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Response of Pulses to Foliar Application of Multinutrients on Yield, Quality, Uptake and Soil Nutrient Status

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A pot culture experiment was carried out with the redgram var. CO(Rg)7 at Tamil Nadu Agricultural University, Coimbatore. The soil used for the experiment was red, calcareous, sandy loam which belongs to the soil series Palladam (*TypicUstropept*). The experiment soil was medium in available N (285 kg ha^{-1}), high in available P (26.75 kg ha^{-1}) and K (287 kg ha^{-1}). The soil was deficient in DTPA-Fe (4.80 mg kg^{-1}), DTPA-Mn (0.25 mg kg^{-1}), DTPA-Zn (0.15 mg kg^{-1}), DTPA-Cu (0.22 mg kg^{-1}), and sufficient in hot water soluble B (0.75 mg kg^{-1}). The experiment was laid out with eleven treatments in a completely randomised design (CRD) replicated thrice to study the effect of foliar application of multinutrients on the yield, quality, uptake and soil nutrient status of redgram. In the treatments of foliar application with different combinations of complex, micronutrient and chelated micronutrient fertilisers at different stages, application of 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% recommended dose of NPK (T_7) recorded the maximum value of yield attributes. Quality parameters such as seed protein content and seed total free amino acid content were enhanced by the foliar application of 0.5% KNO_3 + 2% DAP + micronutrient spray. Application of 100% RD NPK and foliar spraying of 0.5% KNO_3 + 2% DAP + micronutrient recorded the highest macro and micro nutrient uptake which was followed by the treatments that received 100% RD NPK and foliar spray of 0.5% MAP + 0.5% KNO_3 + micronutrients and 100% RD NPK and foliar spray of 0.5% KNO_3 + 2% DAP + chelated micronutrients. Availability of N, P, K, Fe, Mn, Zn, Cu and B contents in soil at different stages was significantly influenced by the various foliar applications. The Chlorophyll 'a', 'b' and total chlorophyll contents were found to be the highest in the treatment that received 100% RD NPK + foliar spray of 0.5% KNO_3 + 2% DAP + micronutrients (T_7).

Key words: Foliar application, Yield attributes, Quality parameters, Chlorophyll content, Nutrient uptake, Soil nutrient status.

India is the largest producer, importer and consumer of pulses accounting for 25% of global production from 35 % of global area under pulses. The productivity of pulses in India is less than half of the productivity levels in the USA and Canada, as the pulses are mainly grown under rainfed conditions in India. Inadequate adoption of production technology is an important factor responsible for low productivity of pulses. It is imperative to develop and adapt more efficient crop production and nutrient management technologies to enhance the productivity of pulses in order to meet the domestic supply and import requirements. Redgram is one of the most important grain legume crops in the tropical and subtropical regions of the world. It is the main source of protein for Indian vegetarians (40-50 %) and is the second most important pulse crop of India next to chickpea.

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 and increase the crop yield. Production of major pulses is constrained by both biotic and abiotic stresses. The foliar application of nutrients could be ascribed to quick access to nutrients by plants at seedling and early development stages. Among the micronutrients Zn, Fe, B, Mn and Mo improved the yield appreciably and foliar spray of micronutrients proved to be economical in pulses (Savithri, 2001). Retention of flowers is possible through foliar application of macronutrients during flower initiation and pod development stages along with soil application of micronutrients (Chaurasia *et al.*, 2005).

Considering the inadequate adoption of production technology that lead to low productivity of pulses, various alternatives were considered over the conventional cultivation practices. With this background, a pot study was conducted to assess the effect of foliar application of multinutrients on the yield and uptake of redgram.

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Material and Methods

Experimental details, climate and soil type

The experiment was conducted at the greenhouse of Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, located in the north western agro climatic zone of Tamil Nadu at 11°N latitude 77°E longitude at an altitude of 426 m above the mean sea level. The soil type used for the pot experiment was red, calcareous, sandy loam that belongs to the soil series Palladam (*TypicUstropept*). The experiment soil was medium in available N (285 kg ha^{-1}), high in available P (26.75 kg ha^{-1}) and K (287 kg ha^{-1}). The soil was deficient in DTPA-Fe (4.80 mg kg^{-1}), DTPA-Mn (0.25 mg kg^{-1}), DTPA-Zn (0.15 mg kg^{-1}), DTPA-Cu (0.22 mg kg^{-1}), and sufficient in hot water soluble B (0.75 mg kg^{-1}).

Treatment details

There were eleven treatments each replicated three times in Completely Randomized Block Design viz., T_1 : 100 % Recommended Dose (RD) 25:50:25 kg NPKS ha^{-1},T_2 : 100 %RD + 2% Diammonium Phosphate (DAP) Foliar Spray (twice), T_3 :100 %RD + 1%19:19:19 Foliar Spray (twice), T_4 : RDF + 0.5% Monoammonium Phosphate (MAP) Foliar Spray (twice), T_5 : 100 %RD + 0.5% KNO_3 + 2% DAP Foliar Spray (twice), T_6 : 100 %RD + 0.5% MAP + 0.5% KNO_3 Foliar Spray (twice), T_7 : 100 %RD + 0.5% KNO_3 + 2% DAP (twice) + micronutrient spray (once) Foliar Spray, T_8 :100 %RD+ 0.5% MAP + 0.5% KNO_3 (twice) + micronutrient spray (once) Foliar Spray , T_9 : 100 %RD+ 0.5% KNO_3 + 2% DAP (twice) + chelated micro nutrient (once) Foliar Spray, T_{10} :100 %RD + 0.5% MAP + 0.5% KNO_3 (twice) + chelated micronutrient spray (once) Foliar Spray and T_{11} : untreated control.

Analysis of soil and plant sample

The soil sample used for conducting the study was air dried, broken with wooden mallet and sieved through 2mm sieve, labelled and stored in cloth bags for further analysis.To study the chemical changes in the soil at various crop growing stages, soil samples were collected from each pot at the respective stages. The Organic Carbon was estimated by Chromic acid wet digestion (Walkley and Black, 1934), available N by alkaline permanganate method (Subbiah and Asijia, 1956), available P by using 0.5 M $NaHCO_3$ (Olsen, 1954), available K by neutral normal NH_4OAc method (Stanford and English, 1949) followed by flame photometry and available micronutrients by DTPA extraction and AAS method (Lindsay and Norvell, 1978), respectively. Besides, plant samples were analysed for N content using Di-acid extraction method (Jackson 1973). Plant P was analysed using triple acid extract and Vanadomolybdate phosphoric acid yellow colour method by Jackson 1973, plant K was analysed using Triple acid extraction method followed by flame photometry (Piper, 1966) and micronutrient content was analysed using Triple acid digestion and AAS method (Lindsay and Norvell, 1978). For statistical analysis of data, Microsoft Excel (Microsoft Corporation, USA) and Agres window version 7.0 packages were used.

Results and Discussion

Effect of foliar nutrition on yield parameters of redgram

Number of pods per plant

Number of pods $plant^{-1}$ is the most important yield attribute for a pulse crop. Foliar application of 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK increased the number of pods $plant^{-1}$. This would be due to the foliar application of higher concentration of multinutrients at critical growth stages which increased the growth and yield

Table 1. Effect of foliar nutrition on yield parameters of redgram at harvest stage

Treatment	Number of pods $plant^{-1}$	Pod length (cm)	Dry matter production of pods (g $plant^{-1}$)	Number of seeds pod^{-1}	100 seed weight (g)
T_1	55.25	5.21	55.89	3.56	6.98
T_2	75.32	5.85	65.25	3.73	7.89
T_3	70.14	5.42	60.21	3.68	7.52
T_4	72.65	5.65	62.15	3.71	7.34
T_5	80.32	6.89	75.75	3.81	9.65
T_6	78.85	6.56	72.32	3.79	8.85
T_7	90.25	7.52	90.48	4.54	12.11
T_8	85.21	7.34	82.25	4.35	11.15
T_9	84.87	7.19	81.13	4.27	10.95
T_{10}	83.54	7.05	80.21	4.15	9.89
T_{11}	45.35	5.00	35.21	3.14	6.25
Mean	77.33	6.33	69.16	3.88	8.96
SEd	1.76	0.16	1.67	0.09	0.10
CD(P=0.05)	3.65	0.33	3.47	0.18	0.21

parameters. These results are in confirmity with the earlier findings of with Yakadri *et al.*, 2002 and Yasari *et al.*, 2012.

Table 2. Effect of foliar nutrition on quality of redgram seeds at harvest stage

Treatment	Protein content (%)	Total free amino acid content (mg)
T_1	41.32	7.32
T_2	45.12	7.52
T_3	43.63	7.45
T_4	44.32	7.51
T_5	45.65	7.58
T_6	45.45	7.54
T_7	49.36	7.85
T_8	48.52	7.82
T_9	47.23	7.64
T_{10}	46.54	7.61
T_{11}	40.35	7.11
Mean	45.22	7.53
SEd	1.08	0.18
CD(P=0.05)	2.25	0.37

Pod length

Among the various treatments, foliar applications of 0.5% KNO_3 + 2% DAP + micronutrient spray along with RDF recorded the highest pod length. Foliar spraying resulted in effective absorption of the nutrients during critical stages of growth and in turn contributed to increased pod length. This result was in accordance with the earlier findings of Sarkar *et al.*, 2001. The increase in yield attributes could be due to supplementation of nutrients at the critical stages of crop growth without physiological stress.

Table 3. Effect of foliar nutrition on Chlorophyll content (mg g^{-1}) of leaves of redgram

Treatment	Chlorophyll 'a' (mg g^{-1})	Chlorophyll 'b' (mg g^{-1})	Total Chlorophyll (mg g^{-1})
T_1	0.5	0.7	1.2
T_2	1.3	1.8	3.1
T_3	0.9	1.5	2.4
T_4	1.1	1.6	2.7
T_5	1.4	2.0	3.4
T_6	1.2	1.9	3.1
T_7	2.0	2.5	4.5
T_8	1.9	2.4	4.3
T_9	1.7	2.3	4.0
T_{10}	1.5	2.1	3.6
T_{11}	0.5	0.5	1.0
Mean	1.27	1.75	3.02
SEd	0.03	0.03	0.08
CD(P=0.05)	0.06	0.07	0.17

Number of seeds per pod

Number of seeds pod^{-1} was significantly influenced by both basal as well as foliar application of multinutrients. Compared to all other treatments, foliar application of 0.5% KNO_3 + 2% DAP + Micronutrient spray recorded the maximum value.This could be due to the higher availability of nutrients supplied through supplemental foliar feeding during seed development stage that retarded senescence and resulted in larger pod filling period leading to greater seed yield plant. These results are in confirmity with earlier findings of Venkatesh *et al.*, 2012. Foliar application of nutrients enhanced the number of floral buds, prevented the floral shedding by maintaining optimum bio - physiological conditions.

Hundred Seed weight

Hundred seed weight was significantly enhanced by the foliar application of 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK. This could be attributed due to the activity of cytokinin predominantly takes place in the root tips and play an active role in cell division. Thus enhanced root activity under foliar fertilization might have increased cytokinin synthesis resulting increased vegetative and reproductive growth of plants. These observations are in line with the findings of with Yasari *et al.*, 2012.

Table 4. Effect of foliar nutrition on uptake of nitrogen, phosphorus and potassium (kg ha^{-1}) by redgram stover

Treatment	Nitrogen	Phosphorus	Potassium
T_1	105.34	15.12	25.42
T_2	112.35	16.95	32.14
T_3	107.35	15.56	28.52
T_4	110.85	16.21	30.74
T_5	118.23	17.65	37.25
T_6	115.54	17.21	34.87
T_7	135.65	20.54	48.23
T_8	128.56	19.78	45.54
T_9	123.52	19.35	43.25
T_{10}	120.78	19.01	39.75
T_{11}	85.52	14.23	22.13
Mean	114.88	17.41	35.25
SEd	2.09	0.36	0.76
CD(P=0.05)	4.33	0.76	1.58

Effect of foliar nutrition on chlorophyll content

Chlorophyll 'a'

The highest chlorophyll 'a' content of 2 mg g^{-1} was recorded in the treatment that received 100% RD NPK + foliar spray of 0.5% KNO_3 + 2% DAP + micronutrient. Lowest chlorophyll 'a'content was recorded by untreated control. Addition of nutrients through leaf increases the leaf N content. As 'N' is essential for chlorophyll synthesis increase in leaf N content result is increase in chlorophyll content. Similar results of increase in chlorophyll 'a' content due to foliar spray was reported by Mondal *et al.,* 2011 in mungbean.

Chlorophyll 'b'

Foliar spraying of 0.5 % of KNO_3 +2% DAP +micronutrients spray along with 100%RD NPK recorded higher Chlorophyll 'b' content. Similar results of increase in Chlorophyll 'b' content due to foliar spray of KNO_3 or urea was reported by Rai *et al.*, 1988 in sugarcane.

Total chlorophyll content

Foliar nutrition of 2 mg g^{-1} recorded total to chlorophyll content. This could be attributed to the increase in nutrient contents of leaves would have increased the total chlorophyll contents especially N, which is essential for chlorophyll synthesis. The

Table 5. Effect of foliar nutrition on total uptake of micronutrients (g kg^{-1}) by redgram stover

Treatment	Fe	Mn	Zn	Cu	Hot water soluble boron
T_1	280.21	27.25	92.13	7.82	6.15
T_2	345.32	32.31	102.25	9.12	7.98
T_3	310.85	29.87	96.25	8.41	6.45
T_4	340.12	31.65	101.56	8.95	7.23
T_5	375.21	37.25	103.16	10.25	9.72
T_6	360.25	36.54	102.55	9.86	8.21
T_7	420.25	48.94	115.23	15.65	12.41
T_8	415.23	46.23	112.31	13.21	12.13
T_9	407.15	40.12	110.56	12.25	11.42
T_{10}	390.14	38.13	108.21	11.12	10.85
T_{11}	272.16	25.14	82.35	6.23	5.62
Mean	356.08	35.76	102.41	10.26	8.92
SEd	8.60	0.70	2.28	0.17	0.21
CD(P=0.05)	17.84	1.45	4.74	0.35	0.44

increase in total chlorophyll content due to foliar spray of KNO_3 or urea was reported by Sritharan *et al.*, 2005 in mung bean and Jagetiya and Kaur, 2006 in soybean.

Effect of foliar nutrition on quality parameters of red gram

Foliar applications of 0.5% KNO3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK has recorded the highest seed protein content. This might be due to the additional amounts of N and P supplied through foliar spraying. It's because N being a constituent of amino acid, the building block of protein contributes directly while P increase the protein content indirectly as it is required in two processes of protein synthesis i.e. activation of amino acid and termination of carbon in m-RNA of polypeptide releasing factors.

This increase in protein content was in accordance with the earlier findings of Mondal *et al.*, 2011. The improvement in quality of red gram seeds could be attributed to the pivotal role of foliar nutrition in improving congenial nutritional environment. Greater availability of N and P and regular supply of metabolites for protein synthesis improves translocation of nutrients from source to sink which ultimately increased protein content in seeds.

Total free amino acid content was significantly influenced by foliar application of multinutrients. Compared to all other treatments, foliar application of 0.5% KNO_3 + 2% DAP + micronutrient spray recorded the highest total free amino acid content similar observations were also reported by Basole *et al.*, 2003 .

Effect of foliar nutrition on uptake of nutrient uptake by redgram

The uptake of N, P and K nutrients were significantly increased by foliar application. N uptake by crop was significantly enhanced by the foliar application and the highest uptake was recorded in the treatment 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK. Nitrogen uptake, which indicates the N supply to the redgram crop, increased substantially during the growth period. The higher uptake of N noticed in the crop might be due to the higher dry matter production. Similar observations was also reported by Dixit *et al.*, 2007.

Foliar applications of 0.5% KNO3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK recorded the highest P uptake. This might be due to supply of the multinutrients through foliar spray which lead to effective absorption of required quantities of P. This results are in corroboration with the previous works of Dixit *et al.*, 2007 and Thakare *et al.*, 2006.

K uptake by crop was also significantly enhanced by the foliar application and the highest uptake was observed with 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK (T_7). This could be attributed to the foliar application of higher concentration of multinutrients at critical growth stages which in turn increased the crop uptake.This is in line with the findings of Dixit *et al.*, 2007 and R. Raman and Venkatrama, 2006.

Foliar applications of 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of

100% RD NPK (T_7) recorded the highest micronutrient uptake. This could be attributed to supply of various combinations of micronutrient fertilizers which ultimately leads to increased uptake by the crop. Similar findings were reported by Sale, 2013.

Table 6. Effect of foliar nutrition on available nitrogen (Alkaline $KMnO_4$-N), available phosphorus (Olsen-P) and available potassium (Neutral normal NH_4 OAC-K) status of soil (kg ha^{-1}) at harvest stage of redgram

Treatment	Available N	Available P	Available K
T_1	244	21.54	242
T_2	253	22.35	249
T_3	249	21.98	245
T_4	250	22.10	246
T_5	261	22.85	256
T_6	255	22.54	254
T_7	276	25.00	278
T_8	271	24.85	273
T_9	268	23.89	268
T_{10}	265	23.54	265
T_{11}	240	21.10	240
Mean	257	22.88	256
SEd	5.02	0.44	4.08
CD(P=0.05)	10.41	0.91	8.47

Effect of foliar nutrition on available nutrient status of soil at different stages of crop growth

Soil available nitrogen

Nitrogen is the foremost element required and essential for all crop growth. It results in higher biomass yields. Nitrogen often affects amino acid composition of protein, and in turn its nutritional quality. Highest available N was observed due to the application of 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK in all crop growing stages of red gram .

The nitrogen supplied through the foliar application during critical stages of growth resulted in less N uptake from the soil. These results are in confirmity with the earlier findings of Gebremedhin, 2015..

Soil available phosphorus

Phosphorus is an essential nutrient for all living organisms and vital component of the substances that are building blocks of genes and chromosomes. In plants, it plays a role in virtually all biochemical processes that involve energy transfer. Foliar application of multinutrients increased the available P status of soil.

Among the treatments, the highest available P content was obtained in 0.5% KNO_3 + 2% DAP + micronutrient spray along with RDF (T_7) in all three stages i.e. vegetative, flowering and post harvest stages. The phosphorus supplied through the foliar application during critical stages of growth results in less P uptake from the soil. Similar observations was also reported by Yadav *et al.*, 2012..

Soil available potassium

Potassium has long been referred to as the 'quality nutrient'. Potassium is a unique element and also plays a regulatory role in plant metabolism and development. It also regulates the opening and closing of stomata, which are essential for photosynthesis, water and nutrient transport. In this pot culture experiment, the available K status was increased with the increased level of foliar application of fertilizers but there was a decreased trend that occurred between the stages.

Table 7. Effect of foliar nutrition on DTPA - Fe, DTPA- Mn, DTPA- Zn, DTPA -Cu and hot water soluble boron status of soil (mg kg^{-1}) at harvest stage of redgram

Treatment	DTPA -Fe	DTPA- Mn	DTPA- Zn	DTPA- Cu	Hot water soluble boron
T_1	4.1	0.07	0.02	0.10	0.55
T_2	4.3	0.09	0.05	0.12	0.59
T_3	4.1	0.08	0.03	0.11	0.56
T_4	4.2	0.09	0.04	0.12	0.57
T_5	4.4	0.11	0.06	0.14	0.61
T_6	4.3	0.10	0.05	0.13	0.60
T_7	4.6	0.15	0.08	0.16	0.65
T_8	4.5	0.14	0.07	0.15	0.64
T_9	4.5	0.13	0.07	0.15	0.63
T_{10}	4.4	0.12	0.06	0.14	0.62
T_{11}	4.0	0.05	0.01	0.09	0.53
Mean	4.30	0.10	0.04	0.12	0.59
SEd	0.08	0.002	0.0009	0.002	0.01
CD(P=0.05)	0.18	0.005	0.0019	0.005	0.02

Among the treatments, the highest available K content was obtained in 0.5% KNO_3 + 2% DAP + micronutrient spray along with RDF (T_7) in all three stages i.e. vegetative, flowering and post harvest stages. The potassium supplied through the foliar application during critical stages of growth results in less K uptake from the soil. This was in line with the earlier findings of Gebremedhin, 2015.

Available micronutrients

The foliar application slightly increased the available micronutrient content of the soil. Foliar spray contains different combinations of micronutrient fertilizers which leads to less uptake of micronutrients from soil and thereby it increases the micronutrients availability.

Among the treatments, the highest available micronutrient content was obtained in 0.5% KNO_3 + 2% DAP + micronutrient spray along with soil application of 100% RD NPK in all three stages i.e. vegetative, flowering and post harvest stages. This results are in confirmity with the previous works of Varalakshmi *et al*., 2005.

Conclusion

In comparison with soil application, foliar application is a method of fertilizing plants directly and it produces an almost immediate effect on the growth and yield parameters of plants. On optimization of foliar treatments, the foliar application of 0.5% KNO_3 + 2% DAP + micronutrient spray along with 100% recommended dose of NPK @ 25:50:25 kg ha^{-1} could be recommended to enhance yield attributes, quality parameters, chlorophyll content, nutrient uptake and soil nutrient status by redgram.

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