Comparative response studies on organic amendments and leguminous intercropping on maize (*Zea mays L.*) agronomic traits and photosynthetic activity

ABSTRACT: The present study aimed to optimize a suitable nutrient management practice with the co-application of organic amendments and leguminous intercropping for sustainable maize production. The experiment was conducted during the *Kharif* and *Rabi* seasons of 2022-'23 in randomized block design following ten treatments. Maize (hybrid COH (M) 6) seeds were sown in rows at a spacing of 60 x 25 cm following the treatments: T_1 - Absolute control, T_2 – Recommended Dose of Fertilizers (RDF) alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping. Observations for plant height, dry matter production (DMP), and Relative Chlorophyll Content (RCC) were recorded at different phenological stages on 30, 45, and 60 DAS. The results showed that the treatment T_5 amended with poultry manure recorded the highest growth attributes and yield during the two consecutive seasons, followed by T_6, T_7, and T_8, whereas the lowest was in T_1. While comparing growth and yield attributes in in the second season (Rabi 2022-'23), the treatments T_7 and T_8 with 75 % RDF + FYM/poultry manure remarked substantial yield increase. The results suggest that co-application of organic manures like poultry manure or FYM with reduced dosages of mineral fertilizer, could be recommended as an optimal nutrient management strategy for sustainable maize production.

Keywords: agronomic traits, legume intercropping, organic amendments, relative chlorophyll content, sustainable maize production

1. INTRODUCTION

Maize (*Zea mays*) stands as the second major cereal crop in terms of production area and productivity. It is a rich source of vitamins, carbohydrates, and protein which makes maize a nutritive diet in many parts of the world [1]. In recent days, other than food and feed purposes, maize is being utilized for ethanol production, which is used as an additive or alternative to petroleum-based fossil fuels [2].

Maize, also known as corn, is a warm-season crop that requires a long growing season with high temperatures and adequate moisture. It can be grown in diverse soil types but prefers well-drained soils with a pH range between 5.5 and 7.5. The maize yield was highly influenced by several factors which include soil types, genetic characteristics, solar radiation, and temperature [3]. Maize requires high levels of nitrogen, phosphorus, and potassium, whereas the fertilization rates and timing should be tailored to soil fertility and crop management practices. Due to its high nutrient consumption, the utilization of mineral fertilizer was found more in recent days [4]. The application of mineral fertilizers to the soil over a period of years renders harmful effects on the soil and environment. Besides, the higher dosage of mineral fertilizers in the soil may tend to affect the texture, water-holding capacity, and organic matter content of the soil. Therefore, decreased organic matter in the soil will result in fluctuations of nutrient fluxes and reduced microbial activities, thereby the nutrient regenerative capacity will fall back and reduce the crop productivity [5].

The practice of integrated nutrient management (INM) is an important key to sustaining soil health and plant-soil feedback. The combined application of mineral nutrients with organic amendments improves the soil organic carbon (SOC) and microbial communities, which aids in nutrient cycles at the soil level. Based on the literature survey, the practice of INM with different organic sources improves maize productivity by 4.7% to 6.7% [6]. The incorporation of organic manures such as FYM and poultry manure increased growth yield when compared to other management practices. [7]. Further, legume intercropping releases a wide range of phytochemicals in the rhizosphere region that enhances the growth and development of active root hairs and improves the active absorption of available nutrients in the soil [8]. Nitrogen use efficiency (NUE) is a sustainable goal to achieve successful crop management in maize [9], It is achieved by differential N fertilization pattern that impacts the physiology, texture, and quality which resulted in tangible changes in the growth as well as yield [10], Recent studies have resulted in that combination of different organic amendments could have a direct and indirect influence in maize crop production [11]. The addition of poultry manure enhances the soil microbial activity and carbon pools, therefore, that aids in better phosphorous uptake in plants, resulting in higher productivity [12]. However, the influence of different organic amendments (FYM, poultry manure) with mineral fertilization and legume intercropping in maize has not been fully studied.

Therefore, the study was conducted to understand the comparative response of organic amendments and leguminous intercropping in agronomic traits of maize at different phenological stages. We hypothesized that organic amendments could increase soil microbial activities and soil-ecosystem services, whereas legume intercropping enhances NUE, thereby increasing plant growth. The study also aimed to optimize a definite combination of nutrient management practices in terms of sustainable maize production.

2. MATERIALS AND METHODS

2.1 Description of the Site

The entire experiment was conducted in the south farm of Karunya Institute of Technology and Sciences, Coimbatore, located at 10.934 ^{0} N latitude and 76.75^0 E longitude and 467 meters above MSL. It is situated in the Western agro-climatic zones of Tamilnadu which is shown in Fig. 1.

2.2 Season and Crop Variety

The experiment was carried out in two consecutive seasons, *Kharif* and *Rabi* 2022. Maize hybrid COH (M) 6 and black gram var VBN 8 were selected as the predominant and intercrop respectively.

2.3 Experimental Design

The experiment was laid out in Randomised Block Design (RBD) with ten treatments and three replicates. The, treatments followed in this trial are: T_1 - Absolute control, T_2 – Recommended dose of fertilizer (RDF) alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping.

2.4 Cultural Practices and Crop Management

The land was well prepared and the treatments comprising organic amendments were imposed one week before sowing. Maize seeds were sown with a spacing of 60x25 cm. For the intercropping treatments, the black gram was sown on the adjacent side of the maize row at a 15 cm distance as shown in Fig. 2. Then, general pest, and weed control measures were adopted, and irrigation was given on a necessary basis.

2.5 Experimental Observations

During each phenological stage (30, 45, and 90 DAS), the physical and physiological growth of maize. such as plant height, dry matter production (DMP), relative chlorophyll content (RCC), and yield attributes like grain and stover yield were recorded during both seasons.

2.6 Statistical Analysis

All the data were subjected to analysis of variance (ANOVA) at F (0.05) significance using STAR (Statistical Tool for Agricultural Research) version 2.0.1.

3. RESULTS AND DISCUSSIONS

3.1 Effect of different nutrient management strategies on the agronomic traits of maize during *Kharif* and Rabi Season 2022- '23

Plant height -

The plant height during the *Kharif* and *Rabi* 2022 are shown in Table.1. The results show that the mean height is significantly higher in the treatment T_5 (RDF + Poultry Manure @4 t ha^{-1} + Black gram intercropping) in both seasons. The treatment T_1 (Absolute Control) registered the least performance in terms of plant height whereas, T_2 (RDF alone) showed a slight decrease from *kharif* to *rabi* season. The reason may be attributed due to the fluctuations in soil microbial ecology. The results agree with Choudhary *et al*., (2023) [13] who reported that long-term mineral fertilizer application reduces soil health and affects the agronomic traits of the crop. The treatment T_7 (75 % RDF + Poultry Manure @4 t ha^{-1} + Black gram intercropping) and T_8 (75% RDF + FYM @12.5 t ha^{-1} + Black gram intercropping) performed better in the *Rabi* season when compared to *Kharif* season. Similarly, the treatments T_9 (50% RDF + Poultry Manure @4 t ha^{-1} + Black gram intercropping) and T_{10} (50% RDF + FYM @12.5 t ha^{-1} + Black gram intercropping) also registered improved performance. The reason might be due to the active nutrient cycles in the soil, catalyzed by the enzymes released by the leguminous crop in the rhizosphere. The findings coincide with the study made by Suhi *et al*., in

2022 that there is a complementary interaction between legumes and cereals which in turn supports the active uptake of nutrients from the soil [8].

DMP -

Dry matter accumulation is the most important factor which decides the nutrient uptake of the crop, and it is directly associated with yield characteristics, (Table.2). The study showed a slight alteration in the dry matter production irrespective of season The treatment T_1 (Absolute control) recorded the least dry matter production in the *rabi* season when compared to *kharif* which might be due to the reduction of available nutrients in the soil. However, the treatments T_3, T_5, T_7, and T_9 have shown an enhanced dry matter accumulation because of the addition of poultry manure. The results corroborate with the findings of Geng *et al*., (2019), who revealed that the addition of poultry manure increases the dry matter production by 9% and more[14]. Intercropping of legumes in the treatments T_5, T_6, T_7, T_8, T_9, and T_{10} supported the physiological growth thereby it resulted in a partial increase in the dry matter accumulation, this result substantiates the findings of Pierre *et al*., (2022a) [15].

3.2 Effect of different nutrient management strategies on the physiological traits of maize during the *Kharif* and Rabi Season 2022 – '23

Relative chlorophyll content -

The data on chlorophyll content observed using the SPAD chlorophyll meter during the *Kharif* and *Rabi* season 2022 is depicted in Fig.2& 3. The results show that the treatment T_5 (RDF + Poultry Manure @ 4 t ha^{-1} + Black gram intercropping) recorded the highest chlorophyll content during both seasons, but there was no statistically significant difference noticed among all the treatments except the control (T_1). This could be mainly due to the superior nutrient content in all the treatments except the control, which could have resulted in a better synthesis of chlorophyll. This is in line with the findings of Pierre *et al*., (2022) wherein the authors state that the chlorophyll content of a crop is altered due to the application of organic manures and intercropping with legumes[15].

3.3 Effect of different nutrient management strategies on the yield attributes of maize during the *Kharif* and Rabi Season 2022– '23.

Grain yield -

The grain yield of maize during the *Kharif* and *Rabi* seasons of 2022 is depicted in Table.3. The grain yield was observed significantly higher in all the treatments that followed the integrated application of mineral fertilizer, and organic amendments along with black gram crop intercropping. Among the treatments T_5 (RDF + Poultry Manure @ 4 t ha^{-1} + Black gram intercropping) and T_6 (RDF + FYM @ 12.5 t ha^{-1} + Black gram intercropping) recorded the highest grain yield of 6.69 and 6.42 t ha^{-1} respectively. However, the grain yield of treatments T_7, T_8, T_9, and T_{10} also showed a partial improvement in the second season (Rabi 2022). The results are associated with the findings of Nath *et al*., (2023) wherein the researcher reports that the integrated combination of manures and intercropping of legumes increases the yield gradually and reforms the soil health [16].

Stover yield -

The stover yield recorded during both the *Kharif* and *Rabi* seasons of 2022 is shown in Table.3. The results showed that the stover yield is significantly higher in the treatment T_5 in both seasons (8.33 t ha^{-1}) and lowest in T_1 (6.20 t ha^{-1}). The increased stover yield in the treatments T_3, T_5, T_7, and T_9 might be attributed due to the nutrient contents available in the poultry manure, whereas, the treatments that have the FYM combination also showed better yield performance than T_2 (RDF alone). The results of the stover yield agree with the findings of Sharma *et al*. (2021) and Mangaraj *et al*. (2022), who stated that the integrated application of different nutrient sources through organic manure can aid better stover yield [17,18].

4. CONCLUSION

Based on the discussions made earlier it was concluded that the treatments T_5 (RDF + Poultry Manure @4 t ha^{-1} + Black gram intercropping) and T_6 (RDF + FYM @ 12.5 t ha^{-1} + Black gram intercropping) showed significant performance in terms of agronomic and physiological traits in maize during the first season. Further, reduction in the RDF in the legume intercropping and organic amendments treatments also remarked an increased yield in the subsequent season. Therefore a partial reduction in the recommended dose of mineral fertilizers along with the addition of organic amendments and legume intercropping may enhance maize productivity gradually and enhance soil health. This management practice also boosts the soil microbial biomass which maintains a better soil-ecosystem service for achieving sustainable agriculture. In future with multiple trials, this study will be authenticated for a cost-effective and eco-friendly nutrient management strategy for maize production.

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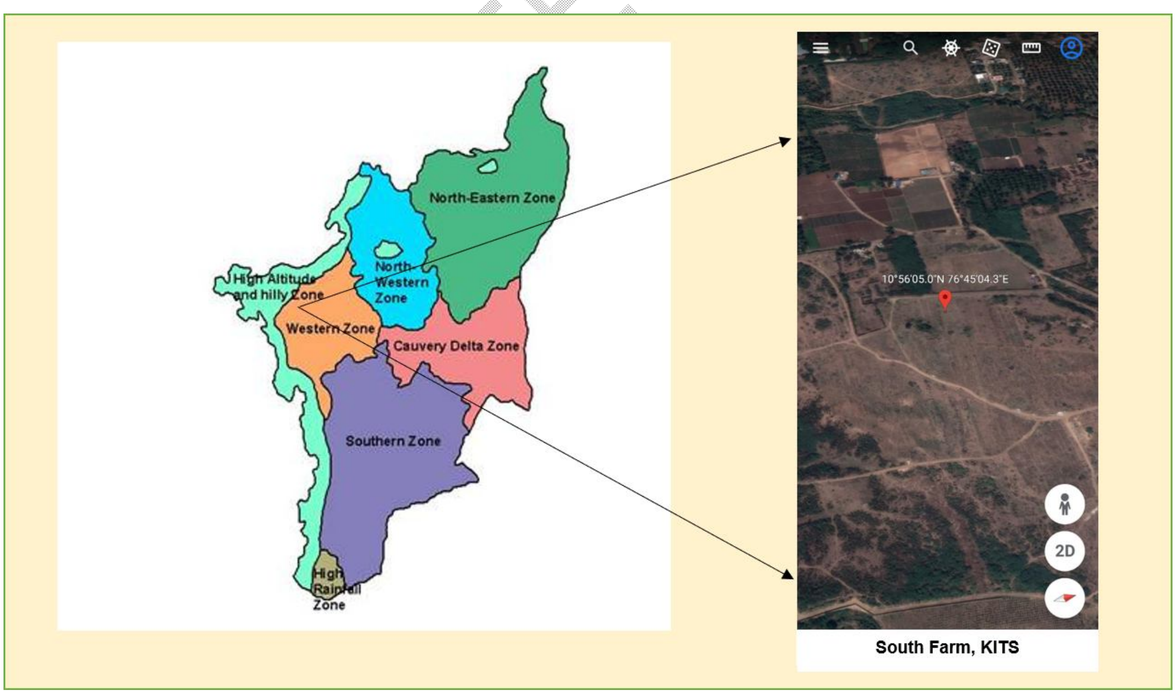

Fig 1. Experimental Site Location During the *Kharif* and *Rabi* Seasons of 2022-'23

Overall Field view

Black gram at the adjacent side of the maize

Fig 2. The Overall Field View and Intercropping of Black Gram

Table 1. Plant Height During the *Kharif* and *Rabi* Seasons of 2022 – '23

	Plant height (cm)					
Treatment	***Kharif* 2022 – '23**			***Rabi* 2022 – '23**		
	30 DAS	**45 DAS**	**90 DAS**	**30 DAS**	**45 DAS**	**90 DAS**
T1	24.47	102.72	156.13	23.27	102.37	155.86
T2	28.93	122.29	169.05	27.83	116.39	167.42
T3	29.09	120.92	174.69	30.09	121.95	176.34
T4	28.13	120.96	169.52	29.13	119.18	170.03
T5	32.34	135.55	203.28	36.34	138.13	206.83
T6	30.49	132.08	199.02	32.69	133.69	200.54
T7	27.63	117.20	170.16	29.63	121.33	179.10
T8	27.44	114.84	166.79	29.44	119.68	174.87
T9	24.92	107.22	161.80	26.92	109.79	163.09
T10	23.00	104.43	157.32	24.70	107.77	158.47
Mean	27.64	117.82	172.78	29.00	119.03	175.25
SE(m)	**1.85**	**6.12**	**9.65**	**1.92**	**6.87**	**10.63**
C.D.	**NS**	**18.33**	**28.90**	**5.74**	**20.57**	**31.84**

**Data represented are mean values of three replicates. Error bars represent standard errors (n = 3). T_1 - Absolute control, T_2 -RDF alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping. (RDF = 135:62.5:50 NPK kg ha^{-1})*

Table 2. Dry Matter Production During the *Kharif* and *Rabi* Seasons of 2022 - 23

	DMP (g $plant^{-1}$)					
	Kharif 2022 – '23			*Rabi* 2022 – '23		
Treatment	**30 DAS**	**45 DAS**	**90 DAS**	**30 DAS**	**45 DAS**	**90 DAS**
T1	16.60	89.77	130.00	14.41	90.14	128.60
T2	17.35	116.34	161.00	18.97	114.48	160.40
T3	17.39	117.41	166.00	17.58	119.58	169.30
T4	17.36	114.54	163.00	16.53	116.44	165.80
T5	18.20	130.65	192.00	21.07	129.55	197.70
T6	17.98	125.15	186.80	19.80	124.58	188.80
T7	17.38	115.49	167.00	17.49	120.41	171.70
T8	17.34	113.21	164.00	17.20	117.77	168.60
T9	16.91	102.86	147.00	15.94	107.32	152.80
T10	16.84	101.44	145.00	15.62	104.07	148.90
Mean	17.34	112.69	162.18	17.46	114.43	165.26
SE(m)	**1.18**	**7.57**	**10.82**	**1.03**	**6.79**	**11.02**
C.D.	**NS**	**22.67**	**32.40**	**3.09**	**20.33**	**33.00**

**Data represented are mean values of three replicates. Error bars represent standard errors (n = 3). T_1 - Absolute control, T_2 -RDF alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping. (RDF = 135:62.5:50 NPK kg ha^{-1})*

Table 3. Grain and Stover Yield During the *kharif* and *Rabi* Seasons of 2022 – '23

	Kharif 2022 – '23		*Rabi* 2022 – '23	
Treatment	**Grain Yield**	**Stover Yield**	**Grain Yield**	**Stover Yield**
T1	4.38	6.35	4.37	6.20
T2	5.46	7.73	5.45	7.59
T3	6.12	8.07	6.14	8.03
T4	5.68	7.92	5.88	7.87
T5	6.51	8.08	6.69	8.33
T6	6.21	7.87	6.42	8.15
T7	5.90	7.78	6.10	8.13
T8	5.41	7.39	5.55	7.44
T9	5.12	6.72	5.21	7.03
T10	5.08	6.41	5.18	6.90
Mean	**5.59**	**7.43**	**5.70**	**7.57**
SE(m)	**0.37**	**0.41**	**0.37**	**0.43**
C.D.	**1.11**	**1.24**	**1.12**	**1.29**

**Data represented are mean values of three replicates. Error bars represent standard errors (n = 3). T_1 - Absolute control, T_2 -RDF alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping. (RDF = 135:62.5:50 NPK kg ha^{-1})*

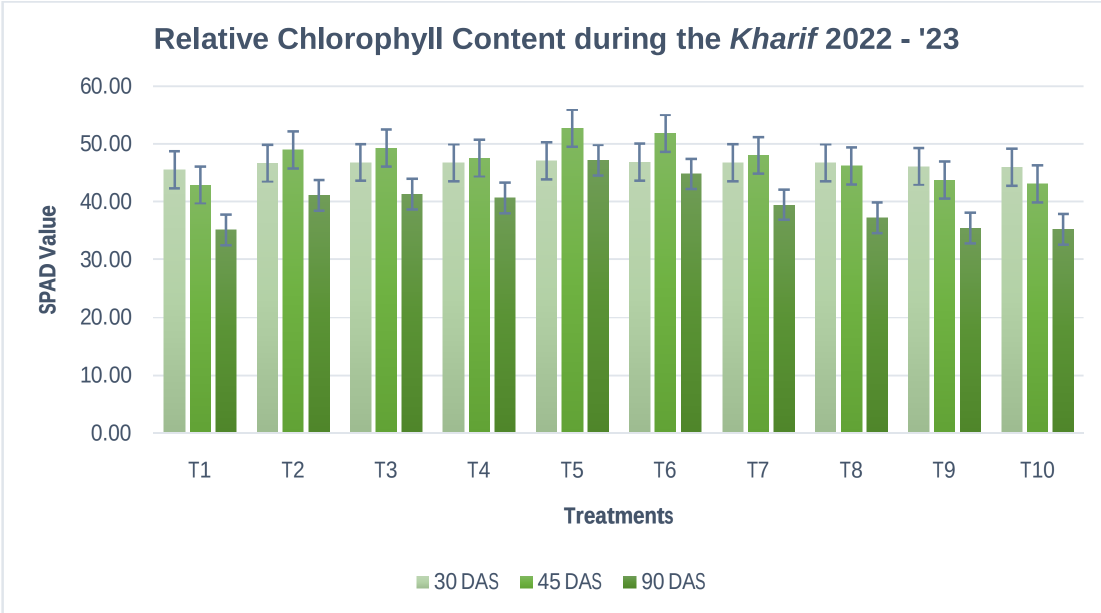

Fig 3. Effect of Different Nutrient Management on the Relative Chlorophyll Content During the *kharif* Season 2022 – '23

***Mean ± S.E.M = Mean values ± Standard error of means of ten treatments. T_1 - Absolute control, T_2 - RDF alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping. (RDF = 135:62.5:50 NPK kg ha^{-1})*

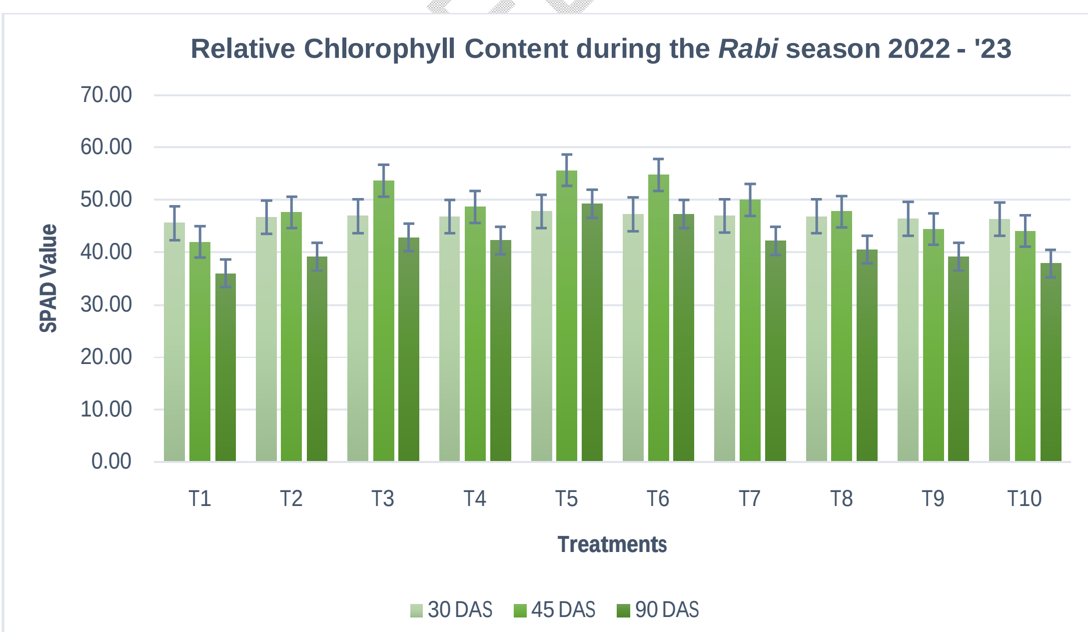

Fig 4. Effect of Different Nutrient Management on the Relative Chlorophyll Content During the *Rabi* Season 2022 – '23

***Mean ± S.E.M = Mean values ± Standard error of means of ten treatments. T_1 - Absolute control, T_2 - RDF alone, T_3 - RDF + Poultry Manure (4t ha^{-1}), T_4 - RDF + FYM (12.5 t ha^{-1}), T_5 - RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_6 - RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_7 - 75 % RDF +*

Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_8 - 75% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping, T_9 - 50% RDF + Poultry Manure (4 t ha^{-1}) + Black gram intercropping, T_{10} - 50% RDF + FYM (12.5 t ha^{-1}) + Black gram intercropping. (RDF = 135:62.5:50 NPK kg ha^{-1})