2- 100% RDF	0.58	0.39	0.49	26.8	22.0	24.4	73.5	62.80	68.15
N_3- 125% RDF	0.61	0.45	0.53	31.3	25.7	28.5	87.0	73.81	80.41
SEm±	0.018	0.019	0.019	0.76	0.62	0.69	2.70	2.280	2.490
CD (P= 0.05)	0.05	0.06	0.06	2.3	1.9	2.1	8.3	7.02	7.66
Sub sub plots : Foliar sprays (F) (3)									
F_1- Control	0.58	0.36	0.47	25.7	21.1	23.4	72.9	59.76	66.33
F_2- Borax - 0.1%	0.57	0.40	0.49	27.5	22.6	25.1	74.4	63.56	68.98
F_3- KNO_3 - 1.0%	0.59	0.45	0.52	29.1	23.9	26.5	77.4	68.49	72.95
SEm±	0.013	0.015	0.014	0.97	0.79	0.88	2.66	2.229	2.445
CD (P= 0.05)	NS	0.04	NS	NS	NS	NS	NS	NS	NS
Interaction									
T x N									
SEm±	0.034	0.033	0.034	1.31	1.08	1.20	4.67	3.948	4.309
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x F									
SEm±	0.029	0.026	0.028	1.67	1.37	1.52	4.61	3.861	4.236
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
N x F									
SEm±	0.0229	0.026	0.024	1.67	1.37	1.52	4.61	3.861	4.236
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
T x N x F									
SEm±	0.039	0.045	0.042	2.89	2.38	2.64	7.98	6.885	7.433
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4(b). Potassium uptake (kg ha^{-1}) as influenced by tillage, nutrient management practices and foliar sprays at different growth stages of redgram during 2019-20 and 2020

Treatments	120 DAS		Pooled	At harvest		Pooled
	2019-20	2020-21		2019-20	2020-21	
Main plots : Tillage practices (T) (3)						
T_1- Conventional tillage with tractor drawn cultivator	104	82	93	137	114	123
T_2- Ploughing with duck foot cultivator upto a depth of 30 cm	121	95	108	157	133	144
T_3- Vertical Tillage with subsoiler upto 60 cm deep at 1.0 m interval	140	110	125	184	148	165
SEm±	6.0	4.7	5.4	6.8	5.5	6.2
CD (P= 0.05)	24	19	22	27	22	24
Sub plots : Nutrient management practices (N) (3)						
N_1- 75% RDF	100	78	89	128	113	119
N_2- 100% RDF	123	96	110	161	130	144
N_3- 125% RDF	143	112	128	190	152	168
SEm±	3.7	2.9	3.3	5.2	3.2	4.1
CD (P= 0.05)	11	9	10	16	10	13
Sub sub plots : Foliar sprays (F) (3)						
F_1- Control	115	90	103	150	122	134
F_2- Borax - 0.1%	122	96	109	160	131	143
F_3- KNO_3 - 1.0%	129	101	115	169	143	154
SEm±	3.6	2.8	3.2	5.2	2.5	3.7
CD (P= 0.05)	NS	NS	NS	16	7	11
Interaction						
T x N						
SEm±	6.4	5.0	5.7	8.9	5.5	7.2
CD (P= 0.05)	20	15	17	29	17	23
T x F						
SEm±	6.1	4.8	5.5	8.7	4.3	6.4
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
N x F						
SEm±	6.1	4.8	5.5	8.7	4.3	6.4
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
T x N x F						
SEm±	10.6	8.4	9.5	14.8	7.5	11.1
CD (P= 0.05)	NS	NS	NS	NS	NS	NS

Foliar application of KNO_3 1 % (F_3) twice at 50 per cent flowering stage recorded maximum phosphorus uptake, followed by borax 0.1 % (F_2) and control (no spray) (F_1) recorded lower nitrogen uptake at harvest stage of redgram during both the years (Table. 3a and 3b).

3.6 Potassium Uptake

Phosphorus uptake differed significantly due to tillage, nutrient doses and foliar applications, whereas, foliar sprays could not exert any significant effect on phosphorus uptake by redgram during both the years.

Tillage and nutrient management practices could not exert significant effect on potassium uptake of redgram at 30 DAS.

In the different tillage practices, higher potassium uptake at 60, 90 120 DAS and at harvest was registered 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) which recorded the lower potassium uptake during both years (Table. 4a and 4b).

Among the different nutrient management practices tried, higher potassium uptake of redgram was registered with application of 125 % RDF (N_3) which was significantly superior to 100 % RDF (N_2) and 75 % RDF (N_1) at different growth stages of redgram.

Higher potassium uptake at harvest was registered with foliar application of KNO_3 1 % (F_3) applied twice at 50 per cent flowering stage which was statistically comparable with borax 0.1 % (F_2) and significantly superior to control (no spray) (F_1) during two years of experiment (Table. 4a and 4b).

Significant variations among the nutrient uptake were observed mainly due to the variation in grain and straw yield of the crop during both the years of study. Maximum uptake of nitrogen, phosphorous and potassium at all growth stages of redgram was recorded with vertical tillage with subsoiler upto 60 cm deep at 1 m interval (T_3). This might be due to adequate availability of moisture and N, P and K nutrients throughout the growth favoured more mineralisation and translocation of nutrients enhanced the vegetative growth which ultimately increased N, P and K concentration in the total plant biomass which inturn increases nutrient uptake in subsoiling as compared to deep ploughing and conventional tillage treatments. Similar results stating that significant effect of vertical tillage on nutrient uptake by plants were reported by Cai et al. [34,10] and Guohua et al. [35].

Higher nitrogen, phosphorous and potassium uptake by plants were registered with 125 % RDF (N_3). This might be due to higher availability of nutrients increased root growth leading to exploitation of more soil volume for absorption and improve the root cation exchange capacity which inturn increases dry matter production and yield coupled with enhanced absorption of the nutrients. These results are in agreement with the findings of Pacharne et al. [36], Priya [10], Nagamani et al. [19] and Kadam et al. [37]. Minimum amount of nitrogen, phosphorous and potassium uptake was measured with 75 % RDF (N_1) due to less availability of nutrients for the plants.

Higher nutrient uptake by redgram at harvest was registered with foliar application of KNO_3-1 % (F_3) twice at 50 per cent flowering stage due to improved nutritional environment in the rhizosphere and plant system, potassium nitrate may help plant to pump sucrose through roots that attracts soil microbes consequently they promote better nutrient uptake by the roots. These results are in accordance with Raj and Mallick [38], Krishna and Kaleeswari [39] and Laishram et al. [27].

The interaction of tillage, nutrient management practices and foliar sprays was found to be not significant in affecting nutrient uptake *viz*., nitrogen, phosphorous and potassium by redgram crop during both the two years of investigation.

4. 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 better seed and stover yield, nutrient uptake under the prevailing condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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