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# Impact of different rice establishment methods and tillage systems on nodulation behaviour of succeeding chickpea and blackgram

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**Abstract**
Rice crop has spread across the state of Telangana producing leaps and bounds of grain every year. Growing rice in traditional paddies is the commonest practice in the state for quite long time. Since these paddies are becoming a point of discussion for their adverse impact on climate, lowering of ground water table and unsuitability of puddled soils for growing succeeding irrigated dry crops which are posing serious threat to sustainability of rice based cropping systems. With an aim to diversify *rabi* season rice and to encourage growing pulses and oilseed crops in order to alleviate the problem of nutritional security and to sustain the productivity and profitability of rice based cropping systems state government has taken several measures but the efforts were not fruitful for many reasons and one important reason is the unsuitability of paddies for growing succeeding I.D crops. A field experiment was conducted to study the performance of different *rabi* crops in different establishment systems of rice grown during *kharif* and with different tillage systems. The experiment was carried out for two consecutive years (2021-22 and 2022-23) at Regional Sugarcane and Rice Research Station (PJTSAU), Rudrur, Nizamabad district of Telangana. Machine transplanting, wet direct seeding and dry direct seeding were the different rice establishment methods during *kharif* season and each main plot of the *kharif* rice was divided into two sub plots *viz*., zero tillage and conventional tillage in which chickpea and blackgram (pulses) were grown in *rabi* season for two years. Among different rice establishment systems, dry direct seeding of rice followed by conventional tillage during *rabi* offered best conditions for establishment, growth and development of chickpea and blackgram as a result both the crops have produced maximum number of active nodules plant$^{-1}$ (14.07 and 14.03; 11.73 and 11.40) in in both the years of study (2021-22 and 2022-23, respectively).

**Keywords:** Rice, pulses, establishment methods, zero tillage, root nodules

## Introduction
Indian agriculture is largely dependent on rice-based cropping systems and rice-rice monocropping is predominant in many parts of the country. Productivity enhancement of these systems secures the livelihood of more than half a billion-farm families. Since Green revolution, in India the food grain production has increased manifold with adoption of input responsive high yielding varieties. Rice based cropping systems continued to be the mainstay of the country in general and state of Telangana in particular. Today rice in India is spread over 45.76 million ha producing 124.36 million tonnes of grain annually with per hectare yield of 2717 kg (Indiaagristat, 2022) [3] and in Telangana it has spread in an area of 3.18 million ha and producing 10.21 million tonnes in 2020-21 (Indiaagristat, 2021) [4]. Today's rice production is often exceeding the actual demand, and procurement become an increasingly difficult task for the government. Although the government is encouraging farmers to switch from *rabi* rice to other productive I.D crops, those efforts are not so fruitful for a variety of reasons. The unsuitability of flooded paddies for succeeding I.D crops during *rabi* is one significant reason.

In rice-based cropping system, rice is commonly established by transplanting which requires huge amount of water and labour. Further, puddling makes the land unsuitable for subsequent irrigated dry crops and manual transplanting in puddled soil results in increased cost of production and reduced profits to farmers (Ali *et al*., 2019) [1]. Today different rice establishment systems under rice are being developed across the globe and they are gaining considerable area every year.

Conservation agriculture (CA) considered being a viable option for sustainable intensification of rice based cropping systems for profitable production. To derive maximum benefit from CA – zero tillage, crop residue retention and crop diversification, location specific appropriate crop rotations need to be developed spearheading towards less water use and climate resilient crops. Recently Govt. of India also taken a policy decision to promote pulses and oil seeds in rice fallow systems instead of cereals to safeguard the nutritional security and remunerative prices to the farmers. Growing a short-duration grain legume like blackgram and chickpea and incorporating the residues into the soil after harvesting the pods is suggested not only for increasing the system productivity but also for making a considerable saving on chemical fertilizer (Kundu and Pillai, 1992) [5]. Rice being the staple food of southern India, it cannot be avoided completely rather keeping *kharif* rice as it is and shifting *rabi* season to other crops like chickpea and blackgram may bring positive changes in the profitability and sustainability of rice-based cropping systems (Panda *et al*., 2018) [6].

An important feature of pulse crops is its ability to establish a symbiotic partnership with specific bacteria (*Rhizobia*), setting up the biological nitrogen fixation process in root nodules that supply plant's nitrogen needs (Thatikunta *et al.*, 2019) [10]. In the present study an attempt was made to study the nodulation behaviour of chickpea and blackgram crops as a succeeding crop of rice under different rice establishment methods and tillage systems by taking total number of nodules plant$^{-1}$ and number of active nodules plant$^{-1}$.

## Materials and Methods

The present experiment was executed at Regional Sugarcane and Rice Research Station (PJTSAU), Rudrur of Nizamabad district (Telangana) with Geographical positioning system (GPS) co-ordinates of 18$^0$33'55.01'' N latitude and 77$^0$52'20.12'' E longitudes and at an altitude of 721 m above mean sea level. Soil of the experimental site belongs to silty clay type based on its particle size distribution and moderately alkaline in reaction with pH of 8.1 and EC 1.94 dSm$^{-1}$. The experiment was carried out in *kharif* followed by *rabi* for two successive years *i.e*., 2021-22 and 2022-23 in split-split plot design with three establishment methods of rice as main plots *viz*., Machine Transplanting ($M_1$), Wet Direct Seeding ($M_2$) & Dry Direct Seeding ($M_3$) followed by two tillage systems {Zero tillage with rice residue mulch ($S_1$) & Conventional tillage ($S_2$)} as sub plots and three I.D crops (Chickpea, Blackgram and Mustard) were taken in the succeeding *rabi* season as sub-sub plots. In zero tillage plots, soil was undisturbed after the harvest of rice except for sowing the crop and in conventional plots a series of tillage operations were carried out using tractor drawn equipment till the soil has come to fine tilth.

The objective of the study was to understand the nodulation behaviour of pulses (chickpea and blackgram) grown after *kharif* rice established under different systems and successive soil conservation practices. Counting of number of nodules and number of active nodules were accomplished by taking five healthy plants of blackgram and chickpea from the gross plot of each treatment at active vegetative growth stage (i.e., 40 DAS in blackgram; 50 DAS in chickpea) and counted for total and active nodules plant$^{-1}$ and expressed in no. of noduels plant$^{-1}$. Nodules with active leghaemoglobin (pink colour inside) are grouped as active nodules.

Results were compared statistically using ANOVA technique of split plot design for individual crop separately. Though the experiment was laid out in split-split plot design, two crops were compared in different establishment and tillage systems separately as these are biologically different entities using ANOVA of split plot design in OP stat software.

**Table 1:** Total and active nodule count (No. plant$^{-1}$) of chickpea and blackgram as influenced by different rice establishment methods and tillage systems

| Treatment | Chickpea | | | | | | Blackgram | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total nodules | | | Active nodules | | | Total nodules | | | Active nodules | | |
| | 2021-22 | 2022-23 | Mean | 2021-22 | 2022-23 | Mean | 2021-22 | 2022-23 | Mean | 2021-22 | 2022-23 | Mean |
| **Main plots: Rice establishment methods** | | | | | | | | | | | | |
| $M_1$: Machine transplanting | 21.02 | 20.82 | 20.92 | 18.65 | 17.62 | 18.135 | 14.23 | 14.32 | 14.27 | 13.00 | 12.85 | 12.925 |
| $M_2$: Wet direct seeding through drum seeder | 19.25 | 19.12 | 19.18 | 17.03 | 17.22 | 17.125 | 13.85 | 13.72 | 13.78 | 12.48 | 12.38 | 12.43 |
| $M_3$: Dry direct seeding through seed drill | 23.78 | 23.62 | 23.70 | 21.32 | 19.37 | 20.345 | 15.83 | 15.82 | 15.82 | 14.65 | 14.42 | 14.535 |
| S.Em± | 0.37 | 0.43 | - | 0.40 | 0.26 | - | 0.38 | 0.36 | - | 0.41 | 0.29 | - |
| CD (P=0.05) | 1.45 | 1.68 | - | 1.56 | 1.02 | - | 1.50 | 1.41 | - | 1.61 | 1.14 | - |
| **Sub plots: Tillage practices** | | | | | | | | | | | | |
| $S_1$: Zero tillage with rice residue mulch | 18.09 | 17.91 | 18.00 | 15.89 | 15.19 | 15.54 | 12.96 | 12.80 | 12.88 | 12.13 | 11.76 | 14.8 |
| $S_2$: Conventional tillage | 24.61 | 24.46 | 24.53 | 22.11 | 20.94 | 21.525 | 16.32 | 16.43 | 16.37 | 14.62 | 14.68 | 23.1 |
| S.Em± | 0.20 | 0.24 | - | 0.26 | 0.21 | - | 0.16 | 0.16 | - | 0.14 | 0.19 | - |
| CD (P=0.05) | 0.71 | 0.84 | - | 0.91 | 0.72 | - | 0.55 | 0.56 | - | 0.48 | 0.64 | - |
| Interaction (M × S) | S | S | - | S | S | - | S | S | - | S | S | - |

**Table 1a:** Interaction effect of rice establishment methods and tillage systems on total nodule count (No. plant$^{-1}$) of succeeding chickpea and blackgram

| Total nodule count of chickpea | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **M × S** | **2021-22** | | | | **2022-23** | | | |
| | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** |
| $S_1$ | 16.83 | 16.07 | 21.37 | 18.09 | 16.63 | 15.87 | 21.23 | 17.91 |
| $S_2$ | 25.20 | 22.43 | 26.20 | 24.61 | 25.00 | 22.37 | 26.00 | 24.46 |
| Mean | 21.02 | 19.25 | 23.78 | 21.35 | 20.82 | 19.12 | 23.62 | 21.18 |
| | S.Em± | | CD (P=0.05) | | S.Em± | | CD (P=0.05) | |
| S at same M | 0.35 | | 1.22 | | 0.42 | | 1.46 | |
| M at same S | 0.45 | | 1.68 | | 0.52 | | 1.97 | |
| **Total nodule count of blackgram** | | | | | | | | |
| **M × S** | **2021-22** | | | | **2022-23** | | | |
| | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** |
| $S_1$ | 12.50 | 12.63 | 13.73 | 12.96 | 12.47 | 12.40 | 13.53 | 12.80 |
| $S_2$ | 15.97 | 15.07 | 17.93 | 16.32 | 16.17 | 15.03 | 18.10 | 16.43 |
| Mean | 14.23 | 13.85 | 15.83 | 14.64 | 14.32 | 13.72 | 15.82 | 14.62 |
| | S.Em± | | CD (P=0.05) | | S.Em± | | CD (P=0.05) | |
| S at same M | 0.28 | | 0.95 | | 0.28 | | 0.97 | |
| M at same S | 0.43 | | 1.64 | | 0.41 | | 1.57 | |

$M_1$: Machine transplanting; $M_2$: Wet direct seeding through drum seeder; $M_3$: Dry direct seeding through seed drill; $S_1$: Zero tillage with rice residue mulch; $S_2$: Conventional tillage

**Table 1b:** Interaction effect of rice establishment methods and tillage systems on active nodule count (No. plant$^{-1}$) of succeeding chickpea and blackgram

| Active nodule count of chickpea | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **M × S** | **2021-22** | | | | **2022-23** | | | |
| | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** |
| $S_1$ | 14.73 | 14.07 | 18.87 | 15.89 | 14.37 | 14.03 | 17.17 | 15.19 |
| $S_2$ | 22.57 | 20.00 | 23.77 | 22.11 | 20.87 | 20.40 | 21.57 | 20.94 |
| Mean | 18.65 | 17.03 | 21.32 | 19.00 | 17.62 | 17.22 | 19.37 | 18.07 |
| | S.Em± | | CD (P=0.05) | | S.Em± | | CD (P=0.05) | |
| S at same M | 0.45 | | 1.57 | | 0.36 | | 1.25 | |
| M at same S | 0.51 | | 1.91 | | 0.36 | | 1.35 | |
| **Active nodule count of blackgram** | | | | | | | | |
| **M × S** | **2021-22** | | | | **2022-23** | | | |
| | $M_1$ | $M_2$ | $M_3$ | Mean | $M_1$ | $M_2$ | $M_3$ | Mean |
| $S_1$ | 11.93 | 11.73 | 12.73 | 12.13 | 11.53 | 11.40 | 12.33 | 11.76 |
| $S_2$ | 14.07 | 13.23 | 16.57 | 14.62 | 14.17 | 13.37 | 16.50 | 14.68 |
| Mean | 13.00 | 12.48 | 14.65 | 13.38 | 12.85 | 12.38 | 14.42 | 13.22 |
| | S.Em± | | CD (P=0.05) | | S.Em± | | CD (P=0.05) | |
| S at same M | 0.24 | | 0.83 | | 0.32 | | 1.11 | |
| M at same S | 0.44 | | 1.71 | | 0.37 | | 1.38 | |

$M_1$: Machine transplanting; $M_2$: Wet direct seeding through drum seeder; $M_3$: Dry direct seeding through seed drill; $S_1$: Zero tillage with rice residue mulch; $S_2$: Conventional tillage

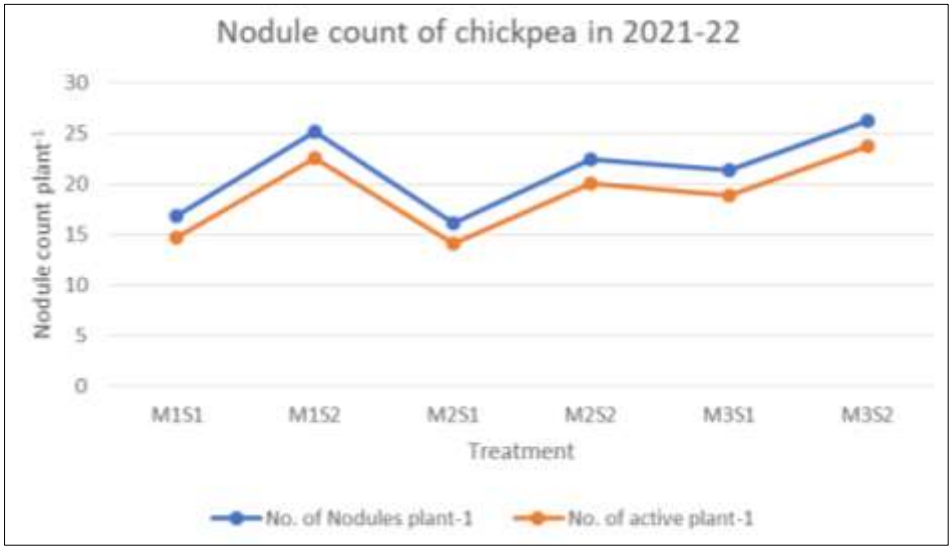



**Fig 1:** Total number of nodules and active nodules plant$^{-1}$ of mchickpea in 2021-22

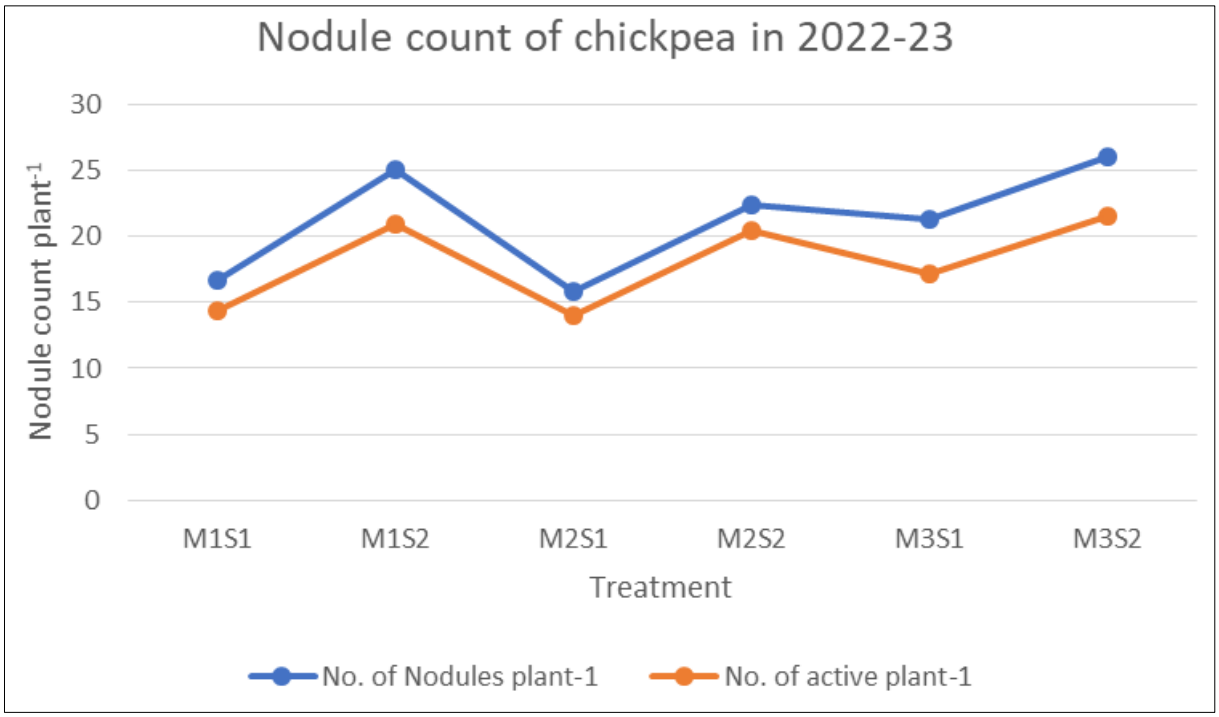



**Fig 2:** Total number of nodules and active nodules plant$^{-1}$ of chickpea in 2022-23

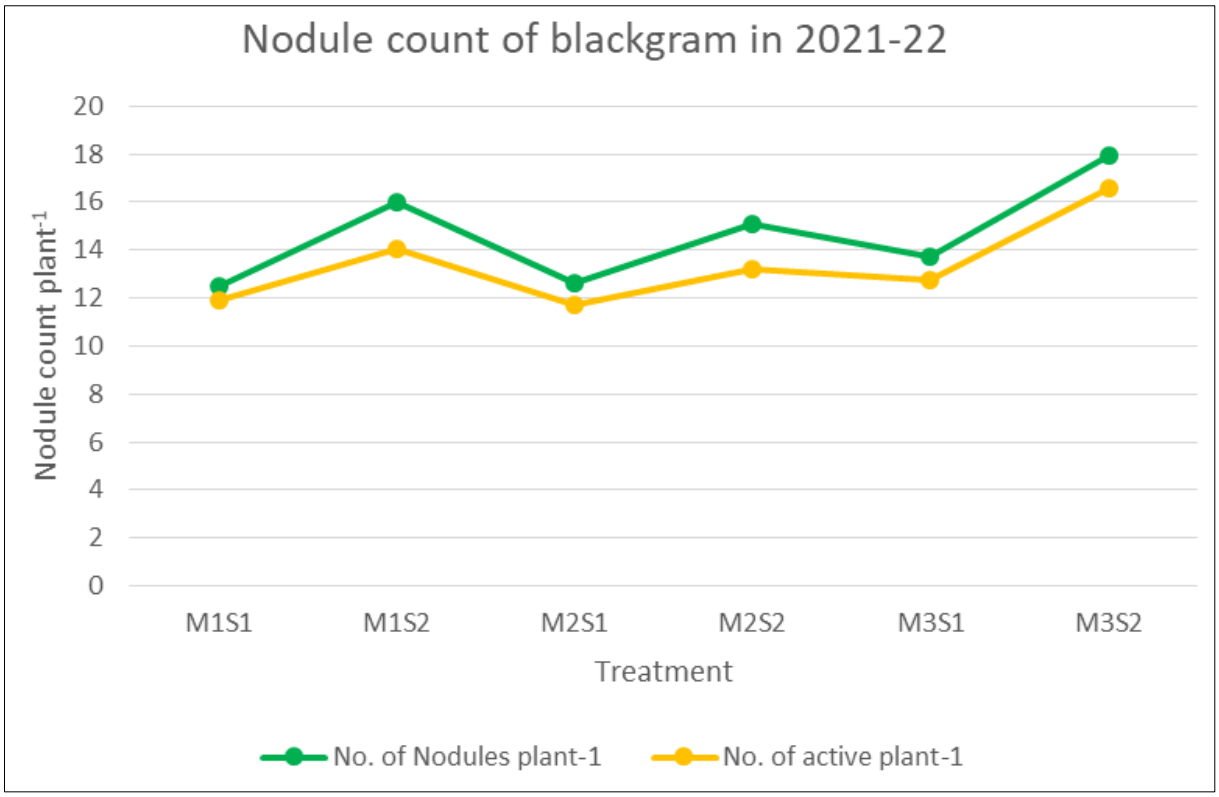
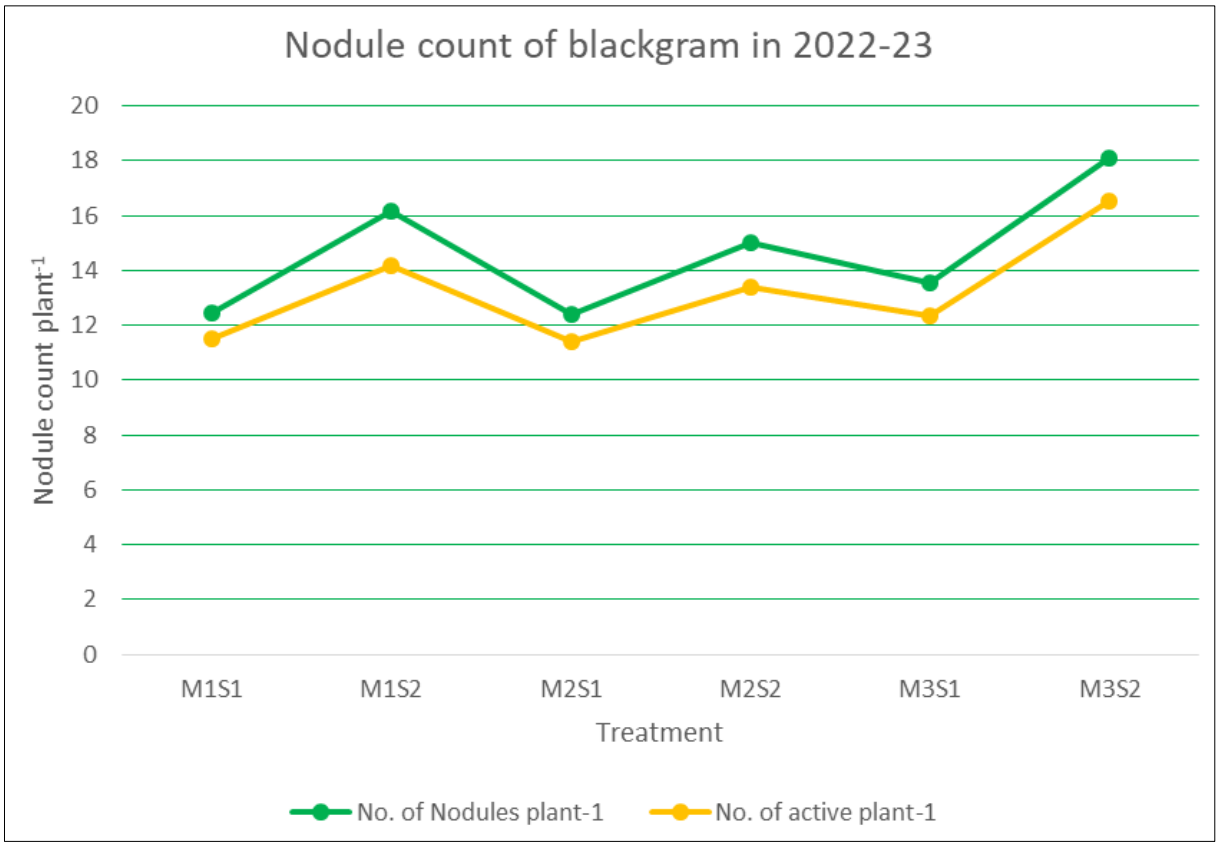



**Fig 3:** Total number of nodules and active nodules plant$^{-1}$ of blackgram in 2021-22




$M_1$: Machine transplanting; $M_2$: Wet direct seeding; $M_3$: Dry direct seeding; $S_1$: Zero tillage with rice residue mulch; $S_2$: Conventional tillage

**Fig 4:** Total number of nodules and active nodules plant$^{-1}$ of black gram in 2022-23

## Results and Discussion

Nodules are the actual site of atmospheric nitrogen fixation and it is the character because of which legumes are considered as drivers of sustainability (Hassan Etesami, 2022) [2]. From the table 1 it is clear that in chickpea during both the years of study (2021-22 and 2022-23) grown after dry direct seeded rice ($M_1$) among rice establishment systems produced highest number of nodules plant$^{-1}$ (23.78 and 23.62) whereas in tillage systems practiced during *rabi*, conventional tillage has favoured the production of higher number of nodules plant$^{-1}$ (24.61 and 24.46) further the proportion of active nodules plant$^{-1}$ observed were also found to be maximum in dry direct seeded rice (21.32 and 19.37) and conventional tillage practice (22.11 and 20.94) in 2021-22 and 2022-23, respectively. With regard to interaction effect dry direct seeding of rice coupled with conventional tillage during *rabi* has given significantly greater number of nodules plant$^{-1}$ (26.20 and 26.00) and number of active nodules plant$^{-1}$ (23.77 and 21.57) in chickpea during 2021-22 and 2022-23, respectively.

Alike results were reported with black gram wherein highest number of nodules plant$^{-1}$ (15.83 and 15.82) and number of active nodules plant$^{-1}$ (14.65 and 14.42) in dry direct seeded rice plots in successive years of 2021-22 and 2022-23, respectively (Table 1). Among different tillage systems conventional tillage practice has produced maximum number of nodules (16.32 and 16.44) and active nodules plant$^{-1}$ (14.62 and 14.68) in both the years of study. Similar interaction results were found in black gram like chickpea wherein dry direct seeded rice followed by conventional tillage has resulted in maximum number of nodules plant$^{-1}$ (17.93 and 18.10) and active nodules plant$^{-1}$ (16.57 and 16.50) in 2021-22 and 2022-23, respectively.

Whereas lowest number of active nodule count plant$^{-1}$ was recorded in wet direct seeded rice plots with zero tillage during 2021-22 (14.07 and 11.73) and 2022-23 (14.03 and 11.40) in chickpea and black gram, respectively. In wet direct seeded plots and machine transplanting plots lower number of nodule count might be due to hard compact soil layer resulted from puddling action. Though impervious layer created during puddling favours rice by improving nutrient availability (N, $P_2O_5$ and Fe) and weed suppression it has adversely affected root growth and nodule development of chickpea and black gram in succeeding *rabi* season due to higher penetration resistance and poor aeration (Saroch and Thakur, 1991) [8]; (Rawat *et al*., 1996) [7]. On the other hand due to low compactness and good soil structure in dry direct seeded plots which provided low penetration resistance and aerobic conditions in soil favoured *rhizobium* to establish on plant roots and produce relatively higher number of nodules plant$^{-1}$ (Singh *et al*., 2017) [9].

## Conclusion

Root nodules play an important role in sustaining soil health through fixing atmospheric nitrogen. Lot of factors influence the growth and establishment of legumes grown in succession to rice crop. Most importantly puddling operation has adversely affected the nodulation behaviour and reduced the number of nodules and number of active nodules plant$^{-1}$ whereas on other hand in dry direct seeded rice followed by conventional tillage has provided favourable environment and soil physical properties which has resulted in higher number

of nodules and active number of nodules plant$^{-1}$ in both chickpea and black gram.

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