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Effect of Agronomic Manipulations on Morpho-physiological and Biochemical Responses of Rainfed Redgram [*Cajanus cajan* (L.) Millsp.]

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ABSTRACT

Background: Pulses play an important role in Indian agriculture and they are the rich sources of protein. Redgram is an essential food legume, mostly cultivated under rainfed condition in India. Due to increasing population the demand of pulses is increased; hence the redgram productivity has to be increased to meet out the requirement. To overcome this problem an investigation was carried out to study the effect of crop geometry, modified canopy architecture and 1% PPFM application on morpho-physiological and biochemical responses of rainfed redgram during north-east monsoon season.

Methods: The treatments comprised of varied **c**rop geometries *viz*, broad casting (farmer's practice), high density planting at 30 × 30 cm and recommended spacing of 60 × 30 cm; modified canopy architectures *viz*. nipping of primary branches at 45 and 60 days after the receipt of soaking rain and foliar application of 1% PPFM spray at 50% flowering to avoid the moisture stress.

Result: The results revealed that sowing at 60 × 30 cm spacing with nipping at 45th day recorded significantly higher seed yield and protein yield of redgram in rainfed condition. Further, nipping at 45th day showed higher level of relative water content (51.6%) associated with lower level of proline (26.61 mg g^{-1}).

Key words: Canopy architecture, Crop geometry, PPFM application, Rainfed condition, Redgram.

INTRODUCTION

Pulses are an important group of crops that provide high quality protein for substantial vegetarian population. In India rainfed agriculture contributes more than 80% to the total pulses production. Although, India is the largest pulses cultivating country in the world, pulses share to total food grain production is only 6-7%. The pulses requirement will be 39 million tons by 2050 with an annual growth rate of 2.2%.

Redgram [*Cajanus cajan* (L.) Millsp.] is an important grain legume mostly cultivated under rainfed condition in India. During 2018 India reported about 4.46 million hectare area under redgram cultivation with a production of 4.18 million tons at 937kg/ha productivity. India also imports around 3.09 million tons of redgram and it forms 6.6% share in India's import basket (Sarkar *et al*., 2018). This is mainly because of low productivity of redgram in India. The low productivity of redgram under rainfed conditions is attributed to poor crop management and soil moisture deficit at critical growth stages (Kumar *et al*., 2020). Hence suitable agronomic management practices to increase the yield potential of redgram under rainfed condition are needed.

Adoption of agronomic practices such as appropriate crop geometry, canopy architecture and spraying of moisture regulators like 1% pink pigmented facultative methylotroph (PPFM) will have positive impact on yield components and yield of redgram under rainfed conditions. Crop geometry plays a major role in increasing the growth and yield of crop. Optimum plant population is an important factor in determining the crop yield and adoption of suitable spacing reduces the competition among the plants and crops (Kithan and Singh, 2017). The modification of canopy architecture by nipping apical buds to arrest the vertical growth of the crop and to induce more number of lateral branches enhances the crop yield. The time of nipping should be standardized to achieve maximum yield by increasing more number of lateral branches (Dhaka *et al*., 2020). Foliar application of 1% PPFM avoids moisture stress to the crop at critical crop growth stage in rainfed condition.

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Keeping all these in view, an experiment was carried out to study the effect of crop geometry, canopy architecture modification by nipping and 1% PPFM application on growth, yield and quality of rainfed red gram.

MATERIALS AND METHODS

An experiment was designed at Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University-Madurai and carried out in a progressive farmer's field in Vadippatti Taluk of Madurai district in Tamil Nadu, India during North-East Monsoon season in 2019 under rainfed condition. The soil of the experimental site was sandy loam in texture and slightly alkaline in nature (pH of 7.85) having available N, P, K and organic carbon content of 324, 16, 295 kg ha^{-1} and 0.52% respectively. The treatments comprised of control (Farmer practice), sowing in 60×30 cm spacing (recommended spacing), high density planting in 30×30 cm spacing, sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain, sowing in 60×30 cm spacing + nipping at 60 days after receipt of soaking rain, sowing in 60×30 cm spacing + 1% PPFM spray, high density planting in 30×30 cm + 1% PPFM spray, sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain +1% PPFM spray , sowing in 60×30 cm spacing + nipping at 60 days after receipt of soaking rain +1% PPFM spray. The experiment was laid out in randomized block design with three replications. The redgram (var. Co (RG) 7) was sown on 31.08.2019 by broadcast method in control (farmer practice) and by dibbling method for others treatments as per the spacing. Entire fertilizer dose of 12.5 kg N, 25 kg P_2O_5 and 12.5 kg K_2O ha^{-1} recommended for rainfed condition was applied basally at the time of sowing. All the recommended agronomic practices were followed as per the TNAU Crop production Guide 2019 for growing of successful crop. The canopy architecture was modified by nipping manually on 45 and 60 days after receipt of soaking rain as per the treatments. Foliar application of 1% PPFM was done at 50 percent flowering as per treatments. All the growth and yield parameters were recorded at stipulated time. The crop was harvested at its full maturity (135 DAS) stage and seed yield and stalk yield were recorded.

A total rainfall 521.7 mm was received in 31 rainy days during the cropping period. The rainfall was well distributed and the crop did not suffer any moisture stress during its entire growing period.

Relative water content (RWC) and accumulation of proline were recorded at harvest stage. RWC was computed by using the formulae given by Barrs and Weatherley (1962) and expressed in percent.

$$RWC\ (\%) = \frac{\text{Fresh weight- Dry weight}}{\text{Turgid weight - Dry weight}} \times 100$$

The proline content was estimated as per the procedure suggested by Bates *et al*. (1973). The amount of proline was expressed as mg g^{-1} of sample.

Rainwater use efficiency (RWUE) was calculated by using the following formulae and expressed in kilogram per hectare millimeter (kg ha^{-1} mm^{-1}).

$$RWUE\ (kg\ ha^{-1}\ mm^{-1}) = \frac{\text{Grain yield (kg /ha)}}{\text{Total rainfall (mm)}}$$

Per day productivity was calculated by using the following formulae and expressed in kilogram per hectare per day (kg ha^{-1} day^{-1}).

Per day productivity (kg $ha^{-1}day^{-1}$) =

$$\frac{\text{Seed yield (kg/ha)}}{\text{Duration of the crop (days)}}$$

Seed protein content was estimated by multiplying N fraction with factor 6.25 and expressed in percentage.

RESULTS AND DISCUSSION

Growth attributes

The plant height was significantly higher in high density planting in 30×30 cm spacing at 90 days after sowing and it was on par with high density planting in 30×30 cm spacing + 1% PPFM spray (Table 1). The higher plant height may be because of competition for light, water and space which resulted in increased plant height of crops in closer spacing as compared to wider spacing (Rasul *et al*., 2012). Modification of canopy architecture by nipping reduced the plant height and increased the number of lateral branches as compared to control. Sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain +1% PPFM spray recorded significant reduction in plant height and it was on par sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain, sowing in 60×30 cm spacing + nipping at 60 days after receipt of soaking rain +1% PPFM spray and sowing in 60×30 cm spacing + nipping at 60 days after receipt of soaking rain, respectively. Nipping the apical bud induced more lateral branches instead of plant hight. Similar findings were also reported by Bhavana *et al*., (2019).

Crop geometry had a significant influence on the number of days to 50% flowering of redgram. Significantly lesser number of days to 50% flowering (80 days) was recorded in high density planting in 30×30 cm spacing and this was on par with high density planting in 30×30 cm spacing + 1% PPFM spray (81 days). The competition for growth resources in high density planting quickens the maturity process. Thus earlier flowering was reported in closer spacing. These findings are in conformity with the observations of Manjesh *et al*. (2019) and Deka *et al*. (2015). Similarly higher number of days to 50% flowering was recorded in no nipping treatments as compared to nipping treatments (Table1). The nipping reduced apical dominance and induced the reproductive growth. No nipping delayed the leaf senescence and increased the duration of vegetative growth delaying the flowering (Khan *et al*., 2018).

The crop growth rate (CGR) is an important parameter used to estimate the production efficiency. The maximum

increases in CGR was recorded between 60-90 days after receipt of soaking rain in all the treatments and declined thereafter towards maturity (Table 1). Among the different treatments high density planting in 30×30 cm spacing recorded significantly higher the crop growth rate and it was at par with high density planting in 30×30 cm spacing + 1% PPFM spray. This may be attributed to higher plant population per unit area in this treatment as also reported by Rajeshkumar *et al*. (2017). Likewise nipping treatments recorded maximum crop growth rate as compared to non nipping treatments. This might be due to increased accumulation of dry matter owing to enhanced production of more lateral branches (Kithan and Singh, 2017).

Relative water content (RWC) and proline content

RWC and proline accumulations are the measures to identify tissue water status. At harvest significantly higher RWC of 51.6% was recorded in sowing at 60 × 30 cm spacing + nipping at 45 days after receipt of soaking rain. Lowest relative water content of 44.5% was recorded in control (Fig 1). Under rainfed ecosystem relative water content for all plant densities was primarily a function of rainfall events and depends on amount of rainfall received (Suresh *et al*., 2013). The well distributed rainfall and optimum plant population throughout the cropping period led to efficient utilization of rain water and available soil moisture resulting in higher RWC in recommended spacing. Broadcasting resulted in lower RWC might be due to uneven plant population and reduced efficiently in using the soil moisture by the crop. High density planting results in increased competition for available soil moisture whereas in normal spacing no such competition occurs.

Through biochemical process plants synthesize osmolytes such as proline which is an indicator of drought tolerance capacity of the plants. Proline accumulation helps in maintaining the osmotic balance in plant cells suffering from water deficiency (Pandian *et al*., 2017). In the present investigation the proline content ranged from 31.52 mg g^{-1}

Table 1: Effect of agronomic manipulations on growth attributes of rainfed redgram.

Treatments	Plant height at 90 days (cm)	Days to 50% flowering	CGR (60-90 days) (g m^{-2} day^{-1})
Control (Farmer practice)	152.8	88	31.93
Sowing at 60 × 30 cm spacing (Recommended)	158.0	86	33.85
High density planting at 30 × 30 cm spacing	172.7	80	45.46
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain	139.5	83	37.75
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain	148.6	86	36.56
Sowing at 60 × 30 cm spacing + 1% PPFM spray	158.1	86	33.57
High density planting at 30 × 30 cm spacing + 1% PPFM Spray	171.5	81	45.30
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain +1% PPFM spray	137.9	83	37.63
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain +1% PPFM spray	145.4	85	36.09
SEm±	6.63	0.6	1.880
CD(p=0.05)	14.07	1.2	3.950

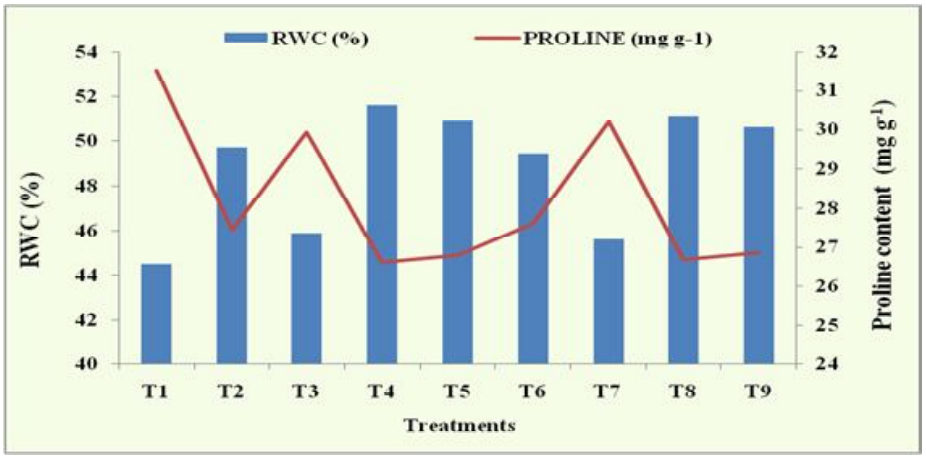

Fig 1: Effect of agronomic manipulations on RWC and Proline of rainfed redgram.

to 26.61mg g^{-1} (Fig 1). Broadcasting resulted in higher proline content followed by high density planting and normal recommended spacing. Closer spacing recorded more proline content as compared to normal recommended spacing, as also observed by Singh *et al*. (2015). Among the different treatments, broadcasting recorded the maximum accumulation of proline and it was associated with lower level of RWC of the crop (Fig 1). Similar findings have also been observed by Shinde *et al*. (2018).

Seed yield, stalk yield and harvest index

The data on seed yield, stalk yield and harvest index are presented in (Table 2). Modified canopy architecture in treatment of sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain resulted in significantly higher grain yield and it was on par with sowing in 60×30 cm + nipping at 45 days after receipt of soaking rain +1% PPFM spray. The yield increase was 72% over control (Farmer practice). Nipping arrests the apical bud dominance and increases the production of side branches thus increase the canopy size, photosynthetic activity and more flower buds per plant leading to enhanced the seed yield. These results are in agreement with the findings of Dhaka *et al*., (2020) and Lakshmi *et al*., (2015). Significantly higher stalk yield was recorded with high density planting in 30×30 cm spacing and it was at par with high density planting in 30×30 cm spacing + 1% PPFM spray. High density planting recorded higher stalk yield as compared to other treatments, this is may due to higher plant population.
per unit area. Similar findings were also reported by Sathyamoorthi *et al*. (2008). Harvesting index represents increased physiological capacity to mobilize photosynthates and translocate to the economical part. Harvest index did not show any significant difference among the treatments. However the maximum harvest index was recorded in sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain followed by sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain +1% PPFM

Table 2: Effect of agronomic manipulations on seed yield, stalk yield and harvest index of rainfed redgram.

Treatments	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
Control (Farmer practice)	878	2375	0.27
Sowing at 60 × 30 cm spacing (Recommended)	1103	2502	0.31
High density planting at 30 x 30 cm spacing	1253	3267	0.28
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain	1512	2838	0.35
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain	1295	2727	0.32
Sowing at 60 × 30 cm spacing + 1% PPFM spray	1132	2523	0.31
High density planting at 30 × 30 cm spacing + 1% PPFM Spray	1209	3182	0.28
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain +1% PPFM spray	1451	2805	0.34
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain +1% PPFM spray	1297	2696	0.32
SEm±	71.4	147.3	0.0215
CD(p=0.05)	151.3	312.4	NS

Table 3: Effect of agronomic manipulations on RWUE and per day productivity ofrainfed redgram.

Treatments	RWUE (kg ha^{-1} mm^{-1})	Per day productivity (Kg ha^{-1} day^{-1})
Control (Farmer practice)	1.68	6.50
Sowing at 60 × 30 cm spacing (Recommended)	2.11	8.17
High density planting at 30 × 30 cm spacing	2.40	9.28
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain	2.90	11.20
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain	2.48	9.59
Sowing at 60 × 30 cm spacing + 1% PPFM spray	2.17	8.38
High density planting at 30 × 30 cm spacing + 1% PPFM Spray	2.32	8.95
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain +1% PPFM spray	2.78	10.75
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain +1% PPFM spray	2.49	9.61
SEm±	**	**
CD(P=0.05)	**	**

** Data were not statistically analysed.

spray. Modified canopy architecture by nipping increased the number of branches used for increasing the source – sink relationship and number of pods per plant leading to higher harvest index (Khan *et al*., 2018).

RWUE and per day productivity

Among the different treatments higher RWUE was recorded with sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain followed by sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain +1% PPFM spray to the tune of 72.6% and 65.4% increase in rain water use efficiency over control, respectively (Table 3). Similarly higher per day productivity were also observed in the above treatments.This may be attributed to well distributed rainfall during crop growth period, adequate availability of soil moisture leading to increased rain water use efficiency and per day productivity of redgram under rainfed condition. As the rainfall was well distributed and the crop did not suffer any moisture stress during the crop growth period, there was no effect of 1% PPFM application to mitigate the moisture stress effect to the crop.

Protein content and protein yield

The seed protein content did not show any significant difference due to crop geometry, modification of canopy architecture and 1% PPFM application treatments. However, higher the protein content was recorded in sowing in 60×30 cm spacing + nipping at 60 days after receipt of soaking rain followed by sowing in 60×30 cm spacing + 1% PPFM spray (Table 4). Protein content of the seed is mainly influenced by the environmental factors and the dose of fertilizer application (Saxena *et al*., 2010). However, the protein yield of redgram was significantly influenced by the different treatments. Significantly higher protein yield was recorded with sowing in 60×30 cm spacing + nipping at 45 days after receipt of soaking rain which was on par with sowing in 60×30 cm + nipping at 45 days after receipt of soaking rain +1% PPFM spray. Increased seed yield and protein yield was noted in nipping at 45th days of the crop (Table 4). Increased canopy size by producing more number of productive branches led to more assimilation of photosynthates and increased seed yield and protein yield as compared to control. Similar findings were also reported by Dhaka *et al*. (2020).

Economics

Maintaining optimum plant population at 60 × 30 cm spacing + nipping at 45 days after receipt of soaking rain recorded maximum gross monetary return, net monetary return and

Table 4: Effect of agronomic manipulations on quality of rainfed redgram.

Treatments	Seed protein content (%)	Protein yield (kg ha^{-1})
Control (Farmer practice)	19.81	174
Sowing at 60 × 30 cm spacing (Recommended)	20.21	223
High density planting at 30 × 30 cm spacing	19.96	250
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain	20.32	307
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain	21.01	272
Sowing at 60 × 30 cm spacing + 1% PPFM spray	20.85	236
High density planting at 30 × 30 cm spacing + 1% PPFM Spray	19.85	240
Sowing at 60 × 30 cm spacing + Nipping at 45 days after receipt of soaking rain +1% PPFM spray	20.54	298
Sowing at 60 × 30 cm spacing + Nipping at 60 days after receipt of soaking rain +1% PPFM spray	20.39	265
SEm±	0.378	14.2
CD(p=0.05)	NS	30.1

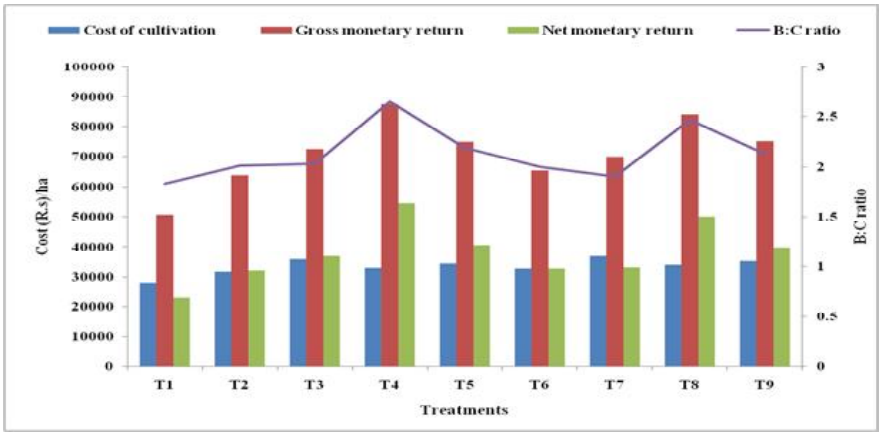

Fig 2: Effect of agronomic manipulations on economics of rainfed redgram.

benefit cost ratio (Fig 2). This was due to effective utilization of resources resulting in higher yield attributes which increases the yield and economics. Similar results were also obtained by Sharma *et al*. (2010) and Srinivasan *et al*. (2019).

Based on the findings of the present investigation it may be concluded that modification of canopy architecture by nipping at 45th day in the crop sown in 60 × 30 cm spacing results in higher level of relative water content, maximum seed yield and protein yield of redgram under rainfed condition.

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