PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 12(2): 1-7
https://doi.org/10.14719/pst.6294

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RESEARCH ARTICLE

Enhancement of seed yield of rice fallow green gram through foliar application of macro and micro nutrients

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OPEN ACCESS

ARTICLE HISTORY
Received: 24 November 2024
Accepted: 20 February 2025
Available online
Version 1.0 : 10 March 2025
Version 2.0 : 01 April 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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CITE THIS ARTICLE
Dhandapani M, Chitra S, Geethanjali S, Sangeetha M, Subrahmaniyan K. Enhancement of seed yield of rice fallow green gram through foliar application of macro and micro nutrients . Plant Science Today. 2025; 12(2): 1-7. https://doi.org/10.14719/pst.6294

Abstract

Seedling vigour and initial establishment of rice fallow green gram is affected due to mechanical harvesting of paddy which requires complete drying of soil. To enhance the synchronous growth and development, foliar application of micronutrients, mono ammonium phosphate, di ammonium phosphate and 19:19:19 was performed during different phases of rice fallow green gram. Combination of MN chelated mixture and 19:19:19 sprayed on four different stages of crop growth enhanced the seed yield of 1266 kg/ha. This study is the first report on the combination of water soluble micro and macro nutrients on enhancing the yield of green gram under rice fallow conditions. The yield enhancement can stabilize rice fallow cultivation of green gram in Cauvery Delta Zone which will directly benefit the farmers and industry.

Keywords

chelated MN mixture; foliar spray; nutrient imbalances; rice fallow; seed yield

Introduction

Green gram, commonly known as mung bean (*Vigna radiata* (L). Wilckzek), is an important pulse crop grown for its protein-rich grains. It is widely cultivated in Southeast Asia including countries such as China, Taiwan, Thailand, Vietnam, Indonesia, South Korea, Japan, India, Myanmar and Pakistan. The species *Vigna radiata* originated in Indian centre with the presence of vast gene pool identified in different geographical locations of the region (1). The sprouts of green gram have excellent antioxidant properties and are recommended as an important diet in obesity conditions. Per capita protein requirement of Indian population is 0.83 g/kg of the body weight per day (2). Pulses are the major protein source for Indian population. Green gram grains serve as a cheap source of protein for the population belonging to the Asian and Southeast Asian region (3). Green gram is consumed in various forms and it contains 24.5% protein, 56% carbohydrate, 4.1% fibre, 3.5% minerals (Ca 124 mg/100 g, P, Fe 7.3 mg/100 g) and calorific value of 334 Kcal/100 g (4). Green gram is an excellent cover crop which improves the soil fertility and suppresses the weeds in perennial crops like coconut, banana and other fruit orchards, requiring minimal management (4). Green gram is an excellent green manure pulse crop with quick foliar coverage for restoring and improving soil fertility in crop rotations with cereals and millets (5, 6). Being a leguminous crop, it fixes the

atmospheric nitrogen and the incorporation of green gram crop residues add major and minor nutrients as well as improve the activity of beneficial microbes in the soil (7-9).

Green gram is primarily cultivated under rainfed conditions, followed by irrigated and rice fallow systems during the rabi and summer seasons. In India, it is cultivated in states like Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal, Haryana, Punjab, Maharashtra, Assam, Andhra Pradesh, Karnataka and Tamil Nadu under rainfed conditions mainly during kharif season with southwest monsoon. It is cultivated in an area of 1 million ha with production of 0.5 million tonnes with average productivity of 550 kg/ha (10-12). Self-reliance in pulses production is an important agenda for the policymakers and agricultural scientists for the food and nutritional security of the nation. Crop diversification and rotation with pulse crops is a good option for increasing the pulse production with greater scope. Rice is cultivated in an area of 140 million ha in India. After rice cultivation, large areas of land remain fallow without subsequent cropping. Rice fallow cultivation of pulses like black gram, green gram and lathyrus will increase the area under pulses considerably (11, 13, 14). Rice fallow cultivation of pulses is an important crop diversification method to conserve the soil and water resources in rice ecosystem which stabilizes the microbiome diversity and population (15-17).

Rice fallow cultivation of green gram is an important relay cropping system in Cauvery Delta Zone after the second season rice crop (October-February). Relay cropping of Rice- green gram is an agro ecological adaptive process by cultivating green gram genotypes under zero tillage with adaptive features viz., germination and initial seedling growth before the harvest of rice, followed by growth and development under low input response conditions. Rice is cultivated in an area of 0.5 million ha in the first season and the total area for second season under rice cultivation is slightly lesser or higher every year. Rice fallow pulses account for 40% of total pulse production of the state. 2.0-3.5 lakh ha is covered under rice fallow pulses in Cauvery Delta Zone. Rice fallow green gram cultivation is practiced in districts of Mayiladuthurai, Tiruvarur, Nagapattinam and Thanjavur of Cauvery Delta Zone under marginal soils following second season rice crop as relay crop (18). Rice fallow adaptive variety, ADT 3 had evolved through hybridization followed by selection from the cross H7016 x Rajendran (G65). ADT 3 matures in 65 days under rice fallow conditions as a relay crop with average yield potential of 350-450 kg per ha and 100 seed weight is 3.2 g. It is uniquely adapted to the marginal soil conditions of Cauvery Delta Zone with low moisture levels and salinity (agritech.tnau.ac.in). Yield varies with soil types considerably from 350-500 kg/ha influenced mainly by soil fertility. Being a relay crop, there is less scope for efficient management for increasing the yield of seeds.

The seed yield of rice fallow green gram is significantly affected by nutrient deficiencies, leading to imbalances in source-sink relationships. Nutrients uptake in rice relay cropping is influenced by the inherent soil fertility in terms of stronger association of relay crop with soil microbiome with nutrients mobilizations (14, 19-21). The roles of rice fallow crop genotype with microbiome association are abiotic tolerances like drought tolerance through water uptake, stomatal closure regulations and salinity, biotic tolerances against wilt, root rot and other foliar diseases like powdery mildew through induced systemic acquired resistance (22). Due to depletion of nutrients, loss of microbiome diversity due to tillage practices and indiscriminate applications of chemical fertilizers, poor establishment of the relay crop of green gram results in poor source sink balances. Poor source is observed with formation of fewer photosynthetic active leaves followed by abscission of leaves during maturity phase caused due to deficiencies of micronutrients (zinc and iron). Formation of fewer flowers followed by flower dropping, less pod setting percentage, formation of lesser number of seeds, ill filling of seeds is the poor sink in rice fallow green gram (23). Hard seeds formation during rice fallow green gram seed production is the major constraints which affect the germination percentage of green gram seeds (24).

To mimic the roles of nutrients mobilisation and uptake through microbiome association in rice fallow green gram, foliar application with combination of macro and micronutrients to increase the seed yield potential, when they are sprayed at critical stages of growth. This study aimed to enhance seed yield in the rice fallow green gram variety ADT 3 by evaluating the effects of foliar applications of combined macro- and micronutrients for economic and soil sustainability.

Materials and Methods

Experimental plot, soil and Sowing method

The trial was conducted at Agricultural Research Station, Tamil Nadu Agricultural University, Pattukottai during January-February 2023. The preceding rice variety grown during the second season (October-2023) was ADT 38, with a duration of 135 days. Immediately after the machine harvest, field is irrigated through flooding, followed by draining. Under waxy soil conditions, manual dibbling was performed with spacing of 25 x 25 cm the same spacing followed for previous rice crop just near the rice stubbles. The green gram seeds were treated with imidachloprid (10 mL/kg of seeds) to prevent infestation of sucking pests during initial vegetative phase viz., thrips and white flies and also to prevent the spread of mungbean yellow mosaic virus (MYMV). Seed rate of 15 kg/acre was maintained with the spacing of 25 x 25 cm. The soil physical and chemical properties of B block are as follows; Soil texture: Sandy clay pH: 6.5, EC: 0.02 dsm^{-1}, organic carbon: 0.38%, Macro nutrients: Nitrogen: 141 kg/ha (low), Phosphorous: 15.6 kg/ha (low), Potassium: 211.25 kg/ha, Micro nutrients: Zinc: 0.88 mg/ kg (low), Iron: 1.19 mg/kg (low), Copper: 0.36 mg/kg (low).

Imposing foliar treatments

Since rice fallow is a relay cropping system, soil application of nutrients was not done. Foliar application of micro and macro nutrients with combinations and without combinations were imposed on 10, 25, 35 and 45 days after sowing of seeds coinciding with initial seedling growth phase, active vegetative phase, reproductive phase and pod formation stage as single spray on individual growth phase as well as four times spray in all four stages (10, 25, 35 and 45 DAS). The micronutrients mixture used in the study is a chelated. The composition is as follows: 2.5% Fe, 1.0% Mn, 3.0% Zn, 1.0% Cu, 0.5% B, 0.1 Mo. MN chelated mixture was sprayed at the concentration of 0.2%. The macro nutrients used in the study are 2.0% DAP (Di ammonium phosphate: 18% N, 46% P_2O_5), 0.5% MAP (Mono ammonium phosphate: 12% N, 61% P_2O_5), 0.5 % 19: 19: 19 (19 % N: 19% P: 19% K). Chelated MN mixture, MAP and 19:19:19 are highly water soluble and user friendly. The details of the commercial products are as follows; MN chelated mixture: Rexolin CKK Micronutrient mixture (Bayer); 19:19:19, Gromor nutrispray (Coromandel), MAP; Gromor spray, N: P: K, 12:61: 0. The approximate cost estimates for four times foliar spraying and nutrients is about Rs. 2500.

Preparation of 2.0% DAP: 2.0 kg of well powdered DAP was mixed with 200 L of water and soaked for 48 hr. Filtered aqueous solution was directly used for spraying using battery operated knapsack sprayer. The details of treatments, nutrients composition, dosage, stage of application and combinations were given in Table 1 and 2.

Biometric observations on seed yield

Biometric observations on seed yield and attributing traits were done.

Seed Yield and attributing traits

1. Plant height (cm) 2. Number of branches 3. Number of leaves per plant 4. Number of yellow leaves per plant 5. Number of clusters per plant 6. Number of pods per cluster 7. Number of flowers 8. Total number of pods per plant 9. Pods setting percentage 10. 100 seed weight 11. Percentage of hard seeds. Hard seeds were counted from 100 seeds from the samples drawn from the seed lot of individual treatments. 12. Total seed yield 13. Seed recovery percentage. The observations were made during reproductive, flowering phase, pod formation, pod maturity and after harvest and seed processing.

Statistical analysis

Total number of treatments-imposed was 12. Number of replications was 3. The design followed was a randomized block design (RBD). Plot sizes of 5 x 3 m were marked with bamboo stakes without forming bunds and a gap of 45 cm was given between plots without sowing of seeds. R statistical software (R. 4.4.1) was used to analyse the data and Duncan multiple range test was performed to study the effect of individual treatments.

Results

Seed yield and attributing traits were analysed statistically and the results are given in Table 1 and 2. Twelve different treatments, involving foliar sprays of micro- and macronutrients, both individually and in combination, were tested on rice fallow green gram (variety ADT 3) during four critical growth stages.

***Effects of foliar spraying of chelated MN mixture on 10 DAS (T_5) growth and yield of Rice fallow green gram*:** Foliar spraying of chelated micronutrients mixture on 10 DAS (T_5) resulted in a seed yield of 153.33 kg/ha and improved initial vegetative growth parameters such as plant height, number of branches and leaves. Pod-related traits, including the number of pods per plant and pod-setting percentage, were also enhanced. However, the treatment resulted in a high percentage of hard seeds (4.9%) and a seed recovery rate of only 65%. foliar application of micronutrients on rice fallow green gram during the seedling stage.

Table 1. Enhancement of growth attributes of rice fallow green gram variety, ADT3 by foliar application of combination of micro and macro nutrients

Treatments	Plant Height (cm)	No. of branches per plant	No. of leaves	No. of yellow leaves	No. of flowers per plant	No. of clusters
T_1: Control	20.5	2.83	10.1	5.30	21.4	6.27
T_2: 0.5% 19:19:19 (10 DAS)	27.6	4.50	20.4	4.80	22.0	6.50
T_3: 0.2% MN (10 DAS)	32.6	4.47	31.7	2.80	28.4	7.10
T_4: 2.0% DAP (35 DAS)	30.4	3.70	22.3	5.00	31.6	10.1
T_5: 0.5% MAP (35 DAS)	36.5	4.30	24.2	4.37	41.6	12.1
T_6: 0.5% 19:19:19 (35 DAS)	33.8	5.27	31.1	3.83	48.6	12.4
T_7: 0.5% 19:19:19 (45 DAS)	28.6	4.87	34.3	4.33	31.6	7.50
T_8: 0.5% 19:19:19 + 0.2% MN (10 DAS)	38.2	5.63	41.5	2.03	44.6	12.0
T_9: 0.5% 19:19:19 + 0.2% MN (25 DAS)	36.0	5.13	39.6	1.90	51.9	12.4
T_{10}: 0.5% 19:19:19 + 0.2% MN (35 DAS)	34.6	5.20	38.7	3.37	58.3	10.0
T_{11}: 0.5% 19:19:19 + 0.2% MN (45 DAS)	41.9	7.10	62.1	1.80	68.0	12.6
T_{12}: 0.5% 19:19:19 + 0.2% MN (10, 25, 35 and 45 DAS)	67.9	10.5	62.6	1.47	96.3	20.4
SE	2.1	0.44	2.7	0.35	1.6	0.8
C.D. at 5%	6.1	1.31	8.0	1.04	4.8	2.6

Note: DAP: Di Ammonium Phosphate; MAP: Mono Ammonium Phosphate; MN: Chelated Micronutrient Mixture

Table 2. Enhancement of seed yield and attributes of rice fallow green gram variety, ADT3 by foliar application of combination of micro and macro nutrients

Treatments	No. of pods per cluster	No. of pods per plant	Pod Setting (%)	No. of seeds per pod	100 seed weight (g)	Hard seed (%)	Seed yield (kg/ ha)	Seed Recovery (%)
T_1: Control	2.60	11.8	46.2	3.63	3.20	4.97	75.6	62.3
T_2: 0.5% 19:19:19 (10 DAS)	3.80	18.8	88.0	4.03	3.40	4.83	126.6	68.4
T_3: 0.2% MN (10 DAS)	3.07	20.0	70.4	5.07	3.24	3.90	153.3	65.4
T_4: 2.0% DAP (35 DAS)	3.83	20.9	66.2	5.00	3.30	3.00	237.2	75.2
T_5: 0.5% MAP (35 DAS)	4.40	31.6	76.0	4.97	3.28	1.50	291.6	74.5
T_6: 0.5% 19:19:19 (35 DAS)	4.60	32.5	66.9	5.33	3.40	1.47	331.6	78.2
T_7: 0.5% 19:19:19 (45 DAS)	3.93	24.4	77.0	4.47	3.80	2.67	305.0	78.5
T_8: 0.5% 19:19:19 + 0.2% MN (10 DAS)	4.53	39.7	89.0	5.27	3.67	1.13	348.3	78.5
T_9: 0.5% 19:19:19 + 0.2% MN (25 DAS)	4.70	47.5	91.4	5.23	3.80	1.07	367.3	80.2
T_{10}: 0.5% 19:19:19 + 0.2% MN (35 DAS)	4.60	54.0	93.1	5.63	3.80	1.17	616.6	85.2
T_{11}: 0.5% 19:19:19 + 0.2% MN (45 DAS)	5.63	50.8	89.7	6.83	3.97	1.50	563.3	88.5
T_{12}: 0.5% 19:19:19 + 0.2% MN (10, 25, 35 and 45 DAS)	7.73	92.2	95.7	7.57	4.20	0.18	1266.6	95.5
SE	2.14	1.6	2.5	0.26	0.07	0.25	17.5	2.2
C.D. at 5%	1.52	4.8	0.6	0.76	0.22	0.77	51.3	1.3

Note: DAP: Di Ammonium Phosphate; MAP: Mono Ammonium Phosphate; MN: Chelated Micronutrient Mixture

***Effects of foliar application of macro nutrients (N, P and N, P, K) at flowering stage of rice fallow green gram*:** 2 .0% DAP (T_2) was sprayed on 35 days at flowering initiation phase. Spraying of 2.0% DAP recorded the seed yield of 237.23 kg/ha. Preparation of DAP spray is always difficult and time consuming. Hence, spraying of 0.5% MAP and 0.5% 19:19:19 was tried, as they were readily soluble in water. DAP spraying sometimes cause phytotoxicity if there is any sedimentation or air drift. 0.5% MAP(T_3) recorded the seed yield of 291.67 kg/ha. Seed yield of 0.5% MAP foliar spraying is slightly higher than the 2.0% DAP, as it may due to the higher P content in its contents. Whereas 0.5% 19:19:19(T_4) recorded the seed yield of 331.67 kg/ha which was higher than 0.5% MAP (T_3). It is assumed that balanced proportion of N, P, K in its contents improved the number of pods (32.6) as well as number of seeds per pod (5.33) compared to 2.0% DAP (20.97, 5.0) and 0.5% MAP (31.67, 4.97). In a research study, 2 rounds of foliar spraying of 2.0% DAP combined with 0.05% Sodium molybdate and 100 ppm salicylic acid on 30 DAS and 45 DAS on green gram recorded the grain yield of 928 kg/ha (25). In an irrigated green gram experiment conducted with foliar spraying of combination of 1% TNAU pulse wonder + 3% seaweed extract + 2% humic and fulvic acid along with RDF (Recommended dose of fertilizer) on 30 and 45 DAS enhanced the seed yield up to 1583 kg/ha in the variety, VBN-4. The combined effects of macro and micronutrients of TNAU pulse wonder and bio stimulants like seaweed extract, humic and fulvic acid enhanced the yield of green gram under irrigated conditions (26). All these studies combined both RDF and foliar spraying of nutrients to enhance the yield. Hence, naturally the green gram must be having normal growth and foliar spraying altered the C: N ratio for flower induction followed by pod setting, seed filling and seed yield.

***Effects of Single foliar spraying of combination of 0.2% MN mixture and 0.5% 19:19:19on 10, 25, 35 and 45 DAS* :** Foliar spraying of chelated MN mixture along with 0.5% 19:19:19 on 10 DAS (T_7) of rice fallow green gram recorded the following growth and seed yield parameters; plant height: 38.2 cm, number of branches:5.63, number of leaves: 41.53, number of yellow leaves: 2.03, number of flowers per plant: 44.63, number of clusters: 12.07, number of pods per cluster: 4.53, number of pods per plant: 39.73, pod setting percentage: 89.02%, number of seeds per pod: 5.27, 100 seed weight: 3.67, hard seed percentage: 1.13%, seed yield: 348.33 kg/ha and seed recovery percentage: 78.54%. Seed yield was higher than single spraying of 0.2% micro nutrient mixture on (T_5) on 10 DAS.

***Effects of foliar spraying of combination of 0.5% 19:19:19 and 0.2 % MN mixture on 45 DAS*:** Foliar spraying of chelated MN mixture along with 0.5% 19:19:19 on 45 DAS (T_{11}) of rice fallow green gram recorded the following growth and seed yield parameters; plant height: 28.6 cm, number of branches: 4.87, number of leaves: 34.3, number of yellow leaves: 5.3, number of flowers per plant: 31.67, number of clusters: 7.5, number of pods per cluster: 3.93, number of pods per plant: 24.40, pod setting percentage: 77.4 %, number of seeds per pod: 4.47, 100 seed weight: 3.2, hard seed percentage: 2.67%, seed yield: 305.0 kg/ha and seed recovery percentage: 78.5%. There was slight increase in yield in the treatment (T_{11}) sprayed with combination of micro and macro nutrients on 45 DAS.

***Effects of four times foliar spraying of combination of 0.2% MN mixture and 0.5% 19:19:19 on 10, 25, 35 and 45 DAS*:** In treatment (T_{12}) with four times foliar spraying of chelated MN mixture along with 0.5% 19:19:19 on 10, 25, 35 and 45 DAS of rice fallow green gram recorded the following growth and seed yield parameters; plant height: 67.97cm, number of branches: 10.5, number of leaves: 62.63, number of yellow leaves: 1.47, number of flowers per plant: 96.33, number of clusters: 20.47, number of pods per cluster: 7.73, number of pods per plant: 92.2, pod setting percentage: 95.71%, number of seeds per pod: 7.57, 100 seed weight: 4.2, hard seed percentage: 0.18 %, seed yield: kg/ha and seed recovery percentage: 95.52 % . Four times spraying of 0.2% chelated MN mixtures along with 0.5% water soluble N, P, K during 4 different growth stages from seedling phase, active vegetative phase, flowering phase and pod setting phase recorded the seed yield of 1266.67 kg/ha.

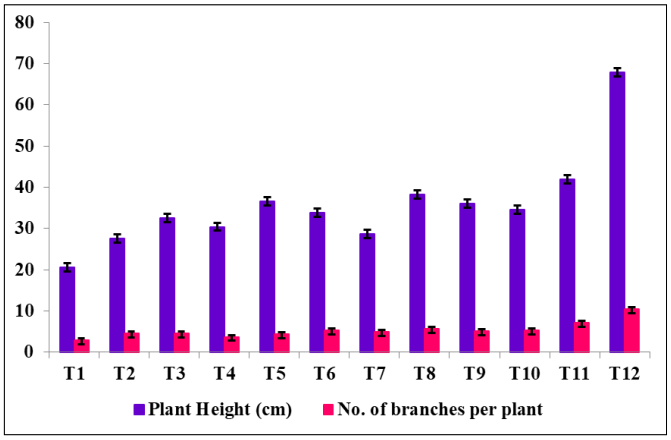

Fig. 1. Enhancement of growth parameters in rice fallow green gram by the application of combinations of micro and macro nutrients.

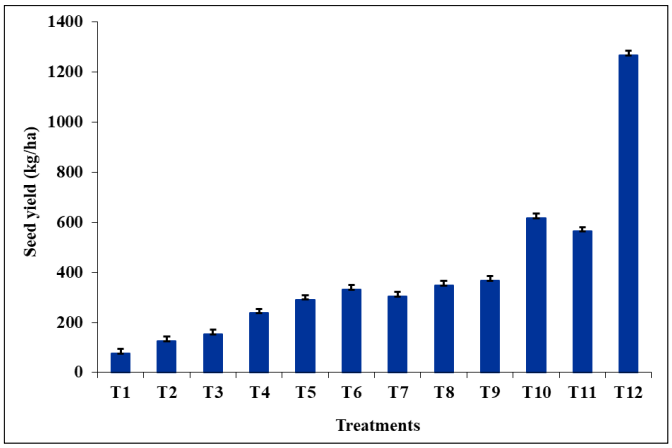

Fig. 3. Enhancement of seed yield in rice fallow green gram by the application of combinations of micro and macro nutrients.

Discussion

In the present study of rice fallow green gram, soil application of nutrients was not feasible due to the relay cropping system. Instead, foliar sprays of micro- and macronutrients during the seedling and active vegetative phases enhanced vegetative growth. Additional foliar sprays during flowering and pod formation phases improved the seed yield by optimizing source –sink dynamics. All the nutrients present in the soil of experiment plots are in deficient levels. Spraying of 0.05% Molybdenum on summer green gram at 2 intervals during pre-flowering and pod development stages recorded the seed yield of 1226 kg/ha in summer green gram variety, Samrat. (27). Molybdenum application has been shown to enhance pod formation, seed filling, leading to increased seed yields. In the present study, treatment T_{12} significantly reduced the percentage hard seeds, a common issue in rice fallow pulses during the summer season caused by water stress. Hard seeds though viable, exhibit delayed germination, which adversely affects seed recovery rates (23). There were no published reports on foliar spraying of micro and macro nutrients on rice fallow green gram so far. In a research study, 2 rounds of foliar spraying of 2.0% DAP combined with 0.05% Sodium molybdate and 100 ppm salicylic acid on 30 DAS and 45 DAS on green gram recorded the grain yield of 928 kg/ha (26). In an irrigated green gram experiment conducted with foliar spraying of combination of 1% TNAU pulse wonder + 3% seaweed extract + 2% humic and fulvic acid along with RDF (Recommended dose of fertilizer) on 30

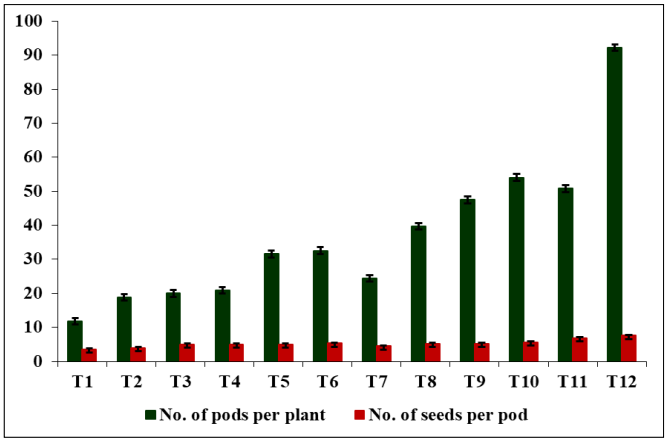

Fig. 2. Enhancement of seed yield parameters in rice fallow green gram by the application of combinations of micro and macro nutrients.

and 45 DAS enhanced the seed yield up to 1583 kg/ha in the variety, VBN-4. The combined effects of macro and micronutrients of TNAU pulse wonder and bio stimulants like seaweed extract, humic and fulvic acid enhanced the yield of green gram under irrigated conditions (26). All these studies combined both RDF and foliar spraying of nutrients to enhance the yield. Foliar spraying of 0.5% KNO_3 on 15 and 30 DAS recorded the yield of 880 kg/ ha on summer green gram variety, CO 8 (12). In the present study of rice fallow green gram, soil application of RDF was not carried out and the experiment plots were deficient in both macro and micro nutrients. Balanced application of micro and macro nutrients through foliar mode resulted in higher yield compared to all other treatments. For vigorous seedling growth, both micro and macro nutrients are essential which would result in faster growth. During active vegetative phase, sufficient uptake of macro and micronutrients required for the vegetative growth enabled the rice fallow green gram to grow actively which were evident by the following parameters viz., plant height, number of branches and number of leaves. Spraying of macro and micronutrients in combination during flowering phase increased the number of flowers and also increased pod setting percentage. During pod formation stage, application of combination of macro and micronutrients increased the number of clusters, number of pods per clusters, number of pods per plant, number of seeds per pod and 100 seed weight. There is drastic reduction in hard seeds percentage and increase in the seed recovery percentage. Combined application of compatible micro and macro nutrients through foliar mode four critical stages of growth rice fallow green gram systematically improved the vegetative and reproductive growth which resulted in increased pod set, 100 seed weight, seed yield and seed recovery percentage. In summer green gram, with recommended dose of fertilizer combined with 2.0% DAP spraying on 20 and 40 days recorded the seed yield of 845 kg/ha (28). It is a routine protocol to spray 2.0% DAP on flower initiation and pod formation stage to increase the yield of pulses. But the early vegetative phase growth was supported by the soil applied RDF. Similar results were obtained with foliar spraying of 1.5% MAP, 1.5% 19:19:19 and 2.0% DAP along with RDF in summer green gram. There were no differences between the foliar spraying treatments (29).

Similar study with foliar spraying of 2.0% DAP along with RDF recorded yield of 830 kg/ha in green gram (30). Application of 1% MAP and 19:19:19 along with RDF recorded the seed yield of 1038 kg/ ha in kharif green gram (31). Rice fallow green gram cultivation is a unique cropping pattern in Cauvery Delta Zone of Tamil Nadu. The cultivation aspects are changing due to several factors like climate patterns, lack of human labourer, poor productivity and unstable income. Rice cultivation is mechanized intensively in CDZ. Combined harvesters are routinely used to harvest and thresh the paddy grains simultaneously. Hence, the field is allowed to dry completely without moisture to facilitate the easy movements of heavy machine and also to speed up synchronous maturity of grains to prevent non threshing of grains. Complete drying of soils affected the yield and quality of rice fallow cultivation of green gram by forced water stress (32). Traditionally, green gram seeds were broadcast 7-10 days before manual paddy harvest, leveraging the residual soil moisture and canopy microclimate to promote germination and seedling elongation. The soil moistures and the canopy climate of paddy induce germinations of green gram and elongate the seedlings due to etiolations. After the harvest of paddy, the sprouts will grow faster and smother the soil surface with their canopy facilitating arresting weeds growth during and promoting the development of rice fallow green gram. Due to mechanical harvest, the soil is completely dried and exposed to hot sun during February-March. Hence, farmers after the harvest irrigate the paddy harvested fields by flooding and under waxy soil conditions, green gram seeds are dibbled manually. But the growth and development are not similar to the typical rice- green gram relay cropping as rice fallow (32). It may be due to changes in the physical, chemical and microbial properties of soil due to drying of soils followed by flooding and dibbling. Changes in soil properties affect the uptake of nutrients and water which influence the growth and development. It is highly essential to restore the rice fallow cultivation of pulses in rice cropping areas like Cauvery Delta Zone to minimize the detrimental effects caused due to excess fertilizers applications during paddy cultivation.

Conclusion

Rice fallow green gram cultivation of variety ADT 3 is a relay cropping method practiced with zero tillage which is affected by nutrient deficiencies causing poor yield. In this study, single spray of either micronutrient alone or macro nutrients alone during critical stages of growth found to be improving the yield to certain extend without attaining maximum yield. Because there is no alteration in source which has influence in sink. As a routine processes of foliar spraying of macro nutrients during flowering stage did not show higher yield. But combinations of micro and macro nutrients from four different growth stages viz., early vegetative phase, active vegetative phase, reproductive phase and pod formation phase altered the source sink imbalances and recorded maximum yield of 1266 kg/ ha against national average of 550 kg/ ha which is showing 130% yield increase under rice fallow conditions which can increase the income of the farmers. It is confirmed that four-time foliar spraying of combinations of micro and macro nutrients is highly economical by increasing the yields. The method is very simple and reproducible in larger scale level of seed production of rice fallow green gram, black gram and *Lathyrus* crops.

Acknowledgements

The authors acknowledge Agricultural Research Station, Pattukkottai, Tamil Nadu Agricultural University for providing financial support.

Authors' contributions

DM and CS have conceptualized the draft. GS and SM reviewed the literature, drafted manuscript. SK finalized the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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