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RESEARCH ARTICLE

Effect of Crop Specific Nutrient Mixtures on Growth, Yield attributes and Yield of Redgram (*Cajanuscajan* L.) under Irrigated Condition

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ABSTRACT

An incubation and pot culture experiments were conducted during *kharif* season of 2017-18 at Department of Soil Science and Agricultural Chemistry, TNAU, Coimbatore to assess the nutrient release pattern from different macronutrient mixtures in soil and to evaluate the effect of crop specific nutrient mixtures on yield and quality of redgram (*Cajanus cajan* L.) under irrigated condition. The experiments were laid out in completely randomized design (CRD) with ten (incubation) and eleven (pot culture) treatments. The treatments comprised of two sources of nitrogenous fertilizers *viz*., Urea and Calcium ammonium nitrate (CAN), one source of phosphatic fertilizer *viz*., Single Superphosphate (SSP), three sources of both nitrogenous and phosphatic fertilizers *viz*., Di-Ammonium Phosphate (DAP), Mono-Ammonium Phosphate (MAP) and Ammonium Sulphate Phosphate (ASP) and two sources of potassic fertilizers *viz.,* Muriate of Potash (MOP) and Sulphate of Potash (SOP). The results of incubation study revealed that application of CAN + DAP + SOP mixture resulted to higher release of nitrogen (2.78 to 18.51 kg ha^{-1}), phosphorus (4.16 to 22.06 kg ha^{-1}) and potassium (0.66 to 23.09 kg ha^{-1}) from 1 to 60 days of incubation (DOI)and the same treatment recorded higher plant height (95.2 cm), number of primary branches (9 $plant^{-1}$), number of root nodules (19 $plant^{-1}$), dry matter production (129 g $plant^{-1}$), number of pods (77.9 $plant^{-1}$), number of seeds (4.2 pod^{-1}) and 100 seed weight (14.5 g), seed yield (772 kg ha^{-1}), stalk yield (3210 kg ha^{-1}) and harvest index of redgram (19.92 %) in pot culture experiment at harvest stage.

Keywords: *Incubation, Nutrient mixtures, Fertilizers, Yield attributes, Dry matter production, Harvest index.*

INTRODUCTION

Pulses play an important role in Indian Agriculture as they restore soil fertility by fixing atmospheric nitrogen through their nodules. The major grain legumes grown in India are chickpea, redgram, green gram, black gram, cowpea, lentil and field pea, etc. Among these grain legumes, redgram (*Cajanus cajan* L.) is the major pulse crop of the tropics and subtropics.

Red gram is grown in an area of about 3.53 million hectares in India with a total production of 2.69 million tonnes. The productivity of red gram in India is only 762 kg ha^{-1} (Agrl stat, 2017). The productivity of pulses in India is low around 762 kg ha^{-1} against 1600 kg in the USA, 1400 kg in China, 1300 kg in the US and the world average is 900 kg ha^{-1} (Agrl stat, 2017). As the low productivity can be attributed by several factors such as cultivation in marginal and relatively poor soils, inadequate irrigation and other inputs, poor management practices, high susceptibility to diseases and insect pests and heavy flower drop. Among the above factors, poor and insufficient fertilizer management is one of the major causes of the low yield of redgram.

Fertilizer is one of the major agro-inputs contributing to the cost of production and productivity in crop production. For proper maintenance of the health of crops and to obtain a high yield, balanced fertilization is necessary at certain intervals throughout the crop period. Nitrogen, phosphorous and potassium are three major nutrients required for the crop production and should be used in proper proportion. Nitrogen and potassium when applied together have a synergistic effect on the crop. Only in the presence of an adequate amount of potassium the best response of nitrogen can be obtained. Nutrient management as the split application of fertilizers, use of different sources of fertilizers and their integrated use have proved to be very effective in increasing nutrient use efficiency, crop productivity and reducing nutrient losses.

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Hence, there is a wide scope for increasing redgram productivity through efficient fertilizer management practices. As redgram requires more of N, P and K for better growth and yield, their application at required quantities will certainly enhance the productivity of the crop. The crop responds well to the fertilizers when applied as fertilizer mixtures in proper proportion rather than applied separately. With this background, a pot culture experiment was conducted to evaluate the effect of crop specific nutrient mixtures on growth, yield attributes and yield of redgram (*Cajanus cajan* L.) under the irrigated condition with the test variety CO (Rg) 7.

MATERIAL AND METHODS

Experimental soil

The soil sample used for conducting the study was air dried, broken with a wooden mallet and sieved through 2 mm sieve. Particle size distribution was determined by International pipette method (Piper, 1966), bulk density, particle density and pore space by cylinder method (Gupta and Dakshinamoorthy, 1980) and water holding capacity by pressure plate apparatus (Richards, 1941). pH and EC of soil sample were determined by using 1:2.5 soil water extract (Jackson, 1973), cation exchange capacity by neutral normal ammonium acetate method (Jackson, 1973) and calcium carbonate content were determined by rapid titration method.

The organic carbon was estimated by chromic acid wet digestion (Walkley and Black, 1934), available N by alkaline permanganate method (Subbaiah& Asija, 1956), available P by using 0.5 M $NaHCO_3$ (Olsen *et al*, 1954), available K by neutral normal NH_4OAC method (Stanford and English, 1949) and available micronutrients by DTPA extraction using Atomic Absorption Spectroscopy (AAS) (Lindsay and Norvell, 1978), respectively. For statistical analysis of data, Microsoft Excel (Microsoft Corporation, USA) and Agrees window version 7.0 packages were used.

Incubation experiment

The incubation experiment was conducted to assess the nutrient release pattern from different macronutrient mixtures in soil, from 22.11.2017 to 24.01.2018 (60 days)at PG Lab, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore.

There are 10 treatments in the incubation experiment. The experiment was laid out in a completely randomized design with three replications. 330plastic cup having a capacity of 50 g and 6 × 4 cm (L × B)and 660 polythene shaking bottles having a capacity of 150 g and 11 × 4 cm (L × B) were used for incubation experiment. The treatments were as follows: T_1– Urea + SSP + MOP, T_2 – Urea + SSP + SOP, T_3– Urea + MAP + MOP, T_4 – Urea + MAP + SOP, T_5 – CAN + DAP + MOP, T_6 – CAN + DAP + SOP, T_7 – Urea + DAP + SOP, T_8 – Urea + DAP + CAN + SSP + SOP, T_9 – ASP + SOP andT_{10} – 19:19:19 + SSP.Macronutrient fertilizer mixtures were prepared and being adjusted to 25:50:25 kg N, P_2O_5 and K_2O ha^{-1} (RDF for redgram). Twenty and five grams of processed soil was weighed and added separately into plastic cups and polythene shaking bottles respectively. Calculated quantities of macronutrient fertilizer mixtures with 5 ml of water were added to plastic cups for available nitrogen analysis and macronutrient fertilizer mixtures with 1 ml of water were added for available phosphorus and potassium analysis respectively.

Soils were moistened to field capacity and incubated for sixty days. Moisture corrections were carried out at alternate days on weight loss basis and continued. Soil samples collected at 1, 3, 5, 7, 14, 21, 28, 35, 42, 49 and 60 days after incubation were shade dried, gently powdered with a wooden mallet, sieved through 2 mm sieve and analysed for changes in nutrient content in soil by adopting standard procedures to understand the nutrient release pattern from different macronutrient fertilizer mixtures.

Pot culture experiment

The pot culture experiment was conducted during *Kharif* (rainy) season of 2017-18 at 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.

There are 11 treatments in the pot culture experiment and the experiment was laid out in completely randomized design with three replications and mud pots having a capacity of 12 kg and height of 55 cm. The treatments details were: T_1– Urea + SSP + MOP, T_2 – Urea + SSP + SOP, T_3– Urea + MAP + MOP, T_4 – Urea + MAP + SOP, T_5 – CAN + DAP + MOP, T_6 – CAN + DAP + SOP, T_7 – Urea + DAP + SOP, T_8 – Urea + DAP + CAN + SSP + SOP, T_9 – ASP + SOP, T_{10} – 19:19:19 + SSP and T_{11} – control. The experimental soil of about 7 kg was thoroughly mixed with 3 kg of sand and then filled in pots up to $3/4^{th}$. Macronutrient fertilizer mixtures were prepared by taking nutrient content of individual fertilizers, multiplying with factor and finally the mixture is adjusted to 25:50:25 kg N, P_2O_5 and K_2O ha^{-1} (RDF for redgram). A uniform dose of 25:50:25 kg N, P_2O_5 and K_2O $ha^{-1}$was applied through individual fertilizer mixtures to pots as fertilizer solution before sowing as per the treatment schedule. Seeds of redgram variety CO (Rg) 7 were first treated with *Trichoderma*

viride @ 4 g kg^{-1} to control the seed-borne diseases. After 24 hours, seeds were again treated with *Rhizobium* and *Pseudomonas* and seeds were dried under shade. In each pot, 5 seeds were sown, irrigation was given as and when required, weeding was done and plant protection measures were taken up against pest and diseases.

In each pot, growth attributes *viz.,* plant height and number of branches were recorded on 30, 60, 90 and 120 days after sowing (DAS). For root nodules count, pots were maintained separately. A number of root nodules per plant were counted from roots on 20 - 25 days after sowing (DAS). For dry matter production, plants were uprooted, air dried and then oven dried at 60°C till constant weight is obtained. The weight was recorded using an electrical top pan balance and dry matter was expressed in grams per plant.

Yield attributes *viz.,* number of pods per plant and number of seeds per pod were recorded on 120 days after sowing (DAS). 100 seeds from the selected plant were counted at random, weighed in electric top pan balance and expressed in grams. Seed yield and stalk yield were recorded at harvest stage and expressed in kg ha^{-1}. Harvest index was calculated by using the following formula.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \times 100$$

RESULTS AND DISCUSSION

Initial characteristics of the experimental soil

Mechanical composition of experimental soil indicated that it contained 24.4 percent coarse sand, 31.89 percent fine sand, 14.25 percent silt and 27.75 percent clay and it belonged to Sandy clay loam texture. The pore space percentage was found to be 41.5 with Bulk density and particle density of 1.37 Mg m^{-3} and 2.58 Mg m^{-3} respectively.

Table 1. Nitrogen release pattern in soil from different macronutrient mixtures (kg ha^{-1})

Treatment	Days of incubation										
	1	3	5	7	14	21	28	35	42	49	60
T_1– Urea + SSP + MOP	0.10	0.33	0.57	0.82	1.37	2.90	3.43	4.96	5.49	7.02	8.49
T_2 – Urea + SSP + SOP	0.13	0.22	0.60	1.00	1.67	2.60	3.70	4.90	5.40	6.70	8.57
T_3 – Urea + MAP + MOP	0.54	0.87	1.17	1.87	2.76	3.29	4.82	5.35	6.88	7.41	9.94
T_4 – Urea + MAP + SOP	0.60	1.03	1.16	1.21	2.81	3.37	4.49	5.71	6.64	6.94	9.72
T_5 – CAN + DAP + MOP	2.59	5.67	7.75	9.20	11.17	12.61	13.03	14.45	15.28	16.28	18.05
T_6 – CAN + DAP + SOP	2.78	5.36	6.94	9.52	11.63	12.73	13.83	14.93	16.03	16.13	18.51
T_7 – Urea + DAP + SOP	0.24	0.23	1.04	1.21	1.74	2.64	3.34	4.47	5.82	6.92	9.02
T_8 – Urea + DAP + CAN + SSP + SOP	0.92	1.10	1.37	2.17	3.25	4.30	5.35	6.45	7.55	8.65	11.05
T_9 – ASP + SOP	0.17	0.24	0.37	0.57	0.82	0.84	0.94	1.60	2.67	3.80	5.49
T_{10} – 19:19:19 + SSP	0.21	0.34	0.64	1.00	0.15	0.82	1.00	1.74	2.37	4.24	6.27
Mean	0.83	1.54	2.16	2.86	3.74	4.61	5.39	6.46	7.41	8.41	10.51
SE d	0.07	0.12	0.17	0.24	0.29	0.35	0.43	0.49	0.55	0.75	0.74
CD (p= 0.05)	0.14	0.25	0.35	0.48	0.60	0.71	0.88	1.00	1.12	1.53	1.50

(Values indicate cumulative increase in available N over initial level; Initial available N in soil =215 kg ha^{-1})

The soil was alkaline in reaction with a pH of 8.40 and an electrical conductivity of 0.77 (dSm^{-1}). The organic carbon content of the soil was 4.5 g kg^{-1} and the CEC was found to be 22.50 c mol (p^+) kg^{-1} of soil. The soil was low in alkaline $KMnO_4$- N (215 kg ha^{-1}), medium in Olsen- P (26 kg ha^{-1}) and high in NH_4OAC extractable potassium (356 kg ha^{-1}). The available S in soil was medium (14 mg kg^{-1}). The micro nutrient contents were as follows: Fe - 4.85 mg kg^{-1}, Zn – 1.39 mg kg^{-1}, Cu – 2.58 mg kg^{-1} and Mn -13.45 mg kg^{-1}.

Table 2. Phosphorus release pattern in soil from different macronutrient mixtures (kg ha^{-1})

Treatment	Days of incubation										
	1	3	5	7	14	21	28	35	42	49	60
T_1– Urea + SSP + MOP	2.66	3.46	4.86	5.53	7.75	9.54	11.54	12.53	14.56	16.50	19.30
T_2 – Urea + SSP + SOP	2.60	3.49	4.90	5.50	7.76	9.56	11.53	12.56	14.53	16.57	19.23
T_3 – Urea + MAP + MOP	1.70	2.48	3.45	4.23	5.53	7.66	9.43	10.60	12.57	14.56	16.53
T_4 – Urea + MAP + SOP	1.75	2.41	3.46	4.03	5.52	7.69	9.42	10.54	12.56	14.46	16.58
T_5 – CAN + DAP + MOP	4.30	5.20	6.03	6.73	8.90	11.10	13.38	14.23	16.30	19.10	21.98
T_6 – CAN + DAP + SOP	4.16	5.06	6.20	6.76	9.33	11.33	13.23	14.23	16.06	19.16	22.06
T_7 – Urea + DAP + SOP	4.27	5.03	6.15	6.73	9.06	11.16	12.90	14.06	16.03	19.06	22.10
T_8 – Urea + DAP + CAN + SSP + SOP	1.43	1.76	2.06	2.58	4.06	6.56	7.58	8.58	10.55	12.56	14.76
T_9 – ASP + SOP	1.40	1.53	2.17	2.53	4.16	6.59	7.53	8.50	10.56	12.53	14.80
T_{10} – 19:19:19 + SSP	1.46	1.55	1.60	2.56	3.50	6.53	7.54	8.56	10.54	13.11	14.10
Mean	2.57	3.20	4.09	4.72	6.56	8.77	10.41	11.44	13.43	15.76	18.14
SE d	0.22	0.24	0.33	0.33	0.56	0.61	0.73	0.93	1.11	1.15	1.42
CD (p= 0.05)	0.45	0.50	0.67	0.68	1.14	1.25	1.49	1.89	2.28	2.35	2.89

(Values indicate cumulative increase in available P over initial level; Initial available P in soil =26 kg ha^{-1})

Nutrient release pattern in soil from different macronutrient mixtures

The maximum nitrogen(2.78 to 18.51 kg ha^{-1}), phosphorus(4.16 to 22.06 kg ha^{-1}) and potassium(0.66 to 23.09 kg ha^{-1}) release was recorded with the treatment CAN + DAP + SOP (T_6) up to 60 DOI at 7days intervals followed by Urea + SSP + SOP (T_2) (0.13 to 8.57 kg ha^{-1}N, 2.60 to 19.23 kg ha^{-1}P and 0.80 to 23.13 kg ha^{-1}K) and CAN + DAP + MOP (T_5) (2.59 to 18.05 kg ha^{-1}N, 4.30 to 21.98 kg ha^{-1} P and 0.23 to15kg ha^{-1} K) and Urea + DAP + SOP (T_7) (0.24 to 9.02 kg ha^{-1}N, 4.27 to 22.10 kg ha^{-1}P and 0.56 to 23.13 kg ha^{-1}K) which were statistically *on par*(Table 1,2 and 3). In general, with an increase in incubation days the release of nitrogen, phosphorus and potassium significantly increased up to 60 days then after it decreased probably due to various losses (Fig 1.2 and 3). Similar results were reported by Bhanuprakash *et al.* (2017) who conducted incubation study of major nutrients as influenced by different slow releasing fertilizers in coastal Karnataka. The results are in consonance with the findings of Raja Rajeshwaran *et al*. (2018) who assess the nitrogen release pattern from fertilizer pellet pack placed in soil.

Table 3. Potassium release pattern in soil from different macronutrient mixtures (kg ha^{-1})

Treatment	Days of incubation										
	1	3	5	7	14	21	28	35	42	49	60
T_1– Urea + SSP + MOP	0.30	0.96	1.36	2.26	4.86	6.16	4.46	6.72	9.06	11.36	14.00
T_2 – Urea + SSP + SOP	0.80	1.76	2.63	3.96	5.36	8.76	13.15	15.03	17.99	20.36	23.13
T_3 – Urea + MAP + MOP	0.26	0.36	1.56	2.63	4.13	6.30	4.20	6.75	9.50	11.23	13.00
T_4 – Urea + MAP + SOP	0.66	1.46	2.26	3.07	5.80	8.78	13.76	15.60	17.72	20.70	23.93
T_5 – CAN + DAP + MOP	0.23	0.50	1.86	2.56	4.26	6.66	4.40	6.82	9.30	11.80	15.00
T_6 – CAN + DAP + SOP	0.66	1.40	2.97	3.93	5.20	8.66	13.92	15.48	17.50	20.50	23.06
T_7 – Urea + DAP + SOP	0.56	1.63	2.90	3.83	5.33	8.23	13.16	15.82	17.76	20.36	23.13
T_8 – Urea + DAP + CAN + SSP + SOP	0.46	1.70	2.73	3.83	5.20	8.36	13.56	15.13	17.60	20.53	23.80
T_9 – ASP + SOP	0.76	1.66	2.03	3.63	5.46	8.26	13.33	15.85	17.88	20.36	23.06
T_{10} – 19:19:19 + SSP	0.13	0.53	0.73	0.93	1.13	1.33	1.53	1.87	1.98	2.33	5.00
Mean	0.48	1.20	2.10	3.06	4.67	7.15	9.55	11.51	13.63	15.95	18.71
SE d	0.04	0.09	0.17	0.26	0.34	0.55	0.79	0.87	1.10	1.28	1.35
CD (p= 0.05)	0.07	0.18	0.34	0.54	0.70	1.12	1.62	1.79	2.25	2.61	2.75

(Values indicate cumulative increase in available K over initial level; Initial available K in soil = 356 kg ha^{-1})

Table 4a. Effect of macronutrient mixtures on growth attributes of redgram

Treatments	Plant height (cm)				Number of primary branches			
	Days after sowing							
	30	60	90	120	30	60	90	120
T_1– Urea + SSP + MOP	19.7	31.3	50.5	82.5	2	3	5	7
T_2 – Urea + SSP + SOP	22.7	34.6	53.9	88.3	3	4	6	8
T_3 – Urea + MAP + MOP	20.1	27.1	46.6	79.3	2	3	5	7
T_4 – Urea + MAP + SOP	21.0	32.7	49.6	81.4	2	3	5	7
T_5 – CAN + DAP + MOP	22.7	34.5	54.4	90.6	3	4	6	8
T_6 – CAN + DAP + SOP	23.9	38.8	57.0	95.2	3	5	7	9
T_7 – Urea + DAP + SOP	22.8	34.5	54.2	89.5	3	4	6	8
T_8 – Urea + DAP + CAN + SSP + SOP	18.8	25.3	44.8	83.9	2	3	5	6
T_9 – ASP + SOP	20.2	29.3	47.8	80.8	2	3	5	6
T_{10} – 19:19:19 + SSP	18.8	27.8	45.5	80.5	2	3	5	6
T_{11} – Control	17.2	25.1	40.2	73.8	1	2	4	5
Mean	20.7	31.0	49.5	84.2	2	3	5	7
SE d	0.37	0.48	0.93	1.70	0.22	0.28	0.47	0.67
CD (p= 0.05)	0.77	1.00	1.87	3.53	0.26	0.58	0.79	0.99

Effect of macronutrient mixtures on growth attributes

Plant height

The application of macronutrient fertilizer mixtures significantly affected plant height (Table. 4a) and higher plant height (23.9, 38.8, 57.0 and 95.2 cm) was observed at all the four stages *viz.*, 30. 60, 90 and 120 days after sowing respectively in the treatment CAN + DAP + SOP, followed by Urea + SSP + SOP (T_2) (22.7, 34.6, 53.9 and 88.3 cm), CAN + DAP + MOP (T_5) (22.7, 34.5, 54.4 and 90.6 cm) and Urea + DAP + SOP (T_7) (22.8, 34.5, 54.2 to 89.5) which were statistically *on par*.This is due to balanced fertilization which improved the nutrient availability resulting in greater nutrient uptake and also might have increased the higher photosynthesis and better translocation of photosynthates to different parts. This would have improved significantly the plant height. Similar findings were reported bySuryakumari *et al.* (2015) who showed that application of Urea + CAN+ MOP recorded the higher plant height in chili (*Capsicum annum* L.).

Table 4b. Effect of macronutrient mixtures on growth attributes of redgram

Treatments	Number of root nodules plant^{-1}	Dry matter production (g plant^{-1})
T_1– Urea + SSP + MOP	10	117
T_2 – Urea + SSP + SOP	16	121
T_3 – Urea + MAP + MOP	11	116
T_4 – Urea + MAP + SOP	11	105
T_5 – CAN + DAP + MOP	16	122
T_6 – CAN + DAP + SOP	19	127
T_7 – Urea + DAP + SOP	16	120
T_8 – Urea + DAP + CAN + SSP + SOP	13	107
T_9 – ASP + SOP	11	111
T_{10} – 19:19:19 + SSP	13	109
T_{11} – Control	9	86
Mean	13.2	112.8
SE d	0.28	1.75
CD (p= 0.05)	0.58	3.63

Number of primary branches per plant

The number of branches per plant was significantly affected by different macro nutrient fertilizer mixtures (Table 4a). Application of CAN + DAP + SOP (T_6) produced significantly higher number of branches (3, 5, 7 and 8 per plant) at 30. 60, 90 and 120 days after sowing respectively, followed by Urea + SSP + SOP (T_2) (3, 4, 6 and 8 per plant), CAN + DAP + MOP (T_5) (3, 4, 6 and 8 per plant) and Urea + DAP + SOP (T_7)(3, 4, 6 and 8 per plant) which were statistically *on par*. Increase in a number of branches in response to nitrogen is understandable.

Table 5. Effect of macronutrient mixtures on yield attributes of redgram

Treatments	Pods plant^{-1}	Seeds pod^{-1}	100 seeds weight (g)
T_1– Urea + SSP + MOP	70.5	3.5	12.3
T_2 – Urea + SSP + SOP	74.1	3.9	13.1
T_3– Urea + MAP + MOP	70.8	3.5	11
T_4 – Urea + MAP + SOP	70.7	3.5	11
T_5 – CAN + DAP + MOP	74.2	4.0	13.1
T_6 – CAN + DAP + SOP	77.9	4.2	14.5
T_7 – Urea + DAP + SOP	74.3	3.9	13.1
T_8 – Urea + DAP + CAN + SSP + SOP	61.8	3.6	11.6
T_9 – ASP + SOP	70.0	3.6	11.6
T_{10} – 19:19:19 + SSP	68.5	3.7	12
T_{11} – Control	52.6	2.9	8.9
Mean	69.6	3.7	12.0
SE d	1.5	0.0	0.2
CD (p= 0.05)	3.16	0.15	0.44

Nitrogen is an important constituent of protoplasm, enzymes, nucleoproteins and amino acids. Calcium ammonium nitrate (CAN) contained a considerable amount of N and Ca for plant use which is essential for the formation of chlorophyll and for photosynthesis in plants. Similar results were reported by Ali *et al.* (2007) who indicated that application of 150 kg K_2O ha^{-1} in the form of sulphate of potash (SOP) registered the higher number of branches (10.47 plant^{-1}).

Number of root nodules per plant

The higher root nodules (19 per plant) were observed at 25 days after sowing (DAS) with the application of CAN + DAP + SOP (T_6) followed by Urea + SSP + SOP (T_2), CAN + DAP + MOP (T_5) and Urea + DAP + SOP (T_7) which were *on par* with each other (Table 4b). This increase might be due to the response of plants to nitrogen application which would have enhanced nitrogen mining capacity of plants and translocation of photo assimilates brought about by faster root growth. These results are line with findings of Chmelikova and Hejcman (2014) who analyzed the effect of nitrogen, phosphorus and potassium on nodulation and growth of lettuce (*Trifolium medium* L.) and they proved that application of 80 kg P_2O_5 ha^{-1} recorded a higher number of root nodules (4.5 plant^{-1}).

Table 6. Effect of macronutrient mixtures on yield of redgram

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index (%)
T_1– Urea + SSP + MOP	663	2998	18.11
T_2 – Urea + SSP + SOP	731	3018	18.99
T_3 – Urea + MAP + MOP	645	2917	18.11
T_4 – Urea + MAP + SOP	643	2908	18.11
T_5 – CAN + DAP + MOP	735	3056	18.89
T_6 – CAN + DAP + SOP	772	3218	19.92
T_7 – Urea + DAP + SOP	733	3014	18.55
T_8 – Urea + DAP + CAN + SSP + SOP	615	2883	17.58
T_9 – ASP + SOP	665	2986	17.73
T_{10} – 19:19:19 + SSP	584	2825	17.13
T_{11} – Control	515	2038	15.36
Mean	663.7	2896.5	18.0
SE d	12.97	65.69	0.40
CD (p= 0.05)	26.91	136.24	0.84

Dry matter production

The higher dry matter production (126.79 g plant^{-1}) was observed at 120 days after sowing with the application of CAN + DAP + SOP (T_6) followed by Urea + SSP + SOP (T_2)(121.00 g plant^{-1}), CAN + DAP + MOP (T_5) (121.96 g plant^{-1})and Urea + DAP + SOP (T_7)(120.0 g plant^{-1}) which were *on par* with each other (Table 4b).

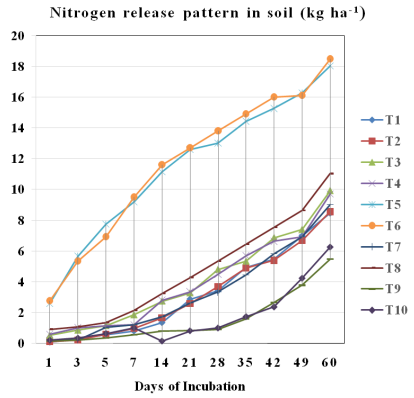

Figure 1. Nitrogen release pattern in soil from different macronutrient mixtures (kg ha^{-1})

This is due to balanced fertilization which improved the nutrient availability resulting in greater nutrient uptake and also might have increased the higher photosynthesis and better translocation of photosynthates to different parts. This would have improved significantly higher plant height and a higher number of branches.

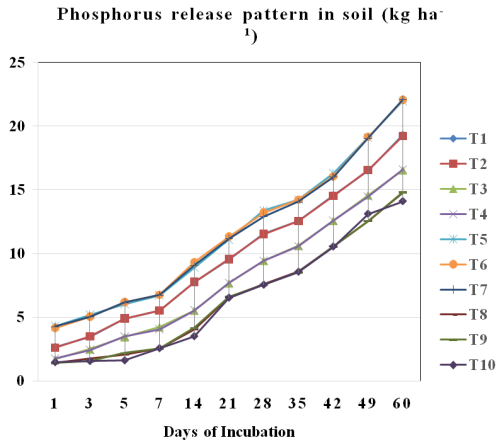

Figure 2. Phosphorus release pattern in soil from different macronutrient mixtures (kg ha^{-1})

The product of a number of branches and plant height is taken as an indication of the total dry matter production of the plant. Similar results have been reported by Bairwa *et al.* (2012) who observed that application of 60 kg P_2O_5 ha^{-1} in the form of Diammonium phosphate (DAP) recorded higher dry matter (8.84 g plant^{-1}).

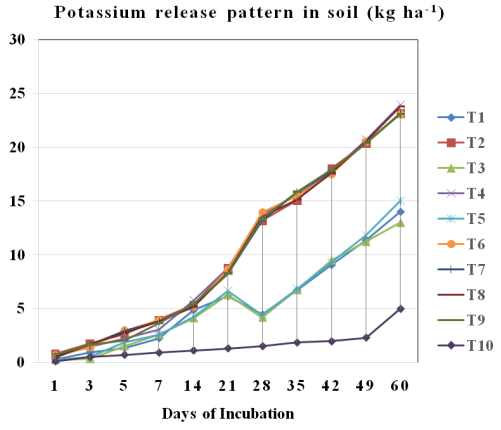

Figure 3. Potassium release pattern in soil from different macronutrient mixtures (kg ha^{-1})

Yield attributes and seed yield

Application of CAN + DAP + SOP significantly increased both yield attributes and seed yield *viz.,* number pods (77.9 plant^{-1}), number of seeds (4.2 pod^{-1}) and 100 seed weight (14.5 g) (Table 5 and 6). Maximum seed yield (772 kg ha^{-1}), stalk yield (3218 kg ha^{-1}) and harvest index ((19.92 %) were recorded the application of CAN + DAP + SOPfollowed by Urea + SSP + SOP (T_2), CAN + DAP + MOP (T_5) and Urea + DAP + SOP (T_7) which were statistically *on par* with each other. This could be attributed to the fact that added fertilizers contained nutrients *viz.,* N, P, K, Ca and S and these nutrients enhanced the availability of nutrients to plants. This leads to enhanced photosynthetic activity, profuse shoot and root growth, thereby activating greater absorption of these nutrients from the soil, followed by efficient transfer of these metabolites in the seed with the resultant increase in a number of pods plant^{-1}, number of seeds pod^{-1} and 100-seed weight, seed yield, stalk yield and harvest index. These results are in conformity with Wahid *et al.* (2009) who observed a significant increase in the number of siliqua, number of seeds, 100 seed weight, seed yield in canola hybrids due to the application of DAP.

CONCLUSION

From the study, it was concluded that among different macronutrient fertilizer mixtures,Application of CAN + DAP + SOP (T_6) showed the maximum release of nutrients and improvement in growth, yield attributes and yield of redgram. The higher yield was obtained with the application of nitrogen as CAN source, phosphorus + nitrogen as DAP source and potassium as SOP source when compared to the other sources. The mixture, CAN + DAP + SOP contains an appreciable quantity of N, P, K, Ca and S. Hence, CAN + DAP + SOP can be effectively utilized in the place of conventionally used Urea + DAP +MOP to obtain maximum seed yield in redgram.

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