PRODUCTIVITY ENHANCEMENT OF GREEN GRAM (*Vigna radiata* (L.) WILCZEK) UNDER SYSTEM OF CROP INTENSIFICATION (SCI)

By

KODURU SOWMYA

(2020-11-125)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM- 695 522

KERALA, INDIA

2022

DECLARATION

I, Koduru Sowmya (2020-11-125) hereby declare that the thesis entitled **"PRODUCTIVITY ENHANCEMENT OF GREEN GRAM (*Vigna radiata* (L.) WILCZEK) UNDER SYSTEM OF CROP INTENSIFICATION (SCI)"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other university or society.

Vellayani

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CERTIFICATE

Certified that the thesis entitled **"PRODUCTIVITY ENHANCEMENT OF GREEN GRAM (*Vigna radiata* (L.) WILCZEK) UNDER SYSTEM OF CROP INTENSIFICATION (SCI)"** is a record of research work done independently by **Ms. Koduru Sowmya** (2020-11-125) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associateship, or fellowship to her.

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ACKNOWLEDGEMENT

Thanks to Almighty 'GOD' and 'MOTHER EARTH' who are more benevolent and merciful made be capable to complete this task.

It is with great reverence I place on record, my deepest sense of gratitude and indebtedness to my major advisor ***Dr. Bindhu J.S.*** *Assistant Professor, Integrated farming system research station, Karamana, for her meticulous supervision, sincere suggestions, untiring help, parental support, and constant encouragement. I am eternally grateful for her kind assistance and dedicated involvement in my research work, without which I could not have completed thesis in time.*

With great pleasure I express my heartiest and esteem sense of gratitude to ***Dr. Shalini Pillai P****. Professor and Head, Department of Agronomy, College of Agriculture, Vellayani and a member of Advisory committee for her valuable suggestions, dazzling comments, wholehearted support, and timely help throughout the period of investigation during the period of endeavour.*

I am greatly indebted to ***Dr. Jacob D,*** *Assistant Professor and Head, AICRP-IFS, OFRC, Kayamkulam, and a member of Advisory committee, for the support, guidance, encouragement, and valuable suggestions in pursuit of the work.*

I humbly express my gratitude to ***Dr. Gladis R,*** *Associate Professor, Department of Soil Science and Agricultural Chemistry, Agricultural Research Station, Thiruvalla and a member of Advisory Committee for her constant encouragement, valuable suggestions, and continued support throughout my research work.*

I sincerely express my obligation and respect to all teachers of Department of Agronomy for their constant encouragement, support, and valuable advice.

A very special thanks to ***Ganesh chettan*** *and his family for their love and timely help.*

I am thankful to my classmates ***Ashish Koshy George, Bokka Navyashika, Gibi Mariam Thomas, Sajan Thomas, Anjali S, Harikrishna Sagar*** *and* ***Surendar*** *for their support and kind help in times of need.*

I acknowledge the boundless affection, unsolicited help, companionship, and moral support rendered by my friends, ***Samyukta Simhi, Arani Jyothi, Bhavya Musti, Joshna Vanam, Divina Matla, and Pallavi K.N****. I warmly remember their role in making the period of my study here a memorable and cherished one.*

Words were inadequate to express special thanks to my dearest friends, ***Bharath Pulipati*** *and* ***Vara Lakshmi Kale*** *who were there with my journey of bighearted support and for their unbounded love.*

Finally, I thank all those who extended helped and support to me in one way or another in the successful completion of this thesis work.

(**Koduru Sowmya)**

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation / Symbol	**Expansion**
%	Per cent
@	at the rate of
ºC	Degree Celsius
₹	Indian Rupee
BCR	Benefit cost ratio
CD (0.05)	Critical difference at 5% level
CGR	Crop growth rate
cm	Centimetre
cm^2	Square centimetre
DAP	Diammonium Phosphate
DAS	Days after sowing
DMP	Dry matter production
$dS\ m^{-1}$	Deci Siemens per metre
E	East
EC	Electrical conductivity
et al	Co-workers/ Co-authors
Fig.	Figure
g	Gram
g^{-1}	Per gram
$g\ plant^{-1}$	Gram per plant
ha^{-1}	Per hectare
K	Potassium
KAU	Kerala Agricultural University
KNO_3	Potassium nitrate
$kg\ ha^{-1}$	Kilogram per hectare

LAI	Leaf area index
m	Metre
m^{-2}	Per metre square
mL L^{-1}	Milli litre per litre
N	North
N	Nitrogen
NAR	Net assimilation rate
NS	Non-significant
No.	Number
P	Phosphorus
POP	Package of practices
pH	Potenz hydrogen
RGR	Relative growth rate
RDF	Recommended dose of fertilizer
RH	Relative humidity
SCI	System of crop intensification
SEm	Standard Error of mean
sp	Species
t ha^{-1}	Tonnes per hectare
viz.	Namely

INTRODUCTION

1. INTRODUCTION

Pulses, endowed with unique ability of nitrogen fixation constitute an important component of crop diversification and resource conservation in farming systems. The food legumes, particularly the grain or pulses are important food stuff in tropical and subtropical countries (Mohbe *et al*., 2015). Green gram [*Vigna radiata* (L.) Wilczek] is one of the thirteen food legumes grown in India and the third most important pulse crop after chickpea and pigeon pea.

Green gram is one of the important pulse crops and a drought resistant crop, suitable for summer fallows of Kerala. Though have multifarious advantages, productivity of green gram is declining year by year due to various reasons. There is a need for enhancing the productivity of this crop by adopting low-cost production technologies.

Adoption of system of crop intensification (SCI) practices in green gram may enhance the productivity and reduce the gap between per capita availability and consumption and enhancing the resource use efficiency of the farming system. SCI is an agricultural production strategy that seeks to increase and optimize the benefits that can be derived from making better use of available resources: soil, water, seeds, nutrients, solar radiation, and air. It includes ecosystem services taking full account of the factors and interactions of time and space so that field operations are conducted in a timely way (Garbach *et al.,* 2017). For pulses like system of rice intensification (SRI), SCI methods are also relevant which are resource limited, nutritionally vulnerable households as it relies minimally on purchased inputs. System of crop intensification practices enable the crop to grow and develop potentially which provides enhanced production in sustainable and eco-friendly manner (Sowmya *et al.,* 2022).

System of crop intensification approach seeks not just to get more output from a given amount of inputs, but aims to achieve higher output with less use of or less expenditure on land, labour, capital, and water by making modifications in crop management practices (Uphoff *et al.*, 2011). SCI has emerged as a next generation agroecological innovation. SCI principles and practices build upon the productive potentials that derive from plants having larger, more efficient, longer-lived root systems and from their symbiotic relationships with a more abundant, diverse, and active soil biota.

Large areas are left fallow after the harvest of rice in India. These summer fallows are effectively utilised for crop intensification and diversification. Integrating the two core principles of SCI *i.e.,* spacing, and foliar nutrition, pulse crops can be raised effectively with minimum resources because of their uniqueness of nitrogen fixation, deep extensive root system, low crop water requirement and ability to withstand drought.

Performance of each crop plant is significantly influenced by the pattern of planting. The mean rectangularity, or the ratio of the distance between plants within a row to the distance between rows, has been applied to measure spatial arrangement. Mean population yield rather than individual plant yield within the population has been used to quantify the influence of rectangularity (Fanish and Raghavan, 2020). Foliar spray of nutrients is a well-established tool to complete and to enrich plant nutrition. Many experimental findings proved that foliar application of nutrients increased the growth, better utilization of nutrients, yield attributes and yield in different pulse crops (Yeshwanth, 2020).

Considering the inadequate adoption of production technology that led to low productivity of pulses, various alternatives were considered over the conventional cultivation practices. In pursuit of extending the beneficial effects of SCI, a field study is proposed under system of crop intensification with the following objectives:

Standardization of plant population and assessment of foliar nutrition for enhancing the productivity of green gram in summer fallows through a system of crop intensification.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

An experiment entitled “Productivity enhancement of green gram (*Vigna radiata* (L.) Wilczek) under system of crop intensification (SCI)” was undertaken with the objective of standardization of plant population and assessment of foliar nutrition for enhancing the productivity of green gram under system of crop intensification. Studies on green gram under different methods of spacing by following foliar application of nutrients to enhance productivity were reviewed and presented in this chapter.

2.1 ROLE OF PULSES IN CROPPING SYSTEM

Pulses are basic for a sustainable crop production system endowed with unique ability of nitrogen fixation, which forms an important component of crop diversification and resource conservation in farming systems. These crops fix atmospheric nitrogen for their growth, minimising the need for an external source of nitrogen, but also for their residual effect. They are appropriately termed as mini nitrogen-factories (Singh, 2018). Pulses are a cover crop that significantly increases the rates at which soil carbon accumulates compared to cereals or grasses. Pulses-inclusive crop rotations also have a larger potential for sequestering soil carbon (C) than monocrop systems.

In India rice-wheat cropping system occupies almost 10.5 million hectares, contributing 75 per cent to the national food basket. However, practicing intensive rice-wheat rotation over time leads to lower input use efficiencies, soil heath degradation, receding groundwater table and declining factor productivity. Therefore, crop intensification in the existing system with lower input demanding crop such as pulses is needed for sustaining food security and minimizing overexploitation of natural resources (Rai and Biswakarma, 2021).

Green gram showed the greatest improvement in system productivity among summer legumes, followed by fodder cowpea and black gram (Kumar *et al.*

2012). Green gram inclusion in the crop rotation system has diversified and strengthened the cropping system, alleviated the ill effects of the cereal predominant cropping sequence, and increased soil productivity. It also increased paddy yields and farmer income (Weinberger, 2003).

2.2 SYSTEM OF CROP INTENSIFICATION IN PULSES

Crop intensification system is an agroecological strategy which is improving the crop productivity are now being extended to many crops such as rice, wheat, legumes, sugarcane, mustard etc., SCI is a four-pronged approach that is implemented systematically, in the case of poor soils. It involves soil management and preparation, plant geometry, systematic application of locally produced organic inputs, and foliar applications of nutrients. All these techniques strive to improve crop, soil, water, and crop nutrition over conventional methods in order to increase productivity, profitability, sustainability, food security, and resilience to climate change. It includes ecosystem services that takes full account of time and space factors and interactions so that all field operations are conducted in a timely way (Garbach *et al*., 2017). SCI approach seeks to get more output from a given amount of inputs, with less expenditure on inputs by making modifications in crop management practices (Uphoff *et al*., 2011).

2.2.1 Effect of Plant Geometry on Productivity of Green gram

Pulse crops are grown under diversified agro-ecologies with reasonable external inputs and residual soil moisture, various environmental factors also influence the crop performance in terms of growth, yield and quality. These includes the atmospheric and edaphic factors. Atmospheric factors such as rainfall and light intensity together with edaphic factors such as soil moisture and availability of nutrients influence the crop physiological development thus indirectly influencing the crop growth and productivity.

Production and productivity of the crop is controlled by environmental factors, genotypic features, and management of the crop. Therefore, determining an appropriate crop density is a key initiative to enhance plant performance and productivity (Shiferaw *et al.,* 2018). Optimal spacing helps in the effective utilisation of the growth resources, especially solar radiation as compared to narrow spacing, where plants might have suffered due to shading effects in case of neighbouring rows and more plants. Reducing plant density significantly gives each plant more room to grow both above and below ground.

System of crop intensification (SCI) aims to reduce crop density per acre based on plant type and variety. Reducing crop density per acre by maintaining a specific distance between the plants ensures that adequate natural resources is available per plant, resulting in better crop growth and optimum yield. Healthier plants have stronger "immune and response systems" aid in the production of "phytochemicals," which naturally helps in plant development and shield the plant from environmental stresses (WOTR, 2013).

Amrutha *et al.* (2015) results showed that wider spacing flowered earlier and matured earlier than in closer spacing. It could be attributed to better vegetative growth, plant canopy area, and efficient photosynthetic activity, which may have boosted the reproductive phase in wider spacing instead of closer spacing. The key agronomic management variables that can alter the dynamics of leaf area development, which in turn affects radiation absorption, biomass accumulation, and grain yield, are plant densities and row spacing (Hammer *et al.,* 2014).

Sathiyavani *et al.* (2016) stated that green gram when planted at 25 cm × 25 cm with one seed per hill registered higher grain yield with maximum net income and benefit cost ratio. In comparison to reduced spacing, where plants may have affected due to shading in adjacent rows and more plants, optimum spacing might have smartly utilised the natural resources, notably solar radiation. Green gram can be successfully cultivated in rice fallows with maximum yield and profit, thus helps in strengthening the system's yield and economics (Behera *et al*., 2014).

Maintaining plant population at an optimum level plays a crucial role in crop growth and development, by effective utilisation of moisture, nutrients, and available space (Panwar and Sharma, 2004). Sonboir *et al*. (2019) reported that system of chickpea intensification practices produced higher yield of chickpea compared to traditional crop management practices which may be due to wider spacing and nipping practice.

System of crop intensification in soybean and lentil is achieved through practices of direct seeding, wider and regular spacing of 30 cm x 30 cm by sowing 1-2 seeds hill^{-1}, with two manual weeding and with the application of panchagavya, amritghol and matka khad (PSI, 2009).

Ammaiyappan *et al*. (2021) reported that in red gram by maintaining optimum plant population and modification of canopy architecture by nipping at 45th day recorded maximum seed yield, haulm yield, harvest index and protein yield under rainfed condition.

Hangsing *et al.* (2020) results revealed that in green gram spacing of 30 cm x 10 cm recorded taller plants, no. of leaves, shoot dry weight, LAI, and yield attributes such as pods plant^{-1}, pod length, seed yield and stover yield respectively over other spacing treatments.

Kadam and Kanvilkar (2015) reported that in green gram, height of plants was affected under spacing of 30 cm x 15 cm over other spacings. The wider spacing produced a greater number of branches with functional leaves, greater spread, and more aerial biomass production plant^{-1} over other spacings.

Lawn (1983) reported that row spacing and plant density have been recognised as significant agronomic management techniques that can be utilised to modify the canopy radiation environment under non-limiting conditions. High plant densities and narrow rows have an impact on the crop's radiation environment, which improves radiation interception, biomass production, and potential yield.

Bindhu *et al.* (2014) reported that raising of sesame and black gram in 1:1 ratio can be advised as a viable, ecologically suitable and intensified system for summer rice fallows of the Onattukara tract. The advantage of using legumes in crop diversification helps in increasing the soil nitrogen content, which in turn may be available to crops grown either in the same season or in succeeding season.

A crop's maximum yield can be achieved in a particular environment when planted at a spacing with minimal interplant competition. Optimum spacing, not only allows plants to use soil moisture and nutrients more efficiently but also prevents excessive plant competition. However, yield cannot be enhanced by reducing or increasing row spacing after a certain point. Hence, optimum spacing encourages the plant to produce its maximum yield. Tripathi (2019) indicated that in chick pea, yield contributing parameters were maximum at optimum spacing than over closer row spacing. This is because of effective utilization of nutrient, moisture and solar radiation at wider row spacing than at narrow row spacing.

2.3 WEED MANAGEMENT UNDER SCI

Weeds cause considerable yield losses in green gram, which can range from 40 to 68 per cent (Tamang *et al.,* 2015). Due to the initial slow stature of green gram weeds, appears faster and have more advantage over the crop which exert a dominant effect on the crop. Among the various cultural practice’s choice of crop species, plant population, crop geometry, inter cropping and crop nutrition have profound effect on weed suppression. Increasing crop densities by adjusting plant population effectively reduces the niches available to weeds and lowered the weed density which has more impact in enhancing grain yield by conserving soil moisture, nutrients, and sun light helps in improving soil health. Thus, crop geometry had a major role in non-chemical weed management. Crop geometry of 25 and 50 cm have reduced weed dry matter when compared to wider spacing of 75 cm, when the field is kept weed free upto 30 DAS (Chauhan *et al.,* 2017). In order to maximize seed yield and quality weed management in pulses is crucial to bring down the weeds below threshold level.

In India more than 70 per cent area of pulses is covered under intercropping systems. Pulses promote crop canopy and suppress weeds when intercropped with oilseeds, cereals, coarse grains, and commercial crops, and acts as companion crops by supplementing nitrogen. In intercropping system short duration legumes such as cowpea, black gram and green gram significantly suppressed the weed flora. Cowpea (45.8%) has the highest weed suppression ability followed by green gram (41.5%) and black gram (38.2%). Crops are free from weeds under closer spacing due to availability of less space, light and nutrients for their germination and growth (Yadav *et al.,* 2017).

Strydhorst *et al*. (2008) reported that in faba bean and pea, weed biomass was decreased to 53 and 59 per cent, respectively when the pulse planting density increased from 0.5 to 2.0 times. Various studies have revealed that increased crop density resulted in greater weed suppression (Mohler, 1996).

The germination and growth of weeds will be different under different planting methods. Hence, selection of suitable planting method helps to eliminate weeds to a certain extent. Aslam *et al.* (2007) reported that, flat method of planting recorded significantly less weed population and biomass resulting in 14 per cent yield enhancement in chick pea compared to ridge method. Wider spacing in ridge sowing intercept more solar radiation which will stimulate the luxurious growth of weeds resulted in higher weed biomass.

Intercropping found to suppress the weeds through the formation of good crop cover. Ali (1988) observed that an inclusion of short duration quick growing crops in between the inter-row spaces of long duration tall growing crops suppress the weeds and resulted in significant reduction in cost of weeding. Due to delayed initial development and broader spacing, weed infestation was severe in pigeon pea (Channappagoudar and Biradar, 2007). Talnikar *et al*. (2008) revealed that if weeds were not controlled up to harvest 79.9 per cent yield reduction was observed in pigeon pea. However, soybean was intercropped with pigeon pea, the yield reduction was recorded only 38.2 per cent.

2.4 NUTRIENT MANAGEMENT IN PULSES

Pulses raised under rainfed conditions in marginal lands and in soils of poor growing condition in contrast to cereal crops, which have conventionally cultivated in more productive soils with reliable irrigation supplies. Despite being energy-rich crops, pulses are usually cultivated in energy-starved situations with sparse applications of different sources of fertilisers, which leads to nutritional imbalances and decreased productivity of pulses. Using legumes in crop rotations to enhanced soil nutrient content and crop production is one of the oldest agricultural management practices. According to Porpavai *et al.* (2011), the use of legumes in rice-based cropping systems enhanced rice crop yields and resulted in maximum organic carbon build up. Pulses specifically require sufficient amounts of P, secondary nutrients and Mo, out of the 16 necessary elements. A small amount of 15-20 kg N ha^{-1} is sufficient to meet the demand for most pulse crops because the inbuilt biological nitrogen fixation system enables pulse crops to meet 80–90% of nitrogen requirements. Phosphorus was the second most crucial plant nutrient, but for pulses it presumes to be of primary importance because of its important role in root growth and thereby nitrogen metabolism. Azeez and Adetunji, (2008) reported the increased yield of soybean with supply of nitrogen and phosphorus individually or in combination as the nutrient application significantly improved the uptake of potassium, magnesium, calcium, and sulphur. Potassium application regulates the utilization of other nutrients in the plant system. Sulphur deficiency is more pronounced for pulse crops than for cereals due to higher need for former in producing grain. Under conditions of nutrient deficiency, pulse crops respond positively to the use of micronutrients like Zn, B, Mo, and Fe. Introducing organic manures in addition to fertilisers is crucial for maintaining soil fertility, health, and biological activity.

2.4.1 Role of Foliar Nutrition in Enhancing the Productivity of Pulses

Pulses are diverse and important major crops which play a major role in sustainable agriculture. However, sometimes nutrient uptake from soil is difficult due to physiological stresses such as drought, excessive moisture, inadequate soil pH and low temperature. During summer, plant root systems are not able to absorb nutrients from the soil due to insufficient moisture as well as drought, thus effecting the healthy growth of crop both in a quantitative and qualitative sense. Foliar fertilizers are completely soluble in water and needed nutrients are fast delivered to plants in the form of foliar fertilization during the growing season. The foliar application of different nutrients can variably increase the production and productivity and is considered as the very effective and economic method to overcome plant nutrient deficiency. It is also one of the fastest ways to boost the crop growth. Foliar application of various nutrients is more useful and advantageous than soil nutrient application as it will eliminate leaching and fixation of nutrients.

Active nodulation of any pulse crop ceases 45-50 days after sowing, and for legume plants, leaf senescence begins earlier before maturity thus breaking the source-sink relationship ultimately resulting in reduced yield. Under such circumstances if nutrients are supplied *via* foliar spray is reported to have advantageous effects in improving growth, seed yield and quality parameters (Bhavya *et al.*, 2020).

To boost the productivity of green gram, application of optimum dose of mineral nutrients especially in the form of foliar application has added advantage of speedy and better utilization of nutrients (Kulkarni *et al*. 2015). Saren *et al.* (2017) observed that productivity of green gram is directly correlated with the uptake of nutrients. The study also revealed that the mean yield of grain ranged from 5.7 kg ha^{-1} in lowest fertility gradient to 10.6 kg ha^{-1} in the highest fertility gradient strip.

Manonmani and Srimathi (2009) reported that foliar nutrition was found to be 20 times more effective than soil-applied fertilisers in increasing black gram output as foliar nutrition increased the yield from 12 to 25 per cent. Foliar application of urea at 2 per cent showed an increased plant height (20.24 cm) and DMP (4.22 g plant^{-1}) in green gram (Naidu *et al*., 2015).

Bahadari *et al*. (2020) revealed that the best method for increasing green gram growth, productivity, profitability, production, and economic efficiency was three times foliar application of 2 per cent urea at pre flowering, flowering, and pod development stages (40, 50, and 60 DAS). Foliar application is one of the advancements that provides a successful and economical way to supplement the nutrient requirements during critical stages in green gram.

Nitrogen is an essential and basic macronutrient for plants. It is a component of protoplasm as well as protein. Nitrogen is associated with photosynthetic activity and plays an important role in the production of vegetative biomass. Wagan *et al*. (2017) found that N supplementation through foliage is more appropriate than soil application because it allows for a rapid and efficient transportation of N to the grain. Dey *et al.* (2017) found that in cowpea foliar application of nutrients *viz.*, urea (2%), KCL (2%), $ZnSO_4$ (1.5%) at 15 and 30 DAS recorded significant increase in growth and yield attributes.

According to Dass and Jana (2015), the application of urea (2%) spray followed by NPK (19-19-19) (2%) nutrient spray was the best combination over basal dose fertiliser application for improving seed yield of most of the pulse crops.

Senthilkumar *et al.* (2008) stated that application of urea (1%) through foliar in black gram at 35 and 55 days after sowing was superior in terms of growth parameters such as plant height and number of leaves. Tahir *et al.* (2014) indicated that when (2% DAP + 1% K) was given as foliar spray, the highest protein content (23.80%) was reported in black gram.

Ramesh *et al.* (2007) reported that with foliar nutrition of DAP @ 2 per cent twice (pre-flowering + blooming) in rice fallow pulses have the maximum reproductive efficiency and grain output. In green gram, black gram, cowpea and horse gram, foliar treatment of DAP (2%) dramatically enhanced plant height and the number of branches per plant (Maheswari *et al.*, 2017). Dixit and Elamathi (2007) opined that application of DAP through foliar spray produced the greatest number of nodules in green gram.

The foliar application of phosphorous in the form of DAP eliminates fixation of insoluble triphosphates in soil. Generally, 2 per cent foliar application of DAP is recommended to prevent flower drop and better seed set in green gram (Sivakumar *et al*., 2019). Singh *et al*. (2020) indicated that in chickpea application of 75 per cent RDF + foliar application of DAP (2%) + Urea (2%) + water soluble fertilizers (2%) at 60 DAS and 80 DAS gave higher growth and yield attributes followed by application of 75 per cent RDF + foliar application of water-soluble fertilizer (2%) at 60 DAS and 80 DAS.

According to Kuttimani and Velayutham (2011), application of DAP (2%) + salicylic acid (100 ppm) + 0.05% sodium molybdate improved the nitrogen, phosphorus, and potassium uptake in green gram. Manjunatha *et al*. (2022) stated that irrigating the red gram crop twice at pre-flowering and pod development stages along with nipping practice, pulse magic (1%), and 19:19:19 NPK (1 %) foliar spray at flowering and 15 days after first flowering recorded higher yield attributes and yield.

Marimuthu and Surendran (2015) indicated that NPK (100% RDF) + DAP (2%) + TNAU pulse wonder application at 5.0 kg ha^{-1} on 45 DAS can be advised as a nutrient management method for improving the productivity of black gram. During the flower initiation and pod development stages, foliar spray of macronutrients, together with soil application of micronutrients, helps the plant to retain flowers (Chaurasia *et al.*, 2005).

Foliar application of N in the form of urea considerably increased the production of total dry matter and yield while also expressing higher values of physiological parameters such as LAI, CGR, NAR, and SLW (Surendar *et al*., 2013). Sritharan *et al.* (2005) found that foliar application of DAP (2%) and urea (2%) along with micronutrients twice significantly increased the physiological parameters such as LAI, CGR and DMP in black gram. Meena *et al.* (2017) evaluated the effect of foliar nutrition on black gram and stated that highest biological yield and economic returns was recorded with foliar spray of urea (2%), SSP (2%), zinc EDTA (0.1%) and B (0.2%).

According to Rambilash *et al*. (2012), the row spacing variedly improved the plant height, DMP, RGR, CGR, and NAR at all recorded crop growth stages, leading to improved productivity in green gram. Under 30 cm of row spacing, the highest CGR, RGR, and NAR values were noted, followed by 25 cm and 20 cm. DAP (2%) spraying produced the highest CGR and NAR among the foliar treatments, followed by urea (2%) and KNO_3 (0.5%). DAP (2%) recorded the highest RGR when sprayed, followed by KNO_3 (0.5%) and urea (2%). Gautam (2020) observed the highest RGR at 45-60 DAS in black gram with the foliar application of urea + salicylic acid at 50 ppm.

The minimal farm input and operational requirements in rice and pulse (lentil and lathyrus) rotations resulted in improved economics and energy use efficiency, enabling a viable strategy for including these crops in fallows of rice, where farmers, have low socio-economic status. Kumar *et al*. (2019) reported that among the cropping various systems, rotation with legumes (rice-lathyrus: 1.84 kg ha^{-1} $year^{-1}$, rice-lentil: 1.83 kg ha^{-1} $year^{-1}$ and rice-chickpea:1.84 kg ha^{-1} $year^{-1}$) had lower N_2O emission compared to oil seed inclusive rotations (rice-mustard and rice-linseed of 2.15 kg ha^{-1} $year^{-1}$).

Rao (2013) reported that in black gram foliar application of KNO_3 (1%) produced higher plant height. Vekria *et al.* (2013) reported that foliar nutrition with potassium nitrate in green gram showed promising impacts on growth and yield and was found to be the most effective osmo-protectants in recovering yield losses. Application of potassium seemed to overcome the adverse effects of salt stress and to improve the morphological parameters, yield and yield attributes of green gram grown under salt stress (Rahman *et al.*, 2017). Zanje (2015) reported that soybean plants performed superiorly with foliar application of KNO_3 (2%) and showed higher haulm yield of 26.52 q ha^{-1}.

According to multi-locational research carried out under cereal-based cropping systems, high K demands of crops are linked to high soil K extraction rates, which could result in diminishing K fertility unless replaced from external sources (Singh *et al.*, 2021). Zanje (2015) reported that foliar spray of KNO_3 (2%) improved the NPK soil nutrient status after the experiment when applied at 30 and 45 DAS.

Foliar spray of KNO_3 (0.5%) + DAP (2%) + micronutrient spray along with soil application of NPK (100 % RDF) increased the pods $plant^{-1}$, improved quality parameters like seed protein content and seed total free amino acid content. This might be due to the foliar application of higher concentration of multi nutrients at critical growth stages which increased the growth and yield parameters (Neethu and Kaleeswari, 2018).

Laishram *et al.* (2020) reported that foliar application of KNO_3 (2.0 %) significantly increased the growth attributes *viz.*, plant height, branches $plant^{-1}$, fresh and dry weight of lentil at all the recorded crop growth stages except at 30 DAS. Yield attributes such as pods $plant^{-1}$, seeds pod^{-1} and yield of lentil increased significantly by application of KNO_3 (1.5%). Salicylic acid (200 ppm) and KNO_3 (1.5%) combination gave the maximum system productivity.

Plants quickly and efficiently absorb nitrates at high rates because of greater mobility in soil. Applying N in the form of $NH_4(NO_3)$ or Ca $(NO_3)_2$ provides a speed supply of nutrient. Deotale *et al.* (2015) found that morpho-physiological and yield parameters *viz.*, plant height, leaf area, number of branches, dry matter, RGR, NAR, number of pods $plant^{-1}$, 100 seed weight, and yield $plant^{-1}$ are significantly influenced by foliar application of 0.5 per cent KNO_3 followed by 0.5 per cent Ca $(NO_3)_2$.

2.5 ECONOMICS OF SCI IN PULSES

Crop density have a major impact on the productivity of legumes, maintaining optimum space to individual plants is critical for realising the maximum yield potential during the summer season (Pandey *et al.*, 2022). Sathiyavani *et al.* (2016) reported higher economics in green gram when planted at 25 cm x 25 cm with 1 seedling per hill.

Sreemathi *et al*. (2019) reported that planting black gram at 30 cm x 15 cm with RDF (100%) coupled with foliar spray of TNAU pulse wonder (1.125 %) at flowering (50%) recorded higher yield attributes, yield and the highest profit. The seed yield was 29 per cent higher over other treatments.

Ali *et al.* (2016) observed that foliar application of 2.0 per cent WSF, followed by 1.5 per cent WSF during flowering and pod development stages showed higher economic returns. While no foliar application technique, or control, produced the lowest net returns (Rs. 27,113 ha^{-1})

Kumar *et al.* (2018) stated that treating black gram seeds with Mo and application of 2 per cent urea spray at the beginning of the bloom and 15 days later led to more seeds $plant^{-1}$, the highest production efficiency (9.52 kg ha^{-1} day^{-1}), and economic efficiency. This is due to adequate levels of major nutrients and the availability of molybdenum in the soil, the plant might be able to fix atmospheric nitrogen, which promoted the plant's growth and development and ultimately raised the production of black gram.

The dry matter portioning to grains during the pod filling phase and pod set are the two factors that impact grain yield in legumes like green gram (Geetika *et al.*, 2022). Keerthi *et al*. (2015) reported the higher grain production and economics in green gram with the application of RDF +12.5 t ha^{-1} of farm yard manure, and 25 kg zinc sulphate as basal and foliar application of potassium nitrate (1%) at flowering.

Malik *et al*. (2017) reported that a short fallow between two rice crops in a rotation can be successfully intensified with the inclusion of green vegetable pea. In comparison to the predominant cropping sequence (rice-fallow-rice), adding an additional crop enhanced farm productivity by 1.4 times and farm net income by four times.

Singh and Kirar (2016) stated that higher yield, net income, and B:C was found 15.2 q ha^{-1}, ₹ 29340, B: C ratio 1:2.5, respectively under transplanting of pigeon pea seedling as compared to farmers practices 9.6 q ha^{-1}, ₹ 15120, B:C ratio 1:1.96, respectively.

According to Shashikumar *et al.* (2013), applying recommended fertiliser dose and foliar application of naphthalene acetic acid (40 ppm) + chelated micronutrient (0.5%) + diammonium phosphate (2%) boosted productivity and economic returns in black gram. Athnere *et al.* (2021) stated that foliar spray of potassium nitrate (1%) at two stages (flowering and pod development) showed higher growth attributes, yield and economics in summer green gram.

According to Kuttimani and Velayutham (2011), applying DAP (2%) + salicylic acid (100 ppm) + sodium molybdate (0.05%) two times to the foliage of summer green gram was the most effective nutrient management strategy in terms of both gross and net returns. Soybean when supplied with foliar spray of DAP (2%) increased the gross return (₹ 36,500 ha^{-1}), net return (₹ 20,090 ha^{-1}) and B:C ratio (2.22) (Kumar *et al*., 2013).

Pande *et al*. (2011) reported that growing early-maturing chickpea in rice fallows with enough post-monsoon soil moisture had enhanced resource utilisation. The improved pulse production technologies were highly profitable and net returns were between 130-400 per cent with 30-100 per cent higher grain yields than either nothing or over farmers' practices.

Literature search unveiled the nutritional importance and climate resilience of green gram. Adoption of crop intensification practices in green gram enhances the productivity, resource use efficiency and ecological sustainability of the cropping system. System of crop intensification in the existing system with lower input demanding crop such as green gram is needed for sustaining food and nutritional security and minimizing over exploitation of natural resources in India.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was undertaken with the objectives of standardization of plant population and assessment of foliar nutrition for enhancing the productivity of green gram under system of crop intensification. The experiment was conducted during the period from February 2022 to May 2022 at farmer's field, Varkala.

The details of materials used and methods adopted for the study are described below.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the summer fallows of Chemmakurthy village, Varkala Block of Thiruvananthapuram district. The experimental field is located at 8° 43' 11'' N latitude and 76° 45'50'' E longitude and an altitude of 38 m above the mean sea level. The experimental area was under rice crop during the previous season.

3.1.1 Soil

Prior to the field experiment, a composite sample was taken from 0-15 cm depth and studied for its physico-chemical parameters. The analysed data are presented in the Table 1a and Table 1b. Rating was done as per the package of practices recommendations of the Kerala Agricultural University (KAU, 2016).

The soil of the experiment site was clay loam in texture, strongly acidic, high in organic carbon, medium in available nitrogen and potassium and high in available phosphorus.

3.1.2 Season and Climate

The experiment was conducted in summer fallow after the harvest of rice during February 2022 to May 2022. The data on weather parameters (monthly rainfall, number of rainy days per month, maximum temperature, minimum temperature, relative humidity, evaporation, and sunshine hours) during the cropping period. The data were tabulated based on the standard meteorological weeks and are presented in Appendix I and graphically in Fig.1

3.1.3 Cropping History of Experimental Site

The experimental site was previously utilized for raising a rice crop.

Table 1a. Mechanical composition and physical characteristics of the soil

Particulars	Value	Method adopted
A. Mechanical composition		
Sand	35.3	International pipette method (Piper, 1967)
Silt	35.1	
Clay	29.6	
Textural class	Clay loam	

Table 1b. Chemical characteristics of soil prior to experiment

S. No	Particulars	Value	Rating	Method adopted
1.	Soil reaction (pH)	5.5	Strongly acidic	pH meter with glass electrode (Jackson, 1973)
2.	Electrical conductivity (dS m^{-1})	0.18	Normal	Digital electric conductivity meter (Jackson, 1973)
3.	Organic C (%)	1.32	High	Walkley and Black rapid titration method (Jackson, 1973)
4.	Available N (kg ha^{-1})	328	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available P (kg ha^{-1})	71.2	High	Bray's colorimetric method (Jackson, 1973)
6.	Available K (kg ha^{-1})	188	Medium	Ammonium acetate method (Jackson, 1973)

3.2 MATERIALS

3.2.1 Crop and Variety

Green gram, cultivar CO 8 was chosen for the study. The important characters of the variety are given in Table 2.

Table 2. Important characters of green gram variety, CO 8

Cultivars	Salient features	Source of seed
Parentage	COGG 923 x VC 8040A	Tamil Nadu Agricultural University, Coimbatore
Maturity duration (days)	55-60	
Specific characters	Suitable for single/mechanical harvest. Moderately resistant to YMV and stem necrosis diseases, aphids, and stem fly	

3.2.2 Manures and Fertilizers

Farm Yard Manure @ 20 t ha^{-1} and lime @ 250 Kg ha^{-1} were applied as basal during land preparation. Urea, rajphos and muriate of potash were utilized as fertilisers which contained 46 per cent nitrogen, 20 per cent P_2O_5 and 60 per cent K_2O respectively.

3.3 METHODS

3.3.1 Experimental Design and Layout

Layout plan of the experiment is presented in Fig. 2.

Design	:	Split plot
Treatments	:	4 × 4
Replications	:	4
Plot size	:	3 m × 3 m
Season	:	Summer, 2021- 2022
Location	:	Summer fallows, Farmer’s field, Varkala

3.3.1.1 Treatments

***i. Main Plot Treatments* - Spacing (S) - 4**

S_1 - Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$

S_2 - Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$

S_3 - Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$

S_4 - Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$

***ii. Sub Plot Treatments* - Foliar nutrition (F) at 15 and 30 DAS**

F_1 - Urea @ 2%

F_2 - DAP @ 2%

F_3 - KNO_3 @ 0.5%

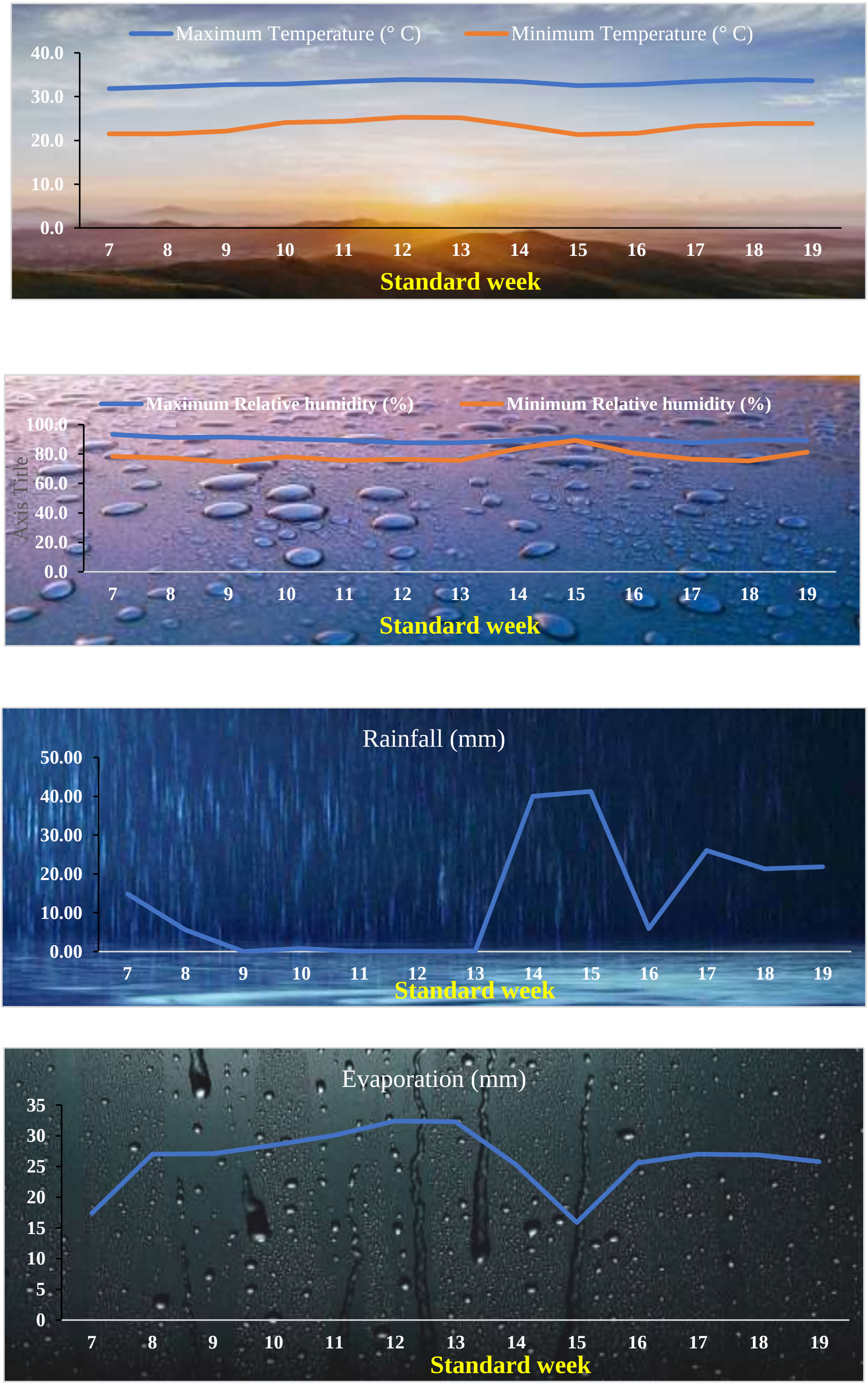
F_4 - DAP @ 2% + KNO_3 @ 0.5

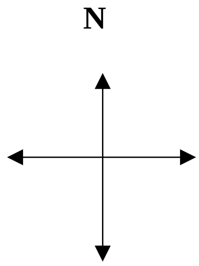
Note: Thinning of plants to maintain seedling number as one per hill and two per hill at 7 DAS

Treatment combinations 16 (4 x 4)

T_1 - S_1F_1	T_9 - S_3F_1
T_2 - S_1F_2	T_{10}- S_3F_2
T_3 - S_1F_3	T_{11}- S_3F_3
T_4 - S_1F_4	T_{12}- S_3F_4
T_5 - S_2F_1	T_{13}- S_4F_1
T_6 - S_2F_2	T_{14}- S_4F_2
T_7 - S_2F_3	T_{15}- S_4F_3
T_8 - S_2F_4	T_{16}- S_4F_4

Fig. 1 Weather data recorded during the crop period (February-2022 to May-2022)





Replication 1

S_1F_1	S_1F_2	S_1F_3	S_1F_4
$S_2 F_4$	$S_2 F_3$	$S_2 F_2$	$S_2 F_1$
$S_3 F_1$	$S_3 F_2$	$S_3 F_3$	$S_3 F_4$
$S_4 F_4$	$S_4 F_3$	$S_4 F_2$	$S_4 F_1$

Replication 2

S_1F_4	S_1F_1	S_1F_2	S_1F_3
$S_3 F_2$	$S_3 F_4$	$S_3 F_3$	$S_3 F_1$
$S_2 F_1$	$S_2 F_4$	$S_2 F_2$	$S_2 F_3$
$S_4 F_1$	$S_4 F_2$	$S_4 F_4$	$S_4 F_3$

Replication 3

$S_2 F_3$	$S_2 F_2$	$S_2 F_1$	$S_2 F_4$
$S_4 F_2$	$S_4 F_3$	$S_4 F_4$	$S_4 F_1$
$S_3 F_4$	$S_3 F_1$	$S_3 F_2$	$S_3 F_3$
S_1F_2	S_1F_3	S_1F_4	S_1F_1

Replication 4

$S_4 F_4$	$S_4 F_1$	$S_4 F_2$	$S_4 F_3$
$S_3 F_1$	$S_3 F_3$	$S_3 F_4$	$S_3 F_2$
S_1F_3	S_1F_2	S_1F_1	S_1F_4
$S_2 F_1$	$S_2 F_4$	$S_2 F_3$	$S_2 F_2$

Fig.2 Layout of the experimental field

Plate 1. Layout of the experimental field

Plate 2. Field view of green gram at the time of sowing

Plate 3. Field view of green gram at 30 DAS

Plate 4. Field view of green gram at 45 DAS

Plate 5. Field view of green gram at 60 DAS

3.3.2 Cultivation Practices

3.3.2.1. Field Preparation

The field was ploughed twice using a tractor drawn cultivator. Weeds and stubbles of previous crop were removed, the field was levelled and later laid out into plots as per the design given in Fig.2

3.3.2.2. Application of Lime, Manures and Fertilizers

Farm yard manure (@ 20 t ha^{-1} containing 4 per cent, 0.2 per cent, 0.2 per cent N, P_2O_5 and K_2O, respectively) was applied as basal and lime (@ 250 Kg ha^{-1} containing 31.53 per cent calcium) was applied at the time of first ploughing.

The different doses of fertilizers as per KAU POP, N @20 kg ha^{-1}, P_2O_5 @30 kg ha^{-1} and K_2O @30 kg ha^{-1} were supplied through urea, rajphos and muriate of potash, respectively. Half the quantity of N and full quantity of P_2O_5 and K_2O was applied at the time of last ploughing. The remaining quantity of N was applied as foliar spray of 2 per cent urea (15 and 30 DAS).

3.3.2.3. Seeds and Sowing

Sowing was done on 14^{th} February 2022 as per the spacing at a seed rate of 20 kg ha^{-1}.

3.3.2.4 Thinning and gap filling

Thinning and gap filling were done at 7 DAS to maintain seedling number as one $hill^{-1}$ and two $hill^{-1}$ and to retain healthy seedlings $hill^{-1}$.

3.3.2.5 Weeding

Hand weeding done twice at 15 and 30 DAS. The major weeds observed in the experimental field were *Oryza sativa, Cyperus difformis, Mimosa pudica*, *Cleome viscosa*, *Echinochloa* sps. and *Marselia quadrifolia*.

3.3.2.6 Plant protection

Tobacco caterpillar (*Spodoptera litura*) incidence was noticed at 20 DAS was controlled by using chlorpyriphos 50% EC @ 1.5 mL L^{-1} and the incidence of spotted pod borer (*Maruca vitrata*) at pod maturity was controlled by using chlorantraniliprole 18.5% SC (CORAGEN®) @ 0.3 L^{-1}.

3.3.2.7 Harvesting

Harvesting was done on 10th May 2022, by pulling out the entire plant when 80 per cent of pods turned brown. After drying, pods were threshed by beating with sticks and seeds are separated. The plant residue was weighed to record haulm yield.

3.4 OBSERVATIONS

Observations on growth characters, physiological parameters, yield and yield attributing characters of green gram were recorded and the mean values were worked out.

Observations on growth characters were taken from five plants from each plot at 15 DAS, 30 DAS, 45 DAS and 60 days after sowing (DAS), and at harvest. After elimination of border plants, five plants were selected randomly and tagged. At harvest, these five tagged plants were used for dry matter estimation and chemical analysis.

3.4.1 Growth and Growth Attributes

Crop growth characters were recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS and at harvest.

3.4.1.1 Plant height

The height of the plant was measured from the ground level to the growing tip of the observation plants and the mean was worked out and expressed in cm.

3.4.1.2 Number of leaves plant^{-1}

The number of fully opened trifoliate leaves were counted from the tagged plants and mean was worked out.

3.4.1.3 Number of branches plant^{-1}

The number of branches per plant was computed from the tagged plants and the mean was worked out.

3.4.1.4 Total leaf area plant^{-1}

Total leaf area was measured by multiplying average number of leaves and average leaf area of lower, middle, and upper leaves.

LA=k (L * W)

Where k is Kemp's constant (for dicot leaves=0.66)

Total leaf area = Average leaf area of plant x average number of leaves

3.4.1.5 Days to 50 per cent flowering

The average number of days taken for 50 per cent flowering in each treatment were noted and recorded.

3.4.1.6 Dry matter production

Dry matter of the plant was recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS and at harvest by destructive sampling of three random plants. These plants were uprooted from each plot carefully without damaging the roots. The plants were dried under shade and then oven dried at 70 ± 5°C till constant weight is obtained. The dry weight of the plants were found and expressed in g plant^{-1}.

3.4.2 Yield and Yield Attributes

3.4.2.1 Number of pods plant^{-1}

Total number of pods from tagged plants from each plot were counted and averaged to get number of pods plant^{-1}.

3.4.2.2 Length of pod (cm)

Length of pods were recorded from 15 randomly selected pods of tagged plants and average was worked out to get pod length, expressed in cm.

3.4.2.3 Number of seeds pod^{-1}

Number of seeds from fifteen randomly selected pods of observation plants were counted and averaged to get average number of seeds pod^{-1}

3.4.2.4 100 Seed weight

From the seed obtained from the tagged plants, 100 seeds were counted, oven dried and their weights were recorded as test weight and expressed in g.

3.4.2.5 Grain yield (kg ha^{-1})

Seed yield plot^{-1} was recorded after threshing and winnowing from each net plot. The seed yield per hectare was worked out and expressed in kg ha^{-1}.

3.4.2.6 Haulm yield (kg ha^{-1})

This was estimated by adding the weight of seed and stover after complete sun drying, obtained from each net plot in kg ha^{-1}, and expressed as haulm yield.

3.4.2.7 Harvest index

Harvest index (HI) was calculated by the formula suggested by Donald and Hamblin (1976), as the ratio between grain yield and biological yield.

3.4.3 Physiological Parameters

Crop growth characters were recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS, and harvest

3.4.3.1 Crop growth rate (CGR) (g m^{-2} d^{-1})

CGR was calculated by the formula suggested by Leopold and Kridemann (1975)

$$\mathrm{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where,

W_2 and W_1 are total dry matter of plant at the time t_2 and t_1, respectively

P: Land area

3.4.3.2 Relative growth rate (RGR) (g g^{-1} d^{-1})

RGR was calculated by the formula suggested by Williams (1946)

$$\mathrm{RGR} = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where,

W_2 and W_1: whole plant dry weight at the time t_2 and t_1, respectively

t_2-t_1: Time interval

3.4.3.3 Net assimilation rate (NAR) (g cm^{-2} d^{-1})

NAR was calculated by the formula suggested by Williams (1946)

$$\mathrm{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e A_2 - \log_e A_1}{A_2 - A_1}$$

Where,

A_1: Total leaf area at initial time (t_1)

A_2: Total leaf area at final time (t_2)

W_1: Initial dry weight

W_2: Final dry weight

3.4.3.4 Leaf area index (LAI)

Leaf area index (LAI) was worked out using the formula suggested by Watson (1947)

$$\text{Leaf area index} = \frac{\text{Total functional leaf area plant}^{-1}}{\text{Land area occupied plant}^{-1}}$$

3.5 OBSERVATION ON WEEDS (15 DAS, 30 and 45 DAS)

3.5.1 Weed flora

Weeds of different species present in the experimental field at 15 DAS, 30 DAS and 45 DAS were identified, recorded, and presented in Table 4.12.

3.5.2 Weed density

Weed density was recorded at 15 DAS, 30 DAS and 45 DAS by placing a quadrate of size 0.5 m × 0.5 m randomly at two sites in each treatment plot. The weeds in the quadrate were counted and expressed as number per meter square.

3.5.3 Weed dry weight

Weed density was recorded at 15 DAS, 30 DAS and 45 DAS by placing a quadrate of size 0.5 m × 0.5 m randomly at two sites in each treatment plot. The number of weeds in the quadrate were uprooted, cleaned, and dried in shade and then in hot air oven at 70 ± 5 °C until constant weight was attained and the dry weight was expressed in g m^{-2}.

3.6 QUALITY ANALYSIS

3.6.1 Crude protein content of the seed (%)

Nitrogen content in seeds of green gram were analysed and percentage crude protein in the seed was calculated by multiplying the percentage of nitrogen with the factor 6.25 (Simpson *et al.*, 1965).

3.7 SOIL ANALYSIS

After the harvest of crop, soil samples were collected from individual plots of the experimental area and were analyzed for organic carbon, available N, P and K. For soil organic carbon analysis, soil sample was sieved through 0.2 mm sieve and for N, P and K analysis the soil sample was sieved through 2 mm sieve and standard procedures were followed according to Table 1b.

3.8 PLANT ANALYSIS

The pod and haulm of the observational plants at harvest stage were used for the analysis of N, P, and K. The samples were dried to constant weight in an electric hot air oven at 70 ± 5°C, ground into fine powder and used for chemical analysis. The required quantity of samples were weighed out accurately and subjected to single acid digestion. The procedure adopted for the chemical analysis are given in Table 3.

Table 3. Standard analytical procedures adopted for plant analysis

Particulars	Method adopted	Reference
N (%)	Modified micro kjeldahl method	(Jackson, 1973)
P (%)	Vanado-molybdo phosphoric yellow colour method using spectrophotometer	(Jackson, 1973)
K (%)	Flame photometry method	(Jackson, 1973)

3.8.1 Nitrogen Uptake

Nitrogen uptake was computed as the sum of the products of dry weight of grain and haulm and the respective nitrogen contents and expressed in kg ha^{-1}.

3.8.2 Phosphorus Uptake

Phosphorus uptake was computed as sum of the products of dry weight of grain and haulm and the respective phosphorus contents and expressed in kg ha^{-1}.

3.8.3 Potassium Uptake

Potassium uptake was computed as the sum of the products of dry weight of grain and haulm and the respective potassium contents and expressed in kg ha^{-1}.

3.9 ECONOMIC ANALYSIS

The economics of cultivation was articulated in terms of net income and benefit cost ratio (BCR), based on cost of cultivation and prevailing price of the produce.

3.9.1 Net Income

Net income was calculated by subtracting cost of cultivation from gross income and is expressed in ₹ ha^{-1}.

3.9.2 Benefit Cost Ratio (BCR)

BCR was worked out as the ratio of gross income to cost of cultivation

$$BCR = \frac{\text{Gross income (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.10 STATISTICAL ANALYSIS

The data were analysed statistically by applying the techniques of analysis of variance (Gomez and Gomez, 1984). Wherever the effects were found to be significant, critical differences were given for effective comparison among the mean. The data were analysed using online tool, GRAPES developed by Kerala Agricultural University.

RESULTS

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4. RESULTS

An experiment entitled ‘’Productivity enhancement of green gram (*Vigna radiata* (L.) Wilczek) under system of crop intensification (SCI)’’ was undertaken to standardize the plant population and to assess the impact of foliar nutrition in enhancing the productivity of green gram under system of crop intensification. The experiment was conducted during the period from February 2022 to May 2022 at farmer’s field Varkala. The experimental data collected were statistically analysed and the results are presented below.

4.1. GROWTH PARAMETERS

The data on growth attributes as influenced by spacing and foliar application during the crop period are presented below. The observations were recorded at 15 DAS, 30 DAS, 45 DAS, and 60 DAS and at harvest.

4.1.1 Plant height

The mean plant height recorded at various growth stages are given in Table 4a and 4b.

A critical appraisal of data during the study revealed that the treatments significantly influenced the plant height of green gram. During the crop period, at 15 DAS plant height was not influenced by spacing. At 30 DAS, taller (23.04 cm) plants were observed in 25 cm × 25 cm spacing with two seedlings hill^{-1} (S_4), and it was on par with the spacing of 25 cm × 15 cm with one seedling hill^{-1} (S_1). The shortest (20.08 cm) plants were observed when planted at 25 cm × 15 cm with two seedlings hill^{-1} (S_2). At 45 and 60 DAS, no significant differences were observed among the treatments. At harvest, the spacing of 25 cm × 15 cm with one seedling hill^{-1} (S_1) recorded taller (54.68 cm) plants and the shortest plants were observed in the spacing of 25 cm × 15 cm with two seedlings hill^{-1} (S_2).

Foliar nutrition has significant influence on plant height at later stages of crop growth. At 15 and 30 DAS, there were no significant influence of foliar nutrition on plant height. At 45 and 60 DAS, KNO_3 @ 0.5% (F_3) recorded the tallest (46.44 cm and 50.06 cm, respectively) plants and was superior to all other treatments. The treatments DAP @2 % (F_2) and DAP @ 2% + KNO_3 @ 0.5 % (F_4) was on par and are inferior to others. At harvest, KNO_3 @ 0.5 % (F_3) recorded taller (54.25 cm) plants and was on par with DAP @ 2% + KNO_3 @ 0.5 % (F_4). The shortest plants were observed in DAP @ 2% (F_2) and Urea @ 2% (F_1). The interaction among spacing and foliar nutrition were not significant at any stage of the study.

4.1.2 Number of leaves plant^{-1}

The analysed data are presented in Table 5a and 5b.

The perusal of data revealed that at 15 and 30 DAS, spacing had no significant influence on number of leaves plant^{-1}. But at 45 DAS, more number of leaves (8.37) were observed at 25 cm × 15 cm with single seedling hill^{-1} (S_1) and it was par at with spacing of 25 cm × 25 cm with single seedling hill^{-1} (S_3). Lesser number of leaves plant^{-1} (5.50) was observed at 25 × 15 cm with double seedling hill^{-1} (S_2) and it was on par with 25 cm × 25 cm with double seedling hill^{-1} (S_4). At 60 DAS, the highest number of leaves (5.75) was observed with spacing of 25 cm × 25 cm with single seedling hill^{-1} (S_3) and lowest number of leaves plant^{-1} (3.93) was observed with spacing of 25 cm × 15 cm with double seedling hill^{-1} (S_2). At harvest, spacing has no significant influence on number of leaves plant^{-1}.

Foliar nutrition had no significant influence on number of leaves plant^{-1} at initial and later stages of crop growth. But at 45 DAS, the highest number of leaves (8.37) were observed with DAP @ 2% + KNO_3 @ 0.5% (F_4). All other treatments were at par.

Interaction effects were found to be significant at 45 DAS. The highest number of leaves (10.50) was recorded in S_3F_4. The treatment combinations S_4F_3, S_2F_3, and S_2F_2 recorded lower number of leaves.

Table 4a. Effect of spacing and foliar nutrition on plant height (cm) of green gram

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**Harvest**
Spacing (S)					
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	9.18	22.90	43.81	48.86	54.68
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	9.15	20.08	40.25	45.19	48.93
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	8.43	21.24	42.94	46.69	52.06
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	8.69	23.04	44.69	46.69	50.12
SEm (±)	0.25	0.66	1.36	1.25	0.98
CD (0.05)	NS	2.097	NS	NS	3.141
Foliar Nutrition (F)					
F_1- Urea @ 2%	8.54	23.54	43.25	48.18	51.12
F_2- DAP @ 2%	8.83	20.89	39.19	43.31	49.00
F_3- KNO_3 @ 0.5%	9.32	22.32	46.44	50.06	54.25
F_4- DAP @ 2% + KNO_3 @ 0.5%	8.76	20.51	42.81	45.88	51.43
SEm (±)	0.27	0.90	1.11	1.27	1.07
CD (0.05)	NS	NS	3.172	3.649	3.078

Table 4b. Interaction of spacing and foliar nutrition on plant height (cm) of green gram

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	Harvest
S_1F_1	8.60	22.13	43.50	55.95	58.50
S_1F_2	9.53	23.00	40.25	44.75	48.75
S_1F_3	9.93	22.50	50.25	51.75	57.00
S_1F_4	8.68	23.98	41.25	43.00	54.50
S_2F_1	9.28	23.28	41.50	43.75	46.25
S_2F_2	8.78	20.40	31.50	37.75	45.25
S_2F_3	8.98	20.53	43.25	51.00	53.75
S_2F_4	9.58	16.13	44.75	48.25	50.50
S_3F_1	8.45	22.13	43.25	46.75	52.00
S_3F_2	8.30	17.68	41.00	45.00	49.50
S_3F_3	9.35	24.25	45.25	48.50	54.75
S_3F_4	7.60	20.93	42.25	46.50	52.00
S_4F_1	7.83	26.65	44.75	46.25	47.75
S_4F_2	8.70	22.50	44.00	45.75	52.50
S_4F_3	9.03	22.00	47.00	49.00	51.50
S_4F_4	9.20	21.00	43.00	45.75	48.75
SEm (±)	0.54	1.81	2.21	2.54	2.15
CD (0.05)	NS	NS	NS	NS	NS

Table 5a. Effect of spacing and foliar nutrition on number of leaves plant^{-1} of green gram

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**Harvest**
Spacing (S)					
S_1- Spacing of 25 cm × 15 cm with single seedling hill^{-1}	2.31	4.00	8.37	5.18	4.12
S_2- Spacing of 25 cm × 15 cm with double seedling hill^{-1}	2.25	3.87	5.50	3.93	4.11
S_3- Spacing of 25 cm × 25 cm with single seedling hill^{-1}	2.31	4.25	8.12	5.75	4.50
S_4- Spacing of 25 cm × 25 cm with double seedling hill^{-1}	2.12	4.12	6.25	4.31	3.93
SEm (±)	0.17	0.23	0.27	0.37	0.26
CD (0.05)	NS	NS	0.879	1.181	NS
Foliar Nutrition (F)					
F_1- Urea at 2%	2.06	4.12	6.56	4.50	4.00
F_2- DAP at 2%	2.12	3.81	6.31	4.75	3.87
F_3- KNO_3 at 0.5%	2.25	4.00	7.00	4.93	4.62
F_4- DAP at 2% + KNO_3 at 0.5%	2.56	4.31	8.37	5.00	4.18
SEm (±)	0.14	0.20	0.31	0.22	0.20
CD (0.05)	NS	NS	0.886	NS	NS

Table 5b. Interaction effect of spacing and foliar nutrition on number of leaves of green gram.

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**Harvest**
S_1F_1	2.50	4.00	7.50	4.75	4.25
S_1F_2	2.00	3.75	7.00	5.00	3.75
S_1F_3	2.25	4.00	9.50	6.00	4.50
S_1F_4	2.50	4.25	9.50	5.00	4.03
S_2F_1	1.75	3.75	5.75	4.01	3.75
S_2F_2	2.25	3.73	5.00	4.25	4.25
S_2F_3	2.50	3.50	5.12	4.00	4.50
S_2F_4	2.50	4.50	6.25	3.50	4.02
S_3F_1	2.52	4.25	6.50	5.00	4.25
S_3F_2	2.25	4.25	7.00	5.52	3.25
S_3F_3	2.00	4.25	8.50	5.50	5.25
S_3F_4	2.75	4.25	10.50	7.00	5.26
S_4F_1	1.75	4.50	6.50	4.25	3.75
S_4F_2	2.00	3.50	6.25	4.25	4.25
S_4F_3	2.25	4.25	5.00	4.25	4.28
S_4F_4	2.50	4.25	7.25	4.51	3.50
SEm (±)	0.28	0.41	0.62	0.43	0.40
CD (0.05)	NS	NS	1.772	NS	NS

4.1.3 Number of branches per plant

The data on mean number of branches are given in Table 6a and 6b.

The results revealed that spacing did not influence the number of branches at 15 and 30 DAS. However, at later stages of crop growth spacing had significant influence on number of branches. Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3) recorded more number of branches (5.18, 5.93 and 6.56, respectively) at 45, 60 DAS and at harvest which was on par with spacing of 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1). At 45 DAS, the lowest number of branches (3.06) was recorded with the spacing of 25 × 15 cm with double seedling $hill^{-1}$ (S_2) and it was on par with spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4). Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4) recorded lower number of branches (4.00 and 4.75, respectively) at 60 DAS and at harvest and it was on par with the spacing of 25 × 15 cm with double seedling $hill^{-1}$ (S_2).

During the initial stages of crop growth foliar nutrition had no significant influence on branching. But at 45 DAS, 60 DAS and at harvest the treatment KNO_3 @ 0.5% (F_3) recorded the highest number of branches (4.62, 6.06 and 6.43, respectively) and all other treatments were statistically on par.

Interaction effect was found to be significant at 60 DAS and at harvest. At both the stages the treatment combination, S_3F_3 recorded more number of branches (8.50 and 9.00, respectively) and found to be statistically on par with S_1F_3. At 60 DAS and at harvest, lower number of branches were recorded in S_2F_2 (3.25) and S_2F_2 (3.75), respectively.

Table 6a. Effect of spacing and foliar nutrition on number of branches of green gram.

Treatments	30 DAS	45 DAS	60 DAS	Harvest
Spacing (S)				
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	2.31	4.68	5.43	6.00
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	2.18	3.06	4.56	5.00
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	2.43	5.18	5.93	6.56
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	2.37	3.43	4.00	4.75
SEm (±)	0.17	0.20	0.33	0.29
CD (0.05)	NS	0.635	1.071	0.933
Foliar Nutrition (F)				
F_1- Urea @ 2%	2.56	4.12	4.81	5.68
F_2- DAP @ 2%	2.12	3.75	4.50	4.87
F_3- KNO_3 @ 0.5%	2.37	4.62	6.06	6.43
F_4- DAP @ 2% + KNO_3 @ 0.5%	2.25	3.87	4.56	5.31
SEm (±)	0.18	0.29	0.35	0.33
CD (0.05)	NS	NS	0.990	0.956

Table 6b. Interaction effect of spacing and foliar nutrition on number of branches of green gram.

Treatments	**30DAS**	**45DAS**	**60DAS**	**Harvest**
S_1F_1	2.00	4.50	4.50	5.50
S_1F_2	2.25	4.00	4.75	4.75
S_1F_3	2.50	5.75	6.75	7.00
S_1F_4	2.52	4.50	5.75	6.75
S_2F_1	2.25	2.50	6.00	6.72
S_2F_2	2.50	3.00	3.25	3.75
S_2F_3	1.75	3.50	5.00	5.50
S_2F_4	2.25	3.25	4.00	4.00
S_3F_1	3.00	6.00	4.75	5.50
S_3F_2	1.75	4.75	5.50	5.75
S_3F_3	2.75	5.75	8.50	9.00
S_3F_4	2.25	4.25	5.00	6.00
S_4F_1	3.00	3.50	4.00	5.00
S_4F_2	2.00	3.25	4.50	5.25
S_4F_3	2.50	3.50	4.00	4.25
S_4F_4	2.00	3.51	3.50	4.50
SEm (±)	0.36	0.58	0.69	0.67
CD (0.05)	NS	NS	1.980	1.913

4.1.4 Total leaf area per plant

Total leaf area at various growth stages were given in Table 7a and 7b.

The results revealed that spacing had significant positive influence on total leaf area at 30 DAS and at 45 DAS. At 30 DAS, spacing of 25 cm × 25 cm with single seedling hill^{-1} (S_3) recorded higher leaf area (227.62 cm^2) and it was on par with spacing of 25 cm × 15 cm with single seedling hill^{-1} (S_1). The lowest leaf area (172.93 cm^2) was recorded with the spacing of 25 cm × 15 cm with double seedling hill^{-1} (S_2). At 45 DAS, spacing of 25 cm × 15 cm with single seedling hill^{-1} (S_1) recorded highest leaf area (1110.26 cm^2) and the lower leaf area (798.26 cm^2) was recorded with spacing of 25 cm × 25 cm with double seedling hill^{-1} (S_4).

Foliar nutrition had significant influence on total leaf area at 45 DAS, the highest leaf area (995.29 cm^2) was recorded in DAP @ 2% + KNO_3@ 0.5% (F_4) while the lowest leaf area (886.35 cm^2) was recorded in DAP @ 2% (F_2).

Interaction effect was found to be significant at 45 DAS, higher leaf area was recorded with the treatment combinations S_1F_1 (1188.50 cm^2) and S_1F_4 (1127.32 cm^2). The lowest leaf area was recorded in S_2F_2 (658.61 cm^2).

4.1.5 Days to 50 per cent flowering

The mean numbers of days to 50 per cent flowering are given in Table 13a and 13b.

The results revealed that treatments had no significant influence on days to 50 per cent flowering. The interaction effects were also found to be non-significant. The mean number of days to 50 per cent flowering varied from 35 to 47 among the treatments.

4.1.6 Dry matter production

Dry matter production at various stages of crop growth is presented in Table 8a and 8b.

At 15 DAS, spacing had no significant influence on dry matter production. However, it differed significantly during the remaining stages of crop growth. At 30 DAS, 45 and 60 DAS and at harvest, spacing of 25 cm × 15 cm with single seedling hill^{-1} (S_1) produced more dry matter (6.42, 12.86, 22.45, and 44.33, g plant^{-1} respectively) and it was on par with the spacing of 25 cm × 25 cm with single seedling hill^{-1} (S_3). At 30 DAS and 45 DAS, the lowest dry matter (4.41 g plant^{-1} and 9.06 g plant^{-1}, respectively) were recorded at the spacing of 25 cm × 15 cm with double seedling hill^{-1} (S_2), but at 60 DAS and at harvest, spacing of 25 cm × 25 cm with double seedling hill^{-1} (S_4) recorded the lowest dry matter (13.17 g plant^{-1} and 20.44 g plant^{-1}, respectively).

Foliar nutrition had significant influence on dry matter production at 30 DAS, 45 DAS, 60 DAS and at harvest. At 30 DAS, DAP @ 2% + KNO_3@ 0.5% (F_4) recorded the highest dry matter (6.12 g plant^{-1}) and it was on par with KNO_3 @ 0.5% (F_3). The lowest dry matter (4.69 g plant^{-1}) was recorded in urea @ 2% (F_1). At 45 DAS, KNO_3 @ 0.5% (F_3) recorded more dry matter (11.67 g plant^{-1}) and it was on par with DAP @ 2% + KNO_3 @ 0.5% (F_4) and the lowest (9.88 g plant^{-1}) was recorded in DAP @ 2% (F_2). At 60 DAS, the treatment DAP @ 2% + KNO_3 @ 0.5% (F_4) recorded the highest dry matter (19.84 g plant^{-1}) and it was on par with KNO_3 @ 0.5% (F_3). The lower dry matter was recorded in DAP @ 2% (F_2) (16.30 g plant^{-1}) which was on par with urea @ 2% (F_1). At harvest, KNO_3 @ 0.5% (F_3) recorded the highest dry matter (36.49 g plant^{-1}) and the lowest (28.20 g plant^{-1}) was observed in DAP @ 2% (F_2).

Interaction effects between spacing and foliar nutrition were found to be significant at 30 DAS, 60 DAS and at harvest. At 30 DAS, the highest dry matter was recorded in S_1F_4 (9.56 g plant^{-1}) and the lowest in S_4F_1 (3.92 g plant^{-1}). At 60 DAS, the highest dry matter was recorded with S_1F_4 (26.63 g plant^{-1}). At harvest, the highest dry matter was recorded in S_3F_3 (48.98 g plant^{-1}) and the lowest value was observed in S_4F_2 (17.52 g plant^{-1}).

Table 7a. Effect of spacing and foliar nutrition on total leaf area (cm^2) of green gram

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	Harvest
Spacing (S)					
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	42.73	225.07	1110.26	580.45	447.51
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	40.79	172.93	816.31	428.80	423.37
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	40.86	227.62	1042.54	561.65	417.66
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	40.68	181.32	798.26	432.57	360.54
SEm (±)	0.72	2.46	19.13	47.66	32.12
CD (0.05)	NS	7.855	61.213	NS	NS
Foliar Nutrition (F)					
F_1- Urea @ 2%	42.00	201.12	948.77	489.00	405.80
F_2- DAP @ 2%	41.48	195.59	886.35	494.17	378.43
F_3- KNO_3 @ 0.5%	40.27	209.75	936.96	506.73	449.88
F_4- DAP @ 2% + KNO_3 @ 0.5%	41.31	200.49	995.29	513.57	414.97
SEm (±)	1.09	4.22	11.38	26.74	26.40
CD (0.05)	NS	NS	32.646	NS	NS

Table 7b. Interaction effect of spacing and foliar nutrition on total leaf area (cm^2) of green gram

Treatments	15 DAS	30DAS	45DAS	60DAS	Harvest
S_1F_1	41.77	230.61	1188.54	500.12	423.81
S_1F_2	45.12	214.57	1094.25	629.47	454.68
S_1F_3	41.02	236.25	1030.92	593.77	431.13
S_1F_4	43.00	218.83	1127.32	598.45	480.43
S_2F_1	42.24	167.25	796.46	407.04	345.15
S_2F_2	43.35	175.75	658.61	463.83	429.58
S_2F_3	38.57	180.25	926.77	459.76	497.82
S_2F_4	39.00	168.50	883.41	384.60	420.93
S_3F_1	41.75	231.56	1012.58	568.52	449.17
S_3F_2	40.70	210.30	990.19	491.05	273.40
S_3F_3	40.50	243.25	1054.30	634.10	558.60
S_3F_4	40.50	225.38	1113.10	552.96	389.48
S_4F_1	42.24	175.05	797.48	480.35	405.07
S_4F_2	36.75	181.75	802.37	392.32	356.07
S_4F_3	41.00	179.26	735.84	339.32	311.99
S_4F_4	42.75	189.25	857.34	518.29	369.04
SEm(±)	2.19	8.45	22.76	53.48	52.81
CD (0.05)	NS	NS	65.291	NS	NS

Table 8a. Effect of spacing and foliar nutrition on dry matter production (g $plant^{-1}$) of green gram

Treatments	15 DAS	30 DAS	45 DAS	60 DAS	At Harvest
Spacing (S)					
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	0.65	6.42	12.86	22.45	44.33
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	0.60	4.41	9.06	15.06	21.86
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	0.69	6.23	12.54	21.65	43.64
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	0.69	5.10	9.40	13.17	20.44
SEm (±)	0.04	0.14	0.47	0.49	0.74
CD (0.05)	NS	0.436	0.510	1.566	2.361
Foliar Nutrition (F)					
F_1- Urea @ 2%	0.68	4.69	10.68	16.88	30.89
F_2- DAP @ 2%	0.65	5.37	9.88	16.30	28.20
F_3- KNO_3 @ 0.5%	0.68	6.00	11.67	19.32	36.49
F_4- DAP @ 2% + KNO_3 @ 0.5%	0.62	6.12	11.64	19.84	34.68
SEm (±)	0.04	0.09	0.27	0.45	0.32
CD (0.05)	NS	0.266	0.769	1.276	0.926

Table 8b. Interaction effect of spacing and foliar nutrition on dry matter production (g plant^{-1}) of green gram

Treatments	15 DAS	30DAS	45DAS	60DAS	Harvest
S_1F_1	0.58	4.29	12.78	21.43	42.51
S_1F_2	0.65	6.84	10.88	18.18	39.66
S_1F_3	0.71	5.00	13.42	23.53	48.37
S_1F_4	0.68	9.56	14.37	26.63	46.77
S_2F_1	0.62	4.28	8.54	11.43	19.82
S_2F_2	0.67	4.15	8.78	14.35	18.96
S_2F_3	0.57	4.30	9.35	17.47	24.20
S_2F_4	0.55	4.93	9.57	16.99	24.47
S_3F_1	0.64	6.26	11.87	22.92	41.91
S_3F_2	0.67	4.52	11.31	20.96	36.67
S_3F_3	0.80	8.46	14.25	21.75	48.98
S_3F_4	0.65	5.70	12.76	21.00	47.00
S_4F_1	0.90	3.92	9.52	11.74	19.34
S_4F_2	0.61	5.97	8.55	11.71	17.52
S_4F_3	0.65	6.26	9.65	14.51	24.41
S_4F_4	0.59	4.27	9.87	14.74	20.50
SEm (±)	0.07	0.19	0.54	0.89	0.65
CD (0.05)	NS	0.533	NS	2.553	1.852

4.2 PHYSIOLOGICAL PARAMETERS

The data on physiological parameters as influenced by spacing and foliar application during the crop period are presented below. The observations for CGR, RGR and NAR were recorded at 15-30 DAS, 30-45, and 45-60 DAS intervals. LAI was recorded at 30 DAS, 45 and 60 DAS.

4.2.1 Crop Growth Rate (CGR)

The results are given in the tables 9a and 9b.

The data revealed that CGR varied significantly with spacing and foliar nutrition. At 15-30 DAS, 30-45 and 45-60 DAS, spacing of 25 cm × 15 cm with single seedling hill^{-1} (S_1) recorded higher CGR values of 6.60, 14.47 and 17.03 g m^{-2} d^{-1}, respectively. The Lowest CGR values of 3.90, 5.01 g m^{-2} d^{-1} and 5.20 g m^{-2} d^{-1}, respectively was observed in S_4 (Spacing of 25 cm × 25 cm with double seedling hill^{-1}).

At 15-30 DAS, foliar nutrition with KNO_3 @ 0.5% (F_3) and urea @ 2% (F_1) recorded the highest (5.95 g m^{-2} d^{-1}) and lowest (4.84 g m^{-2} d^{-1}) CGR, respectively. However, at 30-45 and 45-60 DAS, DAP @ 2% + KNO_3 @ 0.5% (F_4) recorded highest (10.00 and 11.79 g m^{-2} d^{-1}, respectively) and the lowest CGR were observed in DAP @ 2% (F_2) and urea @ 2% (F_1) with the values of 7.40 and 9.12 g m^{-2} d^{-1}, respectively.

Interaction effects found significant with spacing and foliar nutrition at 30-45 and 45-60 DAS. At 30-45 DAS, highest CGR (17.50 g m^{-2} d^{-1}) was recorded in S_1F_4 and the lowest was observed in S_4F_2 (3.80 g m^{-2} d^{-1}). At 45-60 DAS, S_1F_4 recorded highest CGR (18.55 g m^{-2} d^{-1}) and the lowest CGR (4.17 g m^{-2} d^{-1}) was observed in S_4F_1.

4.2.2 Relative Growth Rate (RGR)

The results are presented in Table 10a and 10b.

The results showed decreasing trend towards advanced crop growth stages. The data revealed that the influence of spacing on RGR is significant at 30-45 and

45-60 DAS. At 30-45 and 45-60 DAS, spacing of 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1) recorded higher values of 0.029 and 0.016 g g^{-1} d^{-1}, respectively. At 45-60 DAS, it was on par with the spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3) and spacing of 25 cm × 15 cm with double seedling $hill^{-1}$ (S_2). Lower RGR values were recorded with the spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4) during all growth stages.

Foliar nutrition was found to be significant only at 30-45 DAS. DAP @ 2% + KNO_3 @ 0.5% (F_4) recorded higher RGR (0.026 g g^{-1} d^{-1}) and was at par with urea @ 2% (F_1) and lower RGR (0.022 g g^{-1} d^{-1}) were recorded in DAP @ 2% (F_2) and KNO_3 @ 0.5% (F_3).

Interaction effect between spacing and foliar nutrition was found to be significant at 30-45 and 45-60 DAS. At 30-45 DAS, higher RGR was recorded with the treatment combination of S_1F_4 (0.033 g g^{-1} d^{-1}) and lower (0.016 g g^{-1} d^{-1}) RGR were observed with S_4F_2 and S_4F_3. At 45-60 DAS, higher (0.019 g g^{-1} d^{-1}) RGR was recorded with S_3F_1 and lowest RGR with S_4F_1 (0.006 g g^{-1} d^{-1}).

4.2.3 Net Assimilation Rate (NAR)

The results are given in Tables 11a and 11b.

The results revealed that, NAR showed a decreasing trend with increasing crop duration. The influence of spacing on NAR was found to be significant at 30-45 DAS and 45-60 DAS. At 30-45 DAS, spacing of 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1) recorded the highest NAR (4.20). The lower NAR (3.27) was observed with spacing of 25 cm × 15 cm with double seedling $hill^{-1}$ (S_2) and it was on par with spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4). At 45-60 DAS, higher NAR (3.47) was recorded with the spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3) and it was on par with spacing of 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1) and spacing of 25 cm × 15 cm with double seedling $hill^{-1}$ (S_2). The lowest value of 1.94 was observed in S_4 (spacing of 25 cm × 25 cm with double seedling $hill^{-1}$).

The foliar nutrition had significant influence on NAR at 15-30 and 45-60 DAS. At 15-30 DAS, higher NAR (12.41) was recorded with KNO_3 @ 0.5% (F_3) and it was on par with DAP @ 2% (F_2) and DAP @ 2% + KNO_3 @ 0.5% (F_4). At 45-60 DAS, DAP @ 2% + KNO_3 @ 0.5% (F_4) recorded higher NAR (3.23) and it was on par with KNO_3 @ 0.5% (F_3), however at both these stages lower NAR (9.77 and 2.47, respectively) were observed with urea @ 2% (F_1).

Interaction effect of spacing and foliar nutrition found to be significant during all growth stages. At 15-30 DAS, higher NAR (14.35) was recorded with S_4F_3 and the lower NAR (8.24) was observed with S_4F_1. At 30-45 and 45-60 DAS, higher NAR (4.97 and 4.13, respectively) was recorded in S_1F_4 and the lowest values were observed in S_4F_2 and S_4F_1, respectively.

4.2.4 Leaf Area Index (LAI)

The leaf area index (LAI) recorded at various growth stages are presented in Table 12a and 12b.

The results revealed that at 30 DAS, 45 and 60 DAS, spacing of 25 cm × 15 cm with single seedling hill^{-1} (S_1) recorded higher LAI (0.6, 3.00 and 1.54, respectively) and the lower LAI (0.29, 1.26 and 0.69, respectively) was observed with the spacing of 25 cm × 25 cm with double seedling hill^{-1} (S_4).

LAI was significantly influenced by foliar nutrition only at 45 DAS. The highest LAI (2.16) was recorded in DAP @ 2% + KNO_3 @ 0.5% (F_4). The treatments F_3 and F_1 were at par. The lowest value was recorded in F_2 (DAP @ 2%).

Interaction effect of spacing and foliar nutrition was significant at 45 DAS, the treatment combination S_1F_1 and S_1F_4 recorded higher (3.16) LAI and lower (1.16) LAI was observed with S_4F_3.

Table 9a. Effect of spacing and foliar nutrition on crop growth rate (g m^{-2} d^{-1}) of green gram

Treatments	15-30 DAS	30-45 DAS	45-60 DAS
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	6.60	14.47	16.22
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	6.16	8.25	10.14
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	4.63	7.64	9.71
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	3.90	5.01	5.20
SEm (±)	0.35	0.62	0.94
CD (0.05)	1.108	1.969	3.004
Foliar Nutrition (F)			
F_1- Urea @ 2%	4.84	8.90	9.12
F_2- DAP @ 2%	5.20	7.40	9.50
F_3- KNO_3 @ 0.5%	5.95	9.08	10.87
F_4- DAP @ 2% + KNO_3 @ 0.5%	5.29	10.00	11.79
SEm (±)	0.26	0.41	0.54
CD (0.05)	0.754	1.168	1.541

Table 9b. Interaction of spacing and foliar nutrition on crop growth rate (g m^{-2} d^{-1}) of green gram

Treatments	**15-30 DAS**	**30-45 DAS**	**45-60 DAS**
S_1F_1	5.97	15.09	15.38
S_1F_2	7.23	10.33	12.98
S_1F_3	6.99	14.97	17.97
S_1F_4	6.2	17.50	18.55
S_2F_1	5.88	7.57	5.14
S_2F_2	5.57	8.23	9.88
S_2F_3	6.01	8.97	12.36
S_2F_4	7.17	8.25	13.19
S_3F_1	4.65	6.95	11.79
S_3F_2	3.72	7.24	10.29
S_3F_3	5.88	8.08	7.99
S_3F_4	4.26	8.28	8.78
S_4F_1	2.84	5.97	4.17
S_4F_2	4.29	3.8	4.84
S_4F_3	4.92	4.3	5.18
S_4F_4	3.55	5.97	6.62
SEm (±)	0.53	0.81	1.07
CD (0.05)	NS	2.335	3.082

Table 10a. Effect of spacing and foliar nutrition on relative growth rate (g g^{-1} d^{-1}) of green gram

Treatments	15-30 DAS	30-45 DAS	45-60 DAS
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	0.044	0.029	0.016
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	0.045	0.021	0.014
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	0.047	0.025	0.016
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	0.043	0.021	0.010
SEm (±)	0.002	0.001	0.001
CD (0.05)	NS	0.004	0.004
Foliar Nutrition (F)			
F_1- Urea @ 2%	0.042	0.025	0.012
F_2- DAP @ 2%	0.044	0.022	0.014
F_3- KNO_3 @ 0.5%	0.048	0.022	0.015
F_4- DAP @ 2% + KNO_3 @ 0.5%	0.046	0.026	0.015
SEm (±)	0.002	0.001	0.001
CD (0.05)	NS	0.003	NS

Table 10b. Interaction effect of spacing and foliar nutrition on relative growth rate ($g\ g^{-1}\ d^{-1}$) of green gram

Treatments	**15-30 DAS**	**30-45 DAS**	**45-60 DAS**
S_1F_1	0.044	0.032	0.015
S_1F_2	0.047	0.022	0.015
S_1F_3	0.045	0.029	0.016
S_1F_4	0.042	0.033	0.018
S_2F_1	0.043	0.020	0.008
S_2F_2	0.041	0.022	0.014
S_2F_3	0.045	0.022	0.018
S_2F_4	0.050	0.019	0.017
S_3F_1	0.049	0.023	0.019
S_3F_2	0.043	0.026	0.018
S_3F_3	0.050	0.022	0.012
S_3F_4	0.046	0.027	0.015
S_4F_1	0.033	0.026	0.006
S_4F_2	0.047	0.016	0.009
S_4F_3	0.050	0.016	0.012
S_4F_4	0.044	0.024	0.012
SEm (±)	0.003	0.002	0.002
CD (0.05)	NS	0.006	0.005

Table 11a. Effect of spacing and foliar nutrition on net assimilation rate (g cm^{-2} d^{-1}) of green gram

Treatments	15-30 DAS	30-45 DAS	45-60 DAS
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	9.95	4.20	3.38
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$l	11.05	3.27	2.91
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	11.54	3.85	3.47
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	11.31	3.28	1.94
SEm (±)	0.77	0.21	0.30
CD (0.05)	NS	0.670	0.964
Foliar Nutrition (F)			
F_1- Urea @ 2%	9.77	3.70	2.47
F_2- DAP @ 2%	10.87	3.29	2.78
F_3- KNO_3 @ 0.5%	12.41	3.66	3.22
F_4- DAP @ 2% + KNO_3 @ 0.5%	10.81	3.95	3.23
SEm (±)	0.60	0.16	0.21
CD (0.05)	1.727	NS	0.600

Table 11b. Interaction effect of spacing and foliar nutrition on net assimilation rate (g cm^{-2} d $^{-1}$) of green gram

Treatments	**15 - 30 DAS**	**30 - 45 DAS**	**45 - 60 DAS**
S_1F_1	8.88	4.21	3.14
S_1F_2	11.14	3.09	2.54
S_1F_3	10.39	4.52	3.71
S_1F_4	9.36	4.97	4.13
S_2F_1	10.53	3.05	1.48
S_2F_2	9.61	3.68	2.91
S_2F_3	10.73	3.21	3.60
S_2F_4	13.34	3.13	3.66
S_3F_1	11.42	3.58	4.24
S_3F_2	9.87	3.90	3.99
S_3F_3	14.14	3.92	2.64
S_3F_4	10.74	4.01	3.02
S_4F_1	8.24	3.95	1.01
S_4F_2	12.85	2.51	1.68
S_4F_3	14.35	2.97	2.94
S_4F_4	9.78	3.68	2.12
SEm (±)	1.20	0.33	0.42
CD (0.05)	3.454	0.941	1.200

Table 12a. Effect of spacing and foliar nutrition on leaf area index (LAI) of green gram

Treatments	30 DAS	45 DAS	60 DAS
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	0.60	3.00	1.54
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	0.46	2.17	1.14
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	0.36	1.66	0.89
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	0.29	1.26	0.69
SEm (±)	0.01	0.03	0.11
CD (0.05)	0.018	0.105	0.343
Foliar Nutrition (F)			
F_1- Urea @ 2%	0.42	2.04	1.02
F_2- DAP @ 2%	0.41	1.87	1.08
F_3- KNO_3 @ 0.5%	0.44	2.01	1.09
F_4- DAP @ 2% + KNO_3 @ 0.5%	0.42	2.16	1.08
SEm (±)	0.01	0.02	0.05
CD (0.05)	NS	0.048	NS

Table 12b. Interaction effect of spacing and foliar nutrition on leaf area index of green gram (LAI)

Treatments	**30 DAS**	**45 DAS**	**60 DAS**
S_1F_1	0.61	3.16	1.33
S_1F_2	0.57	2.91	1.67
S_1F_3	0.63	2.74	1.58
S_1F_4	0.58	3.16	1.59
S_2F_1	0.44	2.12	1.08
S_2F_2	0.46	1.75	1.23
S_2F_3	0.48	2.47	1.22
S_2F_4	0.44	2.35	1.02
S_3F_1	0.37	1.62	0.91
S_3F_2	0.33	1.56	0.78
S_3F_3	0.38	1.68	1.01
S_3F_4	0.36	1.78	0.88
S_4F_1	0.28	1.27	0.76
S_4F_2	0.29	1.26	0.62
S_4F_3	0.28	1.16	0.54
S_4F_4	0.30	1.37	0.82
SEm (±)	0.02	0.03	0.11
CD (0.05)	NS	0.096	NS

4.3 YIELD ATTRIBUTES

4.3.1 Number of pods per plant

The results are given in the Table 13a and 13b.

The results revealed that number of pods plant^{-1} varied significantly due to spacing and foliar nutrition. The spacing of 25 cm × 25 cm with single seedling hill^{-1} (S_3) recorded highest number of pods (27.06) and the lower number of pods were observed in double seedlings hill^{-1} treatments (S_2 and S_4).

Among the foliar nutrition treatments higher number of pods (17.19) was recorded in application of KNO_3 @ 0.5% (F_3) and was at par with DAP @ 2% + KNO_3 @ 0.5% (F_4). Application of urea @ 2% (F_1) recorded lower number of pods (15.13) and it was at par with DAP @ 2% (F_2). However, the interaction of spacing and foliar nutrition was not significant.

4.3.2 Length of pod

The results are given in Table 13a and 13b.

Results showed that length of pod varied significantly with spacing and foliar nutrition. Higher pod length (7.99 cm) was observed with spacing of 25 cm × 15 cm with single seedling hill^{-1} (S_1) and it was at par with S_3. Double seedling hill^{-1} (S_2 and S_4) recorded lower mean pod length.

Among the foliar nutrition treatments, KNO_3 @ 0.5% (F_3) recorded the highest value of pod length (8.15 cm) and was superior to all other treatments.

Among the interaction effects, S_1F_3 recorded higher pod length and it was on par with treatment combinations of S_1F_1, S_1F_2, S_3F_3, S_3F_4 and S_4F_3.

4.3.3 Number of seeds per pod

The data summarized in the Table 13a and 13b showed that the number of seeds pod^{-1} was significantly influenced by spacing and foliar nutrition.

The data revealed that the spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3) recorded the higher value of 12.25 and at par with S_2 and S_1. The spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4) recorded the lowest value of 10.63.

Among the foliar nutrition treatments, KNO_3 @ 0.5% (F_3) recorded the highest number of seeds pod^{-1} (12.25). The interactions were found to be not significant.

4.3.4 100 seed weight

The results revealed that influence of spacing and foliar nutrition on 100 seed weight was not significant (Table 14a and 14b).

All the interactions were found not significant.

4.3.5 Grain yield

Data pertaining to yield are presented in Table 14a and 14b.

Yield of green gram was significantly influenced by spacing and foliar nutrition.

A critical perusal of data revealed that spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3) recorded higher grain yield (899.44 kg ha^{-1}) and it was at par with 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1) and these two were significantly superior over other two methods of spacing. The spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4) recorded the lowest (555.70 kg ha^{-1}) grain yield.

The analysed data on foliar nutrition revealed that foliar spray with KNO_3 @ 0.5% (F_3) recorded higher grain yield (880.85 kg ha^{-1}) and it was on par with DAP @ 2% + KNO_3 @ 0.5% (F_4). The lower grain yield (665.19 kg ha^{-1}) was observed in urea @ 2% (F_1) and it was on par with DAP @ 2% (F_2).

The interactions were found not significant

4.3.6 Haulm yield

The results revealed that the haulm yield was significantly influenced by spacing and foliar nutrition (Table 14a and 14b).

The haulm yield was higher (1911.28 kg ha^{-1}) with spacing of 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1) and was at par with spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3). The lowest haulm yield (1210.77 kg ha^{-1}) was recorded with the spacing of 25 cm × 25 cm with double seedling $hill^{-1}$ (S_4).

Among the foliar nutrition treatments, KNO_3 @ 0.5% (F_3) recorded higher haulm yield (1854.29 kg ha^{-1}) and was at par with DAP @ 2% + KNO_3 @ 0.5% (F_4). Urea @ 2% (F_1) recorded lower haulm yield (1399.76 kg ha^{-1}) and was at par with DAP @ 2% (F_2).

The interactions were found not significant.

4.3.7 Harvest index

The data on the effect of spacing, foliar nutrition and their interactions on harvest index are given in Tables 13a and 13b. There were no significant difference in harvest index due to spacing and foliar nutrition.

The interactions were also found not significant.

Table 13a. Effect of spacing and foliar nutrition on yield attributes of green gram

Treatments	No. of pods per plant	Length of pod (cm)	No. of seeds per pod	Days to 50 per cent flowering	Harvest index
Spacing (S)					
S_1- Spacing of 25 cm × 15 cm with single seedling hill^{-1}	19.81	7.99	11.69	40.63	0.31
S_2- Spacing of 25 cm × 15 cm with double seedling hill^{-1}	8.69	7.52	11.31	40.94	0.33
S_3- Spacing of 25 cm × 25 cm with single seedling hill^{-1}	27.06	7.70	12.25	41.56	0.33
S_4- Spacing of 25 cm × 25 cm with double seedling hill^{-1}	9.13	7.56	10.63	41.88	0.32
SEm (±)	0.27	0.10	0.30	0.52	0.01
CD (0.05)	0.859	0.309	0.964	NS	NS
Foliar Nutrition (F)					
F_1- Urea @ 2%	15.13	7.49	11.00	40.62	0.32
F_2- DAP @ 2%	15.31	7.43	11.12	43.00	0.32
F_3- KNO_3 @ 0.5%	17.19	8.16	12.25	40.31	0.32
F_4- DAP @ 2% + KNO_3 @ 0.5%	17.06	7.69	11.50	41.06	0.32
SEm (±)	0.34	0.12	0.25	1.43	0.00
CD (0.05)	0.974	0.347	0.721	NS	NS

Table 13b. Interaction effect of spacing and foliar nutrition on yield attributes of green gram

Treatments	No. of pods per plant	Length of pod (cm)	No. of seeds per pod	Days to 50 per cent flowering	Harvest index
S_1F_1	18.75	8.05	11.25	41.00	0.31
S_1F_2	19.50	8.03	11.00	41.25	0.31
S_1F_3	20.75	8.58	13.25	40.25	0.31
S_1F_4	20.25	7.33	11.25	40.00	0.32
S_2F_1	7.50	7.03	11.00	39.50	0.32
S_2F_2	8.75	7.48	11.75	43.50	0.34
S_2F_3	9.25	7.95	11.25	40.00	0.33
S_2F_4	9.25	7.63	11.25	40.75	0.31
S_3F_1	25.50	7.23	12.00	40.25	0.33
S_3F_2	25.25	7.15	11.25	45.00	0.33
S_3F_3	29.00	8.20	13.50	40.00	0.33
S_3F_4	28.50	8.23	12.25	41.00	0.33
S_4F_1	8.75	7.65	9.75	41.75	0.33
S_4F_2	7.75	7.08	10.50	42.25	0.30
S_4F_3	9.75	7.90	11.00	41.00	0.32
S_4F_4	10.25	7.60	11.25	42.50	0.32
SEm (±)	0.68	0.24	0.50	2.85	0.01
CD (0.05)	NS	0.693	NS	NS	NS

Table 14a. Effect of spacing and foliar nutrition on 100 seed weight, grain, and haulm yield of green gram.

Treatments	100 seed weight (g)	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	3.51	865.07	1911.28
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	3.35	771.77	1606.82
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	3.39	899.44	1827.82
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	3.41	555.70	1210.77
SEm (±)	0.05	26.62	70.21
CD (0.05)	NS	85.151	224.617
Foliar Nutrition (F)			
F_1- Urea @ 2%	3.33	665.19	1399.76
F_2- DAP @ 2%	3.44	723.48	1542.33
F_3- KNO_3 @ 0.5%	3.47	880.85	1854.29
F_4- DAP @ 2% + KNO_3 @ 0.5%	3.42	822.45	1760.31
SEm (±)	0.05	26.42	52.52
CD (0.05)	NS	75.782	150.640

Table 14b. Interaction effect of spacing and foliar nutrition on 100 seed weight, grain yield and haulm yield of green gram.

Treatments	100 seed weight (g)	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
S_1F_1	3.33	718.47	1640.40
S_1F_2	3.36	821.28	1848.81
S_1F_3	3.60	956.82	2099.99
S_1F_4	3.76	963.70	2055.90
S_2F_1	3.26	621.90	1292.74
S_2F_2	3.50	827.88	1619.58
S_2F_3	3.43	849.47	1775.05
S_2F_4	3.22	787.81	1739.89
S_3F_1	3.33	814.09	1633.38
S_3F_2	3.45	780.48	1611.95
S_3F_3	3.47	1058.75	2113.88
S_3F_4	3.30	944.43	1952.05
S_4F_1	3.43	506.31	1032.52
S_4F_2	3.44	464.26	1088.96
S_4F_3	3.37	658.36	1428.23
S_4F_4	3.40	593.87	1293.38
SEm (±)	0.09	52.84	105.04
CD (0.05)	NS	NS	NS

4.4 OBSERVATIONS ON WEEDS

The data on weed observations as influenced by spacing and foliar application during the crop period are presented below. The observations were taken at 15 DAS, 30 and at 45 DAS.

4.4.1 Weed flora

Ten weed species were observed in experimental field (Table 15). The predominant weed species were grasses. The predominant species were *Oryza sativa, Echinochloa colona, Eleusine indica* and *Digitaria ciliaris.* Among, broad-leaved weeds *Cleome viscosa, Melochia corchorifolia, Mimosa pudica* and *Evolvulus nummularius*. *Cyperus iria* was the only sedge observed.

4.4.2 Weed density

At 15 and 30 DAS, there were no difference among the treatments but at 45 DAS, weed density was significantly influenced by spacing and foliar nutrition (Table 16a and 16b). Weed density was lower (9.75 m^{-2}) at 25 cm × 15 cm with double seedling $hill^{-1}$ (S_2). Weed density was higher (15.94 m^{-2}) with the spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3). Foliar nutrition with DAP @ 2% (F_2) recorded lower weed density (10.94 m^{-2}) and it was on par with KNO_3 @ 0.5% (F_3). The higher weed density (15.56 m^{-2}) was observed with urea @ 2% (F_1) and it was on par with DAP @ 2% + KNO_3 @ 0.5% (F_4).

The interaction effects were not significant.

4.4.3 Weed dry weight

The analysed data revealed that weed dry weight varied significantly with spacing and foliar nutrition only at 45 DAS (Table 17a and 17b). Highest weed dry weight (28.92 g m^{-2}) was observed with the spacing of 25 cm × 25 cm with single seedling $hill^{-1}$ (S_3) and it was statistically on par with spacing of 25 cm × 15 cm with single seedling $hill^{-1}$ (S_1). The lowest dry weight (18.54 g m^{-2}) was observed with the spacing of 25 cm × 15 cm with double seedling $hill^{-1}$ (S_2). Among the foliar nutrition treatments, urea @ 2% (F_1) and DAP @ 2% (F_2) recorded the highest and lowest dry weight of 29.62 g m^{-2} and 19.36 g m^{-2}, respectively.

The interaction effects of spacing and foliar nutrition were not significant.

Table 15. Weed flora observed in the experimental site

Scientific name	**Common name**	**Family**
Grasses		
Echinochloa colona	Jungle rice	Poaceae
Digitaria ciliaris	Crab weed/summer grass	Poaceae
Eleusine indica	Goose grass	Poaceae
Broad leaved weeds		
Melochia corchorifolia	Chocolate weed	Malvaceae
Cleome viscosa	Wild mustard	Cleomaceae
Phyllanthus niruri	Seed under leaf	Euphorbeaceae
Amaranthus viridis	Slender amaranth	Amaranthaceae
Mimosa pudica	Touch me not	Fabaceae
Evolvulus nummularius	Dwarf morning-glory	Convolvulaceae
Sedges		
Cyperus iria	Flat sedge	Cyperaceae

Table 16a. Effect of spacing and foliar nutrition on weed density, (No. m^{-2})

Treatments	15 DAS	30 DAS	45 DAS
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	6.31	10.88	14.44
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	5.44	9.25	9.75
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	5.88	9.88	15.94
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	6.00	9.94	13.00
SEm (±)	0.40	0.60	0.46
CD (0.05)	NS	NS	1.468
Foliar Nutrition (F)			
F_1- Urea @ 2%	6.13	10.25	15.56
F_2- DAP @ 2%	5.56	10.00	10.94
F_3- KNO_3 @ 0.5%	5.88	9.63	11.69
F_4- DAP @ 2% + KNO_3 @ 0.5%	6.06	10.06	14.94
SEm (±)	0.40	0.55	0.45
CD (0.05)	NS	NS	1.296

Table 16b. Interaction effect of spacing and foliar nutrition on weed density, (No. m^{-2})

Treatments	15 DAS	30 DAS	45 DAS
S_1F_1	6.25	11.00	16.75
S_1F_2	5.75	11.25	13.25
S_1F_3	6.75	9.50	11.00
S_1F_4	6.50	11.75	16.75
S_2F_1	6.00	9.50	12.00
S_2F_2	5.25	9.25	8.00
S_2F_3	5.00	10.00	8.00
S_2F_4	5.50	8.25	11.00
S_3F_1	6.25	10.50	18.50
S_3F_2	5.50	9.25	12.25
S_3F_3	5.75	9.50	15.25
S_3F_4	6.00	10.25	17.75
S_4F_1	6.00	10.00	15.00
S_4F_2	5.75	10.25	10.25
S_4F_3	6.00	9.50	12.50
S_4F_4	6.25	10.00	14.25
SEm (±)	0.79	1.11	0.90
CD (0.05)	NS	NS	NS

Table 17a. Effect of spacing and foliar nutrition on weed dry weight (g m^{-2})

Treatments	15 DAS	30 DAS	45 DAS
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	0.95	16.02	27.37
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	0.92	15.59	18.54
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	0.84	15.76	28.92
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	0.94	15.14	22.99
SEm (±)	0.10	1.57	0.76
CD (0.05)	NS	NS	2.421
Foliar Nutrition (F)			
F_1- Urea @ 2%	0.90	15.77	29.62
F_2- DAP @ 2%	0.93	15.39	19.36
F_3- KNO_3 @ 0.5%	0.89	15.18	23.02
F_4- DAP @ 2% + KNO_3 @ 0.5%	0.93	16.17	25.82
SEm (±)	0.07	1.26	0.61
CD (0.05)	NS	NS	1.762

Table 17b. Interaction effect of spacing and foliar nutrition on weed dry weight (g m^{-2})

Treatments	15 DAS	30 DAS	45 DAS
S_1F_1	0.95	16.19	32.38
S_1F_2	0.89	15.80	23.95
S_1F_3	0.93	16.15	25.50
S_1F_4	1.03	15.93	27.65
S_2F_1	0.91	15.07	22.95
S_2F_2	0.97	14.60	14.15
S_2F_3	0.89	15.74	16.80
S_2F_4	0.94	16.97	20.28
S_3F_1	0.86	16.44	35.98
S_3F_2	0.90	15.66	21.15
S_3F_3	0.76	14.62	28.08
S_3F_4	0.84	16.31	30.48
S_4F_1	0.88	15.37	27.18
S_4F_2	0.97	15.52	18.20
S_4F_3	0.99	14.21	21.70
S_4F_4	0.91	15.47	24.88
SEm (±)	0.15	2.51	1.23
CD (0.05)	NS	NS	NS

4.5 QUALITY ANALYSIS

4.5.1 Crude Protein

The analysed data revealed that there were no significant variation in crude protein content due to spacing and foliar nutrition. The data is given in Table (18a and 18b).

Among the treatments, the crude protein content varied from 21.25 per cent to 22.23 per cent.

The interaction effects were found not significant.

Table 18a. Effect of spacing and foliar nutrition on crude protein content of green gram

Treatments	Crude protein content (%)
Spacing (S)	
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	21.85
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	21.89
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	21.63
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	21.75
SEm (±)	0.15
CD (0.05)	NS
Foliar Nutrition (F)	
F_1- Urea @ 2%	21.99
F_2- DAP @ 2%	21.92
F_3- KNO_3 @ 0.5%	21.65
F_4- DAP @ 2% + KNO_3 @ 0.5%	21.56
SEm (±)	0.19
CD (0.05)	NS

Table 18b. Interaction effect of spacing and foliar nutrition on crude protein content of green gram

Treatments	**Crude protein content (%)**
S_1F_1	21.75
S_1F_2	21.56
S_1F_3	22.23
S_1F_4	21.88
S_2F_1	22.08
S_2F_2	22.38
S_2F_3	21.88
S_2F_4	21.25
S_3F_1	22.13
S_3F_2	21.88
S_3F_3	21.25
S_3F_4	21.25
S_4F_1	22.00
S_4F_2	21.88
S_4F_3	21.25
S_4F_4	21.88
SEm (±)	0.37
CD (0.05)	NS

4.6 SOIL ANALYSIS

The analyzed data on organic carbon, available N, P, and K after the experiment are presented in Table 19a and 19b.

4.6.1 Organic carbon

Spacing and foliar nutrition had significant influence on organic carbon content of soil. S_1 recorded higher organic carbon content (1.48 %) which was at par with S_2. S_4 recorded the lower organic carbon (1.25 %) and was statistically at par with S_3.

Among the foliar nutrition treatments, DAP @ 2% (F_2) recorded higher organic carbon content (1.57 %) and it was on par with urea @ 2% (F_1). The lower organic carbon (1.20 %) was observed in DAP @ 2% + KNO_3 @ 0.5% (F_4) and it was on par with KNO_3 @ 0.5% (F_3).

All interactions were found not significant.

4.6.2 Available Nitrogen

The influence of spacing and foliar nutrition on nitrogen content of soil was found significant. S_1 recorded more soil nitrogen (378.06 kg ha^{-1}) and it was on par with S_2. The soil nitrogen was lower (321.60 kg ha^{-1}) with S_4 and it was statistically on par with S_3.

Among foliar treatments, DAP @ 2% (F_2) recorded highest soil nitrogen (451.89 kg ha^{-1}) and the lowest content (265.99 kg ha^{-1}) was observed with DAP @ 2% + KNO_3 @ 0.5% (F_4).

The interaction effects were found to be significant. The highest available N content (587.68 kg ha^{-1}) of soil was recorded in S_1F_2 and the lowest (176.78 kg ha^{-1}) was in S_3F_4.

4.6.3 Available Phosphorus

The analysed data revealed that the influence of spacing and foliar nutrition on phosphorus content of soil was significant. S_3 recorded higher available P

(112.42 kg ha^{-1}) and it was on par with S_2. The lowest available P (76.22 kg ha^{-1}) was observed with S_1.

Foliar nutrition with DAP @ 2% + KNO_3 @ 0.5% (F_4) recorded more (113.42 kg ha^{-1}) available P and it was on par with KNO_3 @ 0.5% (F_3). The lower content (82.24 kg ha^{-1}) was observed in urea @ 2% (F_1) and it was on par with DAP @ 2% (F_2).

The interaction effects were significant. The higher available P (144.13 kg ha^{-1}) was recorded with S_2F_4 and the lowest was observed in S_1F_2.

4.6.4 Available Potassium

Spacing and foliar nutrition were significantly influenced the available K status. Among the spacing methods, S_1 recorded higher K value of 193.60 kg ha^{-1} and it was on par with S_2. The lowest (153.40 kg ha^{-1}) was found with S_4 which was significantly inferior to all other spacing treatments.

Foliar nutrition with DAP @ 2% + KNO_3 @ 0.5% (F_4) recorded the highest available K (191.39 kg ha^{-1}) soil, and the lower content (158.74 kg ha^{-1}) was observed with urea@2% (F_1) which was at par with DAP @ 2% (F_2).

Among the interaction effects, the highest available K (270.20 kg ha^{-1}) was recorded with S_2F_4 and lower content was observed in S_4F_1.

4.7 NUTRIENT UPTAKE AT HARVEST

The uptake of nutrients (N, P and K) were significantly influenced by spacing and foliar nutrition (Table 20a and 20b).

Higher nitrogen uptake (48.27 kg ha^{-1}) was recorded with S_1, which was at par with S_2. The lowest uptake (30.64 kg ha^{-1}) was recorded with S_4. Among the foliar nutrition treatments, the highest (49.60 kg ha^{-1}) and the lowest (32.45 kg ha^{-1}) N uptake were recorded with DAP @ 2% + KNO_3 @ 0.5% (F_4) and DAP @ 2% (F_2), respectively. Similarly, among interactions, S_1F_4 recorded the higher N uptake (62.36 kg ha^{-1}) and lower (25.76 kg ha^{-1}) was observed in S_3F_2.

The higher uptake of P (9.14 kg ha^{-1}) was also recorded with S_1 and was at par with S_3. The lower P uptake (6.34 kg ha^{-1}) was recorded in S_4 which was at par with S_2. Among the foliar nutrition treatments, the highest P uptake (10.11 kg ha^{-1}) was recorded by DAP @ 2% + KNO_3 @ 0.5% (F_4) and lower P uptake (5.96 kg ha^{-1}) was observed with urea @ 2% (F_1) which was at par with DAP @ 2% (F_2). Among the interaction effects, the treatment combination of S_3F_4 recorded the higher P uptake and the lowest was observed with S_4F_1.

S_1 recorded the highest K uptake (30.47 kg ha^{-1}). The lowest K uptake (13.19 kg ha^{-1}) was recorded with S_4. Foliar nutrition with KNO_3 @ 0.5% (F_3) recorded higher K uptake (27.07 kg ha^{-1}) and it was statistically on par with DAP @ 2% + KNO_3 @0.5% (F_4). The lower K uptake (17.24 kg ha^{-1}) was recorded by DAP @ 2% (F_2) and it was on par with urea @ 2% (F_1). Among the interaction effects, S_1F_1 recorded higher K uptake (34.61 kg ha^{-1}) and the lower uptake was observed with the treatment combination of S_4F_2 with the value of 9.62 kg ha^{-1}.

Table 19a. Effect of spacing and foliar nutrition on soil organic carbon, available N, P and K at harvest

Treatments	Organic carbon (%)	Available Nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Available Potassium (kg ha^{-1})
Spacing (S)				
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	1.48	378.06	76.22	193.60
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	1.44	363.68	111.35	189.17
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	1.34	331.47	112.42	161.68
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	1.25	321.60	86.46	153.41
SEm (±)	0.04	7.59	3.09	2.29
CD (0.05)	0.116	24.284	9.878	7.327
Foliar Nutrition (F)				
F_1- Urea @ 2%	1.44	379.40	80.35	158.74
F_2- DAP @ 2%	1.57	451.89	82.24	163.41
F_3- KNO_3 @ 0.5%	1.31	297.53	110.43	184.32
F_4- DAP @ 2% + KNO_3 @ 0.5%	1.20	265.99	113.42	191.39
SEm (±)	0.06	4.96	2.47	2.33
CD (0.05)	0.171	14.230	7.080	6.692

Table 19b. Interaction effect of spacing and foliar nutrition on soil organic carbon, available N, P and K at harvest.

Treatments	**Organic carbon (%)**	**Available Nitrogen (kg ha^{-1})**	**Available Phosphorus (kg ha^{-1})**	**Available Potassium (kg ha^{-1})**
S_1F_1	1.53	294.65	71.56	185.58
S_1F_2	1.62	587.68	48.65	203.88
S_1F_3	1.42	335.40	77.19	211.63
S_1F_4	1.35	294.50	107.47	173.34
S_2F_1	1.58	400.83	89.82	161.33
S_2F_2	1.68	398.33	94.33	151.88
S_2F_3	1.33	319.83	117.13	173.28
S_2F_4	1.18	335.73	144.13	270.20
S_3F_1	1.38	413.78	88.81	144.83
S_3F_2	1.51	401.23	93.13	149.28
S_3F_3	1.26	334.10	137.23	185.85
S_3F_4	1.22	176.78	130.49	166.78
S_4F_1	1.26	408.35	71.21	143.25
S_4F_2	1.46	420.33	92.87	148.60
S_4F_3	1.23	200.78	110.17	166.53
S_4F_4	1.05	256.95	71.61	155.25
SEm (±)	0.12	9.92	4.94	4.67
CD (0.05)	NS	28.460	14.159	13.384

Table 20a. Effect of spacing and foliar nutrition on nutrient uptake (kg ha^{-1}) by green gram at harvest

Treatments	Nutrient uptake		
	Nitrogen	**Phosphorus**	**Potassium**
Spacing (S)			
S_1- Spacing of 25 cm × 15 cm with single seedling $hill^{-1}$	48.27	9.14	30.47
S_2- Spacing of 25 cm × 15 cm with double seedling $hill^{-1}$	47.31	7.34	21.65
S_3- Spacing of 25 cm × 25 cm with single seedling $hill^{-1}$	39.74	8.35	25.21
S_4- Spacing of 25 cm × 25 cm with double seedling $hill^{-1}$	30.64	6.34	13.19
SEm (±)	1.74	0.39	1.53
CD (0.05)	5.564	1.251	4.912
Foliar Nutrition (F)			
F_1- Urea @ 2%	40.96	5.96	19.14
F_2- DAP @ 2%	32.45	6.81	17.24
F_3- KNO_3 @ 0.5%	42.94	8.29	27.07
F_4- DAP @ 2% + KNO_3 @ 0.5%	49.60	10.11	27.06
SEm (±)	2.25	0.31	1.04
CD (0.05)	6.451	0.883	2.984

Table 20b. Interaction effect of spacing and foliar nutrition on nutrient uptake (kg ha^{-1}) by green gram at harvest.

Nutrient uptake			
Treatments	**Nitrogen**	**Phosphorus**	**Potassium**
S_1F_1	61.59	7.77	34.61
S_1F_2	37.77	9.22	25.93
S_1F_3	31.35	9.70	32.11
S_1F_4	62.36	9.86	29.24
S_2F_1	36.85	5.00	11.16
S_2F_2	39.30	5.80	16.03
S_2F_3	56.67	7.58	29.73
S_2F_4	56.41	10.96	29.67
S_3F_1	38.10	7.40	18.90
S_3F_2	25.76	7.03	17.74
S_3F_3	43.40	7.91	29.96
S_3F_4	51.71	11.08	34.22
S_4F_1	27.32	3.68	11.89
S_4F_2	26.97	5.18	9.26
S_4F_3	40.32	7.95	16.49
S_4F_4	27.93	8.54	15.12
SEm (±)	4.50	0.62	2.08
CD (0.05)	12.901	1.765	5.969

4.8 ECONOMIC ANALYSIS

The results are presented in Table 21.

Among the treatment combinations, economic analysis revealed that the spacing of 25 cm × 25 cm with single seedling per hill (S_3) along with foliar application of KNO_3 @ 0.5% (F_3) recorded the highest net income (₹ 43868 ha^{-1}) and benefit cost ratio (1.75). Irrespective of foliar application, S_4 (25 cm × 25 cm with double seedling per hill) and the treatment combination S_2F_2 (spacing of 25 cm × 15 cm with double seedling per hill + DAP @2%) were observed to be non-profitable as indicated by negative values for net returns and benefit cost ratios of less than unity.

Table 21. Interaction effect of spacing and foliar nutrition on economics of green gram

Treatments	Net Income (₹ ha^{-1})	BCR
S_1F_1	11266	1.19
S_1F_2	21114	1.36
S_1F_3	33981	1.58
S_1F_4	34398	1.58
S_2F_1	-3870	0.94
S_2F_2	15984	1.25
S_2F_3	17798	1.28
S_2F_4	11567	1.18
S_3F_1	20542	1.35
S_3F_2	17157	1.29
S_3F_3	43868	1.75
S_3F_4	32529	1.55
S_4F_1	-15083	0.77
S_4F_2	-19287	0.70
S_4F_3	-740	0.99
S_4F_4	-7245	0.89

DISCUSSION

5. DISCUSSION

An experiment entitled "Productivity enhancement of green gram (*Vigna radiata* (L.) Wilczek) under system of crop intensification (SCI)" was undertaken to standardize the plant population and to assess the effect of foliar nutrition in enhancing the productivity of green gram under system of crop intensification. The results of the experiment presented in the previous chapter are discussed below.

5.1 EFFECT OF SPACING AND FOLIAR NUTRITION ON GROWTH ATTRIBUTES OF GREEN GRAM UNDER SCI

Planting pattern is an important parameter determining individual crop plant performance. Maintaining optimum spacing between the plants ensures sufficient light, nutrients, and moisture, which results in improved plant growth. To boost the productivity of green gram application of optimum quantity of nutrients specifically in the form of foliar spray has advantage of quick and efficient utilisation of nutrients with minimum losses. The results revealed that spacing and foliar nutrition had a significant effect on the productivity of green gram under SCI.

The results clearly indicated that at harvest single seedling per hill recorded more plant height than double seedling per hill (Fig.3). This may be due to more availability of resources to the plant and less competition between plants. Taller plants with more number of leaves were recorded with the spacing of 25 cm × 15 cm with one seedling per hill (S_1). This might be due to competition between plants for nutrients, sunlight, water, and space at closer spacing, hence promoted vertical development over horizontal growth (Sathiyavani *et al.,* 2016).

The ability of crop to produce branches is predominantly a genetic trait, but environmental factors may also affect the number of branches per plant, which is essential for increasing the seed output of green gram.

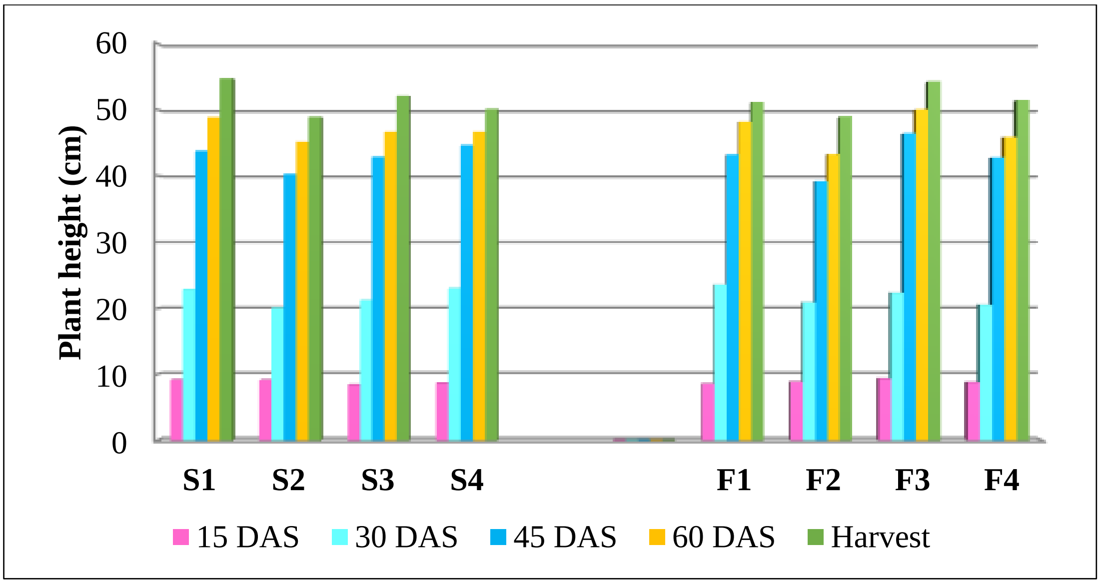

Fig.3 Plant height of green gram as influenced by spacing and foliar nutrition

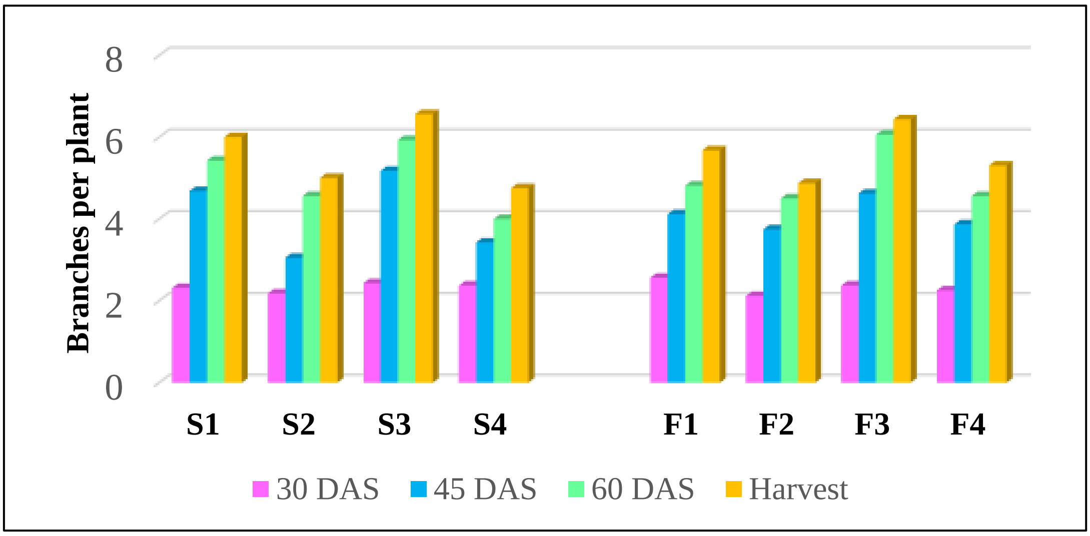

Fig.4 Branches per plant of green gram as influenced by spacing and foliar nutrition

The number of branches was higher with S_3 and it is on par with S_1. The results clearly indicated that optimum spacing with reduced plant density might have provided more room for the plant to produce a greater number of branches (Fig.4). Double seedling per hill treatments recorded the lowest number of branches, this might be due to absence of horizontal space for the plant to expand its canopy and due to high plant density. The higher leaf area (Fig.5) and dry matter production in S_3 and S_1 were due to vigorous growth of the plant due to less intra and inter specific competition The key agronomic management variables that can alter the dynamics of leaf area development, which in turn affects radiation absorption, biomass accumulation, and grain yield, are plant densities and row spacing (Hammer *et al.*, 2014). Days to 50 per cent flowering is governed by phenology of the particular cultivar, than due to spacing. Thus, spacing had no influence on days to 50 per cent flowering.

Foliar application of nutrients is a key crop management technique that aids in maximising crop yields by supplementing soil fertilisation. The application of fertilizers through foliar application is productive and cost-effective way to supplement the nutrient requirements during crucial phases in green gram. Plant height and number of branches per plant were not significantly influenced by the foliar nutrition during the initial stages, but at later stages application of KNO_3 @ 0.5% (F_3) recorded taller plants with more branches. The increase in plant height with foliar application of KNO_3 might be due better resilience towards moisture stress and in turn accelerated the plant growth effectively. Jagtap *et al.* (2021) and Athnere *et al.* (2021) also reported increase in growth attributes with the application of potassium nitrate.

The results clearly revealed the influence of spacing and foliar nutrition on number of leaves, leaf area and dry matter production under SCI. The results on spacing revealed that single seedling per hill at both spacings recorded more leaf area with higher dry matter production. Foliar application treatments, with KNO_3 @ 0.5% (F_3) and DAP @ 2% + KNO_3 @ 0.5 % (F_4) produced more leaf area that leads to enhanced DMP. These findings support those Ali *et al.* (2016) who observed that applying foliar nutrients enabled greater availability and reduced interference with nutrient absorption. This paves the way for production of more biomass, which increased the amount of dry matter. This is also due to the foliar application of higher concentration of multi nutrients at critical growth stages increased the growth and yield parameters (Neethu and Kaleeswari, 2018).

Application of sufficient nutrients, particularly in the form of foliar spray, provides the added benefit of promoting rapid and effective absorption of nutrients (Kulkarni *et al*., 2015). Among the treatment combinations, maximum number of leaves were produced with spacing of 25 cm × 25 cm with single seedling per hill applied with DAP @2% + KNO_3 @0.5 %. Number of branches plant^{-1} recorded higher with the combination of spacing of 25 cm × 25 cm with single seedling per hill and KNO_3 @0.5%. This is due to efficient translocation of applied nutrients over the crop canopy and optimum utilisation of available resources under reduced plant density. The spacing of 25 cm × 15 cm with one seedling per hill and urea @2% resulted in higher leaf area. Dey *et al*. (2017) also reported the enhanced nutrient availability to plants resulted in higher plant growth in terms of plant height and leaf area which in turn contributed higher DMP production.

Total dry matter production was higher with S_1 and F_4 during 30 and 60 DAS, and S_3 and F_3 at harvest. Nitrogen, phosphorus, and potassium are essential and basic macronutrients for plants. Nitrogen is associated with photosynthetic activity and plays an important role in the production of vegetative biomass. The partitioning of dry matter to grains during the pod filling phase and pod set are the two factors that impact grain yield in legumes like green gram (Geetika *et al.,* 2022).

5.2 EFFECT OF SPACING AND FOLIAR NUTRITION ON PHYSIOLOGICAL PARAMETERS OF GREEN GRAM

Physiological parameters are used to determine the changes in crop growth in relation to time and is a function of light interception of canopy and influenced by leaf area, photosynthetic rate, and leaf angle. The positive response on crop growth rate is due to phytohormone interaction on growth and development (Mir *et al*., 2010).

Physiological parameters like CGR, RGR, NAR and LAI were influenced by spacing and foliar nutrition. S_1 showed higher CGR, RGR and LAI, due to better growth attributes. LAI increased with crop growth up to 45 DAS and there after it gets declined (Fig.6). This was attributed to leaf fall and leaf senescence. Abid *et al*. (2018) reported that higher values of LAI resulted due to better branching which resulted in higher leaf area. In our experiment also S_1 had higher number of branches which resulted in higher LAI. NAR was higher with S_3, compared to narrow spacing, optimum spacing helps in proper utilization of growth resources, particularly solar radiation (Shiferaw *et al.,* 2018). Similarly, these results were validated by (Rambilash *et al*., 2012).

Kumar *et al*. (2018) observed that foliar nutrition at flowering stage had significant influence on CGR and RGR in black gram. The analysed data indicated that foliar application resulted in increased CGR values up to 60 days after sowing (DAS). The values for RGR showed a decreasing trend as crop advanced in age. LAI values were increased till the 45 DAS due to peak period of vegetative growth, after which they began to decline. This was in conformity with the findings of Abid (2017). For all the treatments, NAR showed a decreasing trend towards maturity. A similar decline in RGR due to decrease in NAR was also reported by Pooja A.P (2021) in black gram. Foliar nutrition with KNO_3 @ 0.5% (F_3) and DAP @ 2% + KNO_3 @ 0.5 % (F_4) might have met the nutrient requirement of the crop during critical stage, and thus the crop growth.

Among the treatment combinations, S_1F_4 recorded higher CGR. This might be due to dependence of CGR on radiation use efficiency (Cirilo *et al*. 2009). The value of RGR was higher initially and towards harvest, it declined gradually. The higher RGR were recorded with S_1F_4 at 45 DAS and S_3F_1 at 60 DAS. Net assimilation rate (NAR) is higher with S_4F_3 at 30 DAS, but the treatment

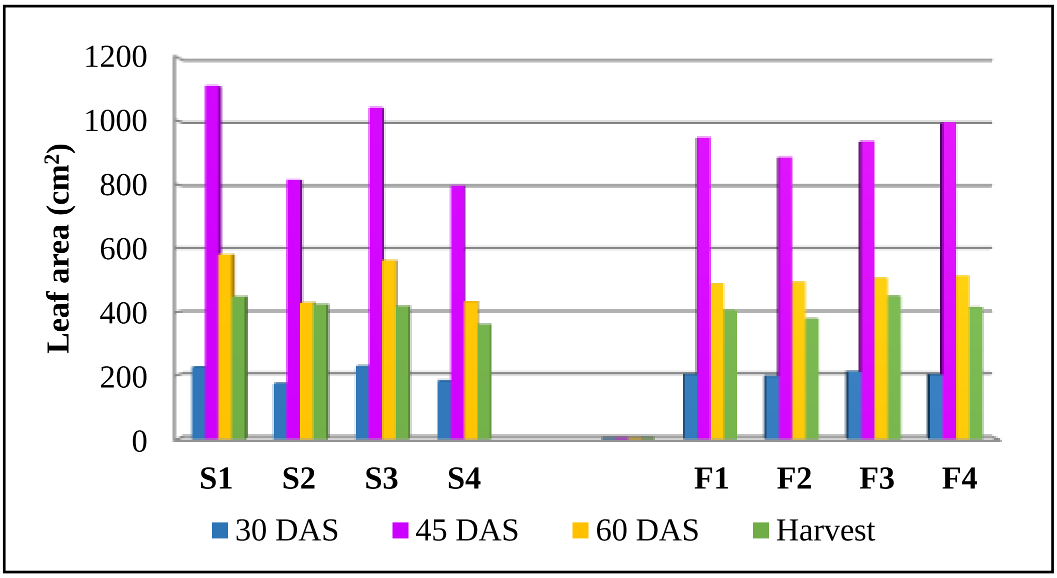

Fig.5 Leaf area of green gram as influenced by spacing and foliar nutrition

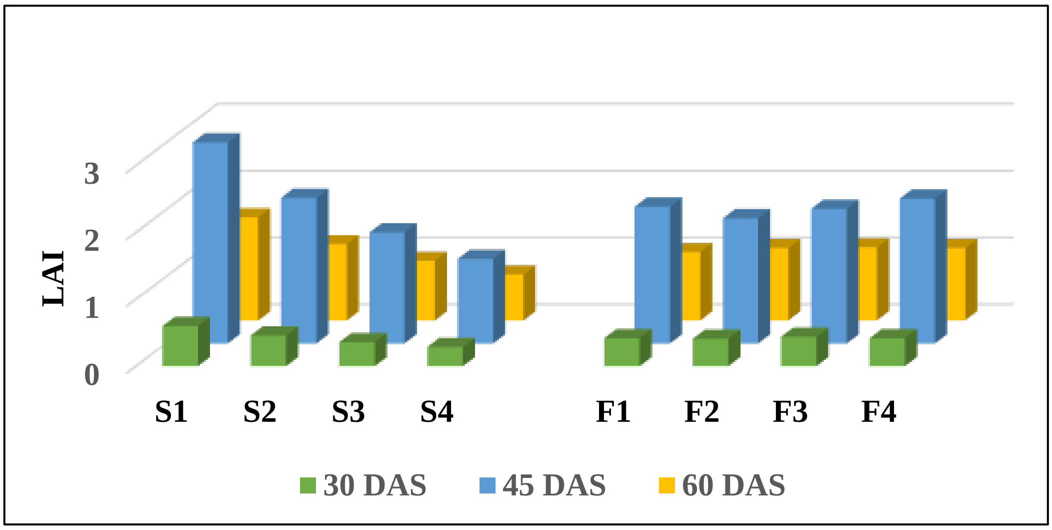

Fig.6 Leaf area index (LAI) of green gram as influenced by spacing and foliar nutrition

combination S_1F_4 recorded higher during 45 and 60 DAS. Increased dry matter production and optimum plant density might have resulted in higher NAR. LAI was higher with S_1F_2.

5.3. EFFECT OF SPACING AND FOLIAR NUTRITION ON YIELD, YIELD ATTRIBUTES AND QUALITY OF GREEN GRAM UNDER SCI

Multiple factors have a direct or indirect impact on yield attributes. Plant density have a major impact on the final yield of most legumes, maintaining optimum space to individual plants is critical for realising the maximum yield potential during the summer season (Pandey *et al.* 2022). Advancements in yield-attributing traits with optimum spacing and foliar nutrition results in an increased, number of pods plant^{-1}, number of seeds pod^{-1} and length of pod. But 100 seed weight and harvest index were not influenced by them.

S_3 recorded higher number of pods plant^{-1} and number of seeds pod^{-1}. Foliar application of N allows for a rapid and efficient transportation of N to the grain (Wagan *et al*., 2017). Pod length was higher with S_1. The difference may be due to better utilisation of applied nutrients and less competition due to wider spacing (Fig.7).

The results revealed that grain yield and haulm yield were significantly influenced by spacing (Fig.8). The spacing of 25 cm × 25 cm with single seedling per hill (S_3) recorded higher grain yield (899.44 kg ha^{-1}) and it was on par with S_1 and significantly superior to the other two spacings. This may be due to effective utilization of the growth resources, particularly due to space and solar radiation. These treatments have more leaf area and LAI indicating higher photosynthetic efficiency. When plants suffered due to mutual shading in case of adjoining rows and more plants in double seedling treatments the yield were drastically reduced to 10.7 per cent and 38.2 per cent in S_2 and S_4, respectively over their single seedling treatments. Similar results were reported by Sathiyavani *et al.* (2016). The high grain yield can also be due to the absence of weed interference as reported by

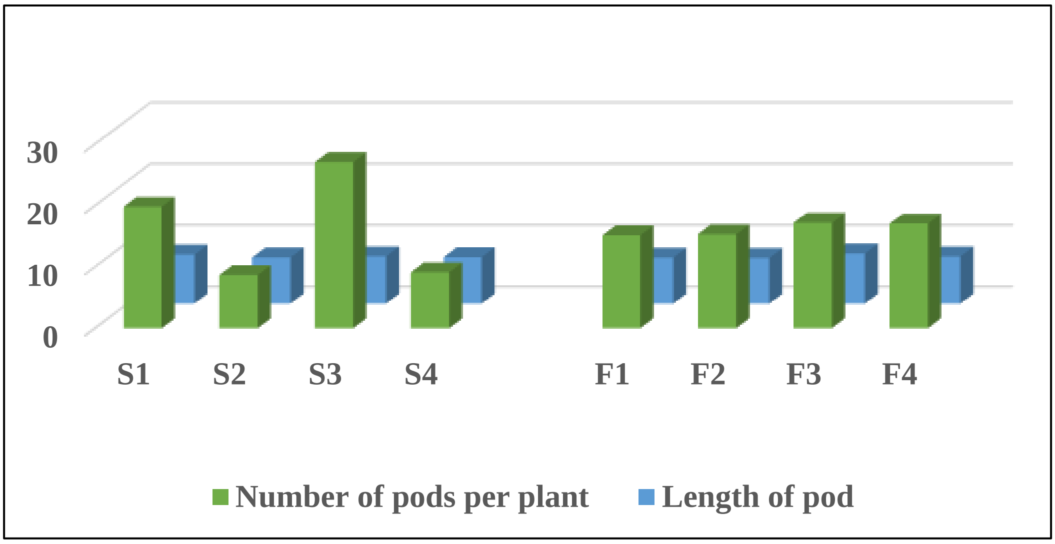

Fig.7 Yield attributes of green gram as influenced by spacing and foliar nutrition

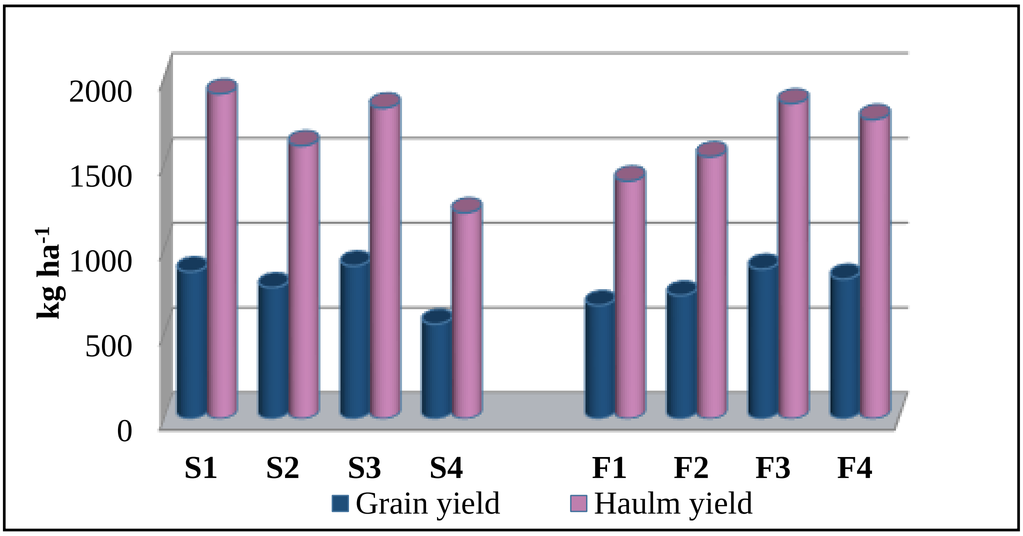

Fig.8 Grain yield and haulm yield of green gram as influenced by spacing and foliar nutrition

Strydhorst *et al*. (2008). S_4 recorded the lowest (555.70 kg ha^{-1}) seed yield. This may be due to more competition for resources between plants for water and soil nutrients led to lesser yield. The haulm yield was higher with S_1 and it was on par with S_3, this is due to more amount of dry matter produced by plant population per unit area. Even though more plant density was observed with S_2, but the amount of dry matter produced per plant was low due to heavy competition among the plants for growth resources resulted in shorter plants.

The number of pods, length of pod and number of seeds per pod were higher with the foliar application of KNO_3 @ 0.5% (F_3). Higher grain yield (880.85 kg ha^{-1}) was observed with foliar nutrition of KNO_3 @ 0.5% (F_3) it was on par with DAP @2% + KNO_3@0.5% (F_4). Haulm yield also followed the same trend as grain yield. When macro and micronutrients were administered to the foliage during crucial phases of the crop, they were efficiently absorbed and transferred to the growing pods, resulting in a greater quantity and better-filled pods. Crop productivity may be impacted by the NPK ratio being balanced and the ease with which nutrients are assimilated, which could lead to an increase in yield. Water-soluble nutrient spraying promotes nutrient and water uptake, enhancing photosynthesis and food accumulation in edible parts (Phandis, 2010).

This might be also due to the ability of potassium nitrate to tolerate the water stress and thus helped in retention of a greater number of flowers leading to more yield attributes and final yield. These findings are in line with Athnere *et al.* (2021), Jagtap *et al*. (2021) and Neethu and Kaleeswari (2018) in summer green gram. This is also credited with rapid absorption and complete utilization of nutrients thus mitigating the nutrient stress.

Among the treatment combinations, S_1F_3 recorded the higher pod length. This might be due to less competition and effective utilisation of translocated photosynthates from source to sink. Optimization of N and K nutrient interactions resulted in better yield attributes. The results demonstrated that supplying legume plants with supplemental nitrogen has positive impact on boosting growth and increasing seed output.

The crude protein content of green gram was not influenced by spacing and foliar nutrition.

5.4 EFFECT OF SPACING AND FOLIAR NUTRITION ON WEED FLORA, WEED DENSITY AND WEED DRY WEIGHT UNDER SCI

In general, for short duration pulses the critical period of crop weed competition were 30 and 60 DAS for short and long duration pulses, respectively (Kumar *et al*., 2016). The composition of weed flora over the experimental plot were grasses, sedges, and broad-leaved weeds. This composition is same as that of wet land rice field as the green gram was raised in the summer-fallows.

Weed density and weed dry weight varied with plant population (Fig.9 &10). During the study, lower density of weeds and dry weight were observed with S_2. This might be due to competition for the natural resources among inter plant population and weeds. A substantial number of studies have found that increased crop density results in increased weed suppression. Higher weed density and weed dry weight were observed with S_3.

Wider spacing might have intercepted more solar radiation which will stimulate the vigorous growth of weeds resulted in higher weed density and biomass. These results are in conformity with Aslam *et al*. (2007).

Among the foliar nutrition treatments, the lowest weed density and weed dry weight were reported by DAP @2% (F_2) and the highest was reported by urea @2% (F_1). The favourable effect of foliar application of fertilizers on weeds might be due to improved photosynthetic efficiency. The application of urea may cause more vegetative growth resulted in high dry matter production.

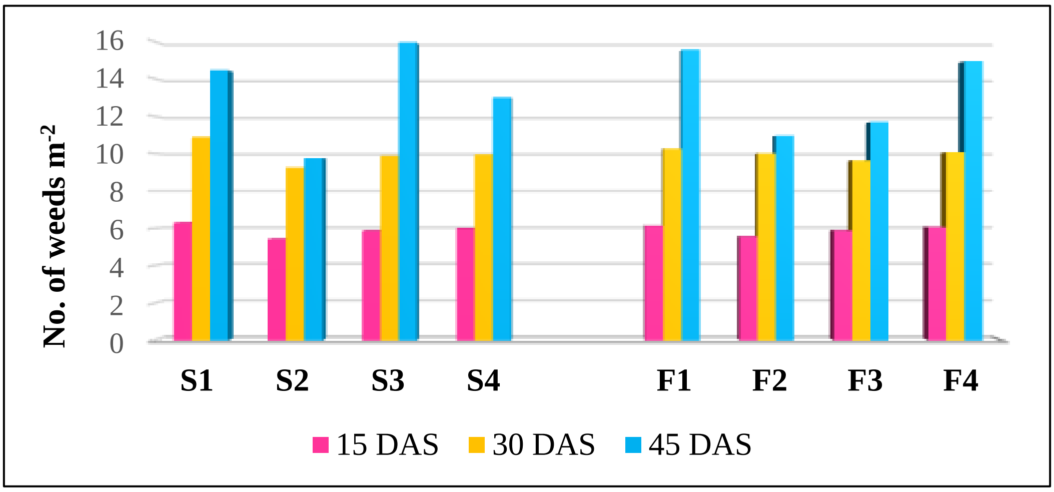

Fig.9 Weed density as influenced by spacing and foliar nutrition

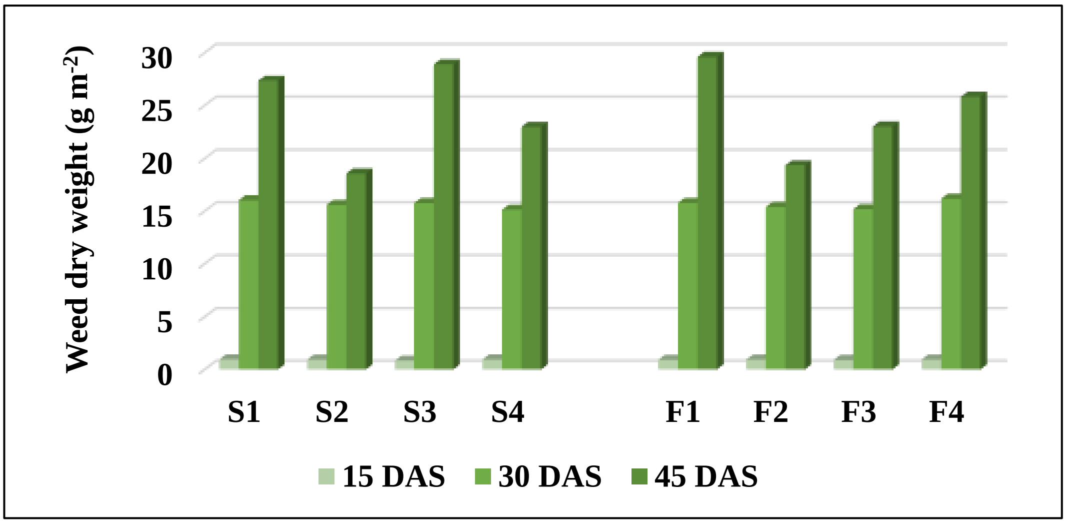

Fig.10 Weed dry weight as influenced by spacing and foliar nutrition

5.5 EFFECT OF SPACING AND FOLIAR NUTRITION ON SOIL ORGANIC CARBON AND AVAILABLE NPK UNDER SCI

There were significant variation in organic carbon content and available N, P and K in soil after the experiment (Fig.11). Studies conducted by Jensen *et al*. (2012) also reported that the inclusion of legumes in crop rotation improves the organic carbon and available nutrients in the soil. Bindhu *et al*. (2014) also reported the positive build-up of nitrogen through sustainable crop intensification with green gram and black gram in summer fallows.

The highest organic carbon was reported by S_1 which was on par with S_2. This might be due to the decomposition of applied farm yard manure coupled with left over residue of previous rice crop. Foliar nutrition with DAP @2% (F_2) recorded higher value which was on par with urea @2% (F_1). Bochalya *et al*. (2021) also reported the increased organic carbon status of soil with foliar application of nutrients.

The perusal of data on soil NPK status after the experiment revealed that, there was significant difference among soil NPK status with respect to spacing, foliar nutrition and their interactions. Thamburaj (1991) reported that legumes in crop rotation increased the NPK content of the soil after the experiment.

The treatments with more plant population reported to have higher soil NPK, this may be due to high plant density, deep tap root system, and absence of weed interference. Available NPK was found to be higher in the treatments with higher organic carbon, may be due to better fixation of atmospheric nitrogen. Sakin (2012) also reported that soil organic carbon influence has a positive influence on nitrogen content.

In case of foliar nutrition, DAP @2% (F_2) and DAP @2% + KNO_3 @0.5% (F_4) had the synergistic effects NP and NPK positive nutrient interactions, which might have promoted growth parameters, better root proliferation and development thus helped in greater mobilization of available nutrients. The interaction effect was reflection of main and sub-plot factors, S_1F_2 recorded the higher nitrogen,

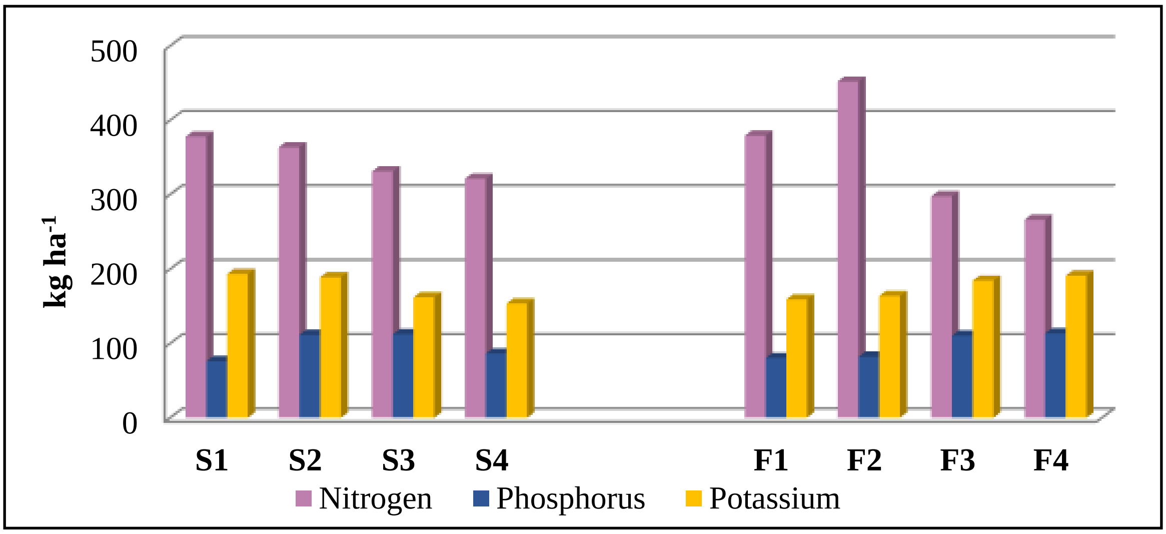

Fig.11 Soil nutrient status after the experiment as influenced by spacing and foliar nutrition

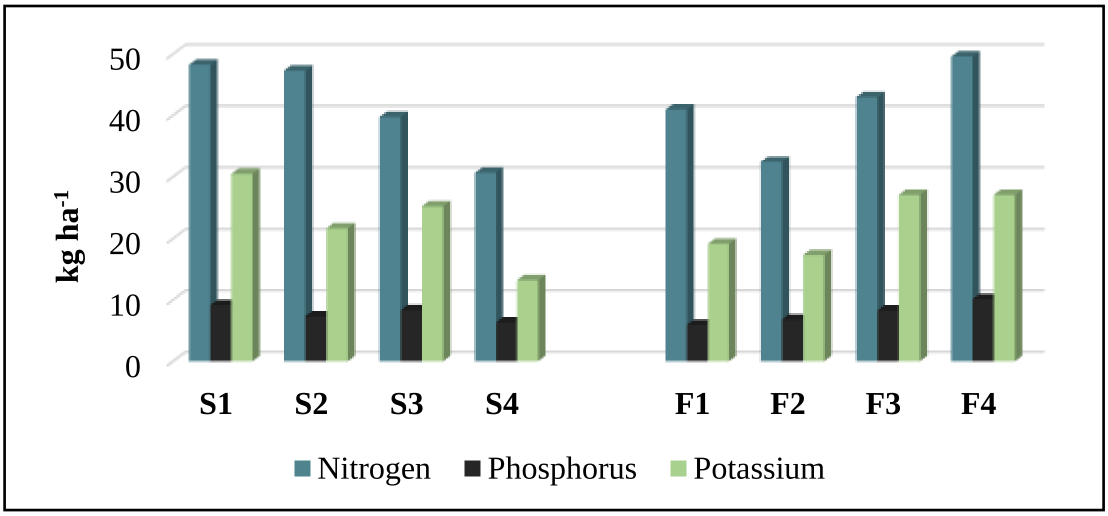

Fig.12 N, P and K uptake at harvest as influenced by spacing and foliar nutrition

phosphorus status and potassium were higher in S_2F_4. This can be correlated with higher plant population accompanied with more nodule number which might have contributed to greater rhizo-deposition.

5.6 EFFECT OF SPACING AND FOLIAR NUTRITION ON UPTAKE OF NUTRIENTS UNDER SCI

Nutrient uptake by crop is related to nutrient content in the plant and dry matter production which in turn depends on photosynthetic ability of the plant. Comparatively higher NPK uptake were observed with S_1 and with S_3 (Fig.12). These treatments had increased growth attributes *viz*., plant height, number of leaves per plant, number of branches and LAI, thus resulted in higher DMP.

Among the foliar nutrition treatments, higher N and P uptake was observed with DAP @2% + KNO_3 @0.5% (F_4), and K uptake was noticed with KNO_3 @ 0.5% (F_3). This could be due to the effective translocation of multi-nutrients applied *via* foliage, which leads to increased activity of functional root nodules, resulting in increased leaf area, DMP, and nutrient uptake. Fritzs (1978) reported that small amounts of fertilizers applied through foliar nutrition at critical stages stimulates the plant metabolism and increases the uptake of nutrients. Among the treatment combinations, higher uptake of NPK was observed in S_3F_2, S_3F_4 and S_1F_1, respectively. Increased photosynthetic efficiency, assimilation and dry matter production and uptake of nutrients was reported by Amjad *et al.* (2004) and Calhor (2006). This can also be due to lower weed density and weed dry matter production in these treatments.

5.7 EFFECT OF SPACING AND FOLIAR NUTRITION ON ECONOMICS OF GREEN GRAM UNDER SCI

Adoption of cultivation practices depends on the economic feasibility. The perusal data of the study showed that economic analysis also followed the same trend as that of grain yield of green gram. The net income and benefit cost ratio varied with spacing and number of seedlings per hill. The spacing of 25 cm × 25 cm with single seedling per hill (S_3) supplied with foliar nutrition of KNO_3 @ 0.5% (F_3) recorded the higher net returns and benefit cost ratio. This clearly shows that foliar application of nutrients is the cheapest cultural practice that could fetch higher profits with minimum production cost. These results are in conformity with the findings of Sathiyavani *et al.* (2016) in green gram and Singh *et al.* (2009) in black gram. This might due to effective utilisation of both above and below ground resources effectively thus contributing to better growth and yield attributes. The BCR were depicted in Fig. 13.

From the study it could be concluded that, planting green gram at a spacing of 25 cm x 25 cm with single seedling per hill with recommended dose of fertilizers, supplemented with foliar application of KNO_3 at 0.5% at 15 and 30 DAS could be recommended for higher productivity and profitability of the crop in summer rice fallows under the system of crop intensification.

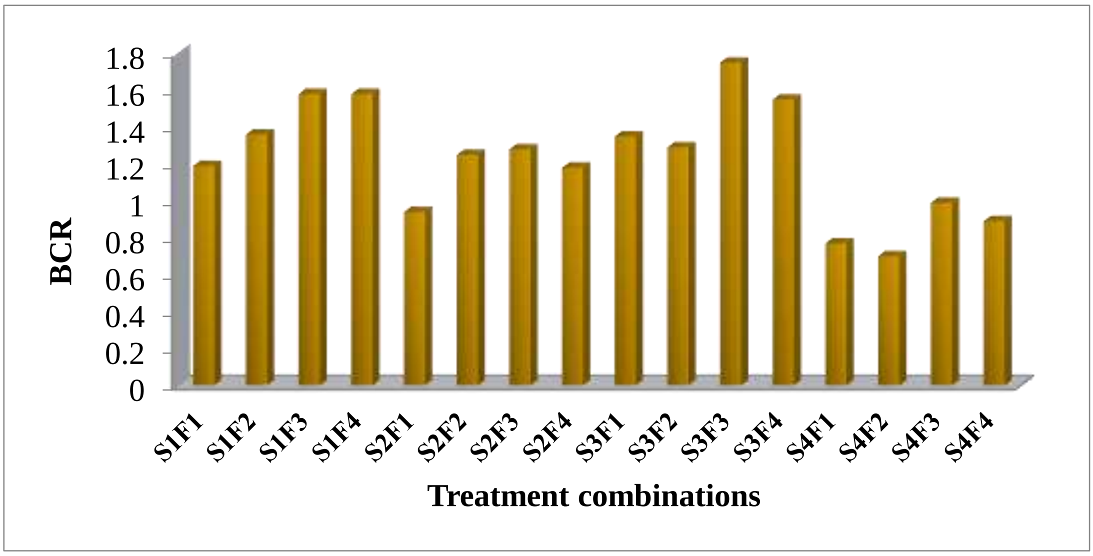

Fig.13 B:C ratio as influenced by spacing and foliar nutrition in green gram

SUMMARY

6. SUMMARY

An experiment entitled "Productivity enhancement of green gram (*Vigna radiata* (L.) Wilczek) under system of crop intensification (SCI)" was undertaken to standardize the plant population and to assess the effect of foliar nutrition in enhancing the productivity of green gram under system of crop intensification. The experiment was conducted during February 2022 to May 2022 at farmer's field Varkala, Thiruvananthapuram.

The experiment was laid out in split plot design with 16 treatment combinations and four replications. The main plot treatment was spacing (S_1- spacing of 25 cm x 15 cm with single seedling per hill, S_2 - spacing of 25 cm x 15 cm with double seedling per hill, S_3 -spacing of 25 cm x 25 cm with single seedling per hill, S_4- spacing of 25 cm x 25 cm with double seedling per hill) and the sub plot treatment was foliar application (F_1 - Urea at 2%, F_2 - DAP at 2%, F_3 - KNO_3 at 0.5%, F_4 - DAP at 2% + KNO_3 at 0.5% at 15 and 30 DAS).

The results of the experiment are summarized below.

The growth attributes of green gram were recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS and at harvest. Growth attributes varied significantly due to spacing and foliar nutrition.

During the crop period, at 15 DAS plant height was not influenced by spacing. At 30 DAS, taller (23.04 cm) plants were observed in S_4, and it was at par with S_1. The shortest (20.08 cm) plants were observed in S_2. At 15 and 30 DAS, there were no significance influence of foliar nutrition on plant height. F_3 recorded the tallest (46.44 cm and 50.06 cm, respectively) plants and was superior to all other treatments at 45 and 60 DAS. The interaction among spacing and foliar nutrition were not significant at any stage of the study.

At 45 DAS, more number of leaves (8.37) were observed with S_1 and it was par with S_3. Lower number of leaves $plant^{-1}$ (5.50) was observed with the S_2 and it was on par with S_4. At 60 DAS, the highest number of leaves (5.75) was observed with S_3 and S_2 recorded the lowest number of leaves plant^{-1} (3.93). Foliar nutrition had no significant influence on number of leaves plant^{-1} at initial and later stages of crop growth. But at 45 DAS, the highest number of leaves (8.37) were observed with F_4. All other treatments were at par. Interaction effects were found to be significant at 45 DAS. The highest number of leaves were recorded in S_3F_4.

S_3 recorded more branches plant^{-1} (5.18, 5.93 and 6.56, respectively) at 45, 60 DAS and at harvest which was at par with S_1. During the initial stages of crop growth foliar nutrition has no significant influence on branching. F_3 recorded the highest number of branches (4.62, 6.06 and 6.43, respectively) at 45 DAS, 60 DAS and at harvest and all other treatments were statistically on par. Interaction effect found to be significant at 60 DAS and at harvest. At both the stages the treatment combination, S_3F_3 recorded higher number of branches and found to be statistically on par with S_1F_3.

At 30 DAS, S_3 recorded higher leaf area (227.62 cm^2) and it was on par with S_1. At 45 DAS, S_1 recorded the highest leaf area (1110.26 cm^2) and the lower leaf area (798.26 cm^2) was recorded in S_4. Foliar nutrition had significant influence on total leaf area at 45 DAS, the highest leaf area (995.29 cm^2) was recorded in F_4 while the lowest leaf area (886.35 cm^2) was recorded in F_2. Among the treatment combinations higher leaf area was recorded with the S_1F_1 and S_1F_4 at 45 DAS. The results revealed that treatments had no influence on days to 50 per cent flowering.

S_1 produced more dry matter (6.42, 12.86, 22.45, and 44.33, g plant^{-1} respectively) at 30 DAS, 45 DAS, 60 DAS and at harvest, and it was on par with S_3. At 30 DAS, F_4 recorded the highest dry matter (6.12 g plant^{-1}) and it was at par with F_3. At 45 DAS, F_3 recorded more dry matter (11.67 g plant^{-1}) and it was at par with F_4. At 60 DAS, F_4 recorded the highest dry matter (19.84 g plant^{-1}) and it was at par with F_3. But at harvest, F_3 recorded the highest dry matter (36.49 g plant^{-1}). Interaction effects of spacing and foliar nutrition were found to be significant at 30, 60 DAS and at harvest.

The physiological parameters, CGR, RGR, NAR, and LAI varied significantly with spacing and foliar nutrition. At 15-30 DAS, 30-45 and 45-60 DAS, S_1 recorded higher 6.60 g m^{-2} d^{-1}, 14.47 and 17.03 g m^{-2} d^{-1}, respectively values of CGR. At 15-30 DAS, foliar nutrition with F_3 and F_1 recorded the highest and lowest (5.95 and 4.83 g m^{-2} d^{-1}) CGR, respectively. However, at 30-45 and 45-60 DAS, F_4 recorded highest (10.00 and 11.79 g m^{-2} d^{-1}, respectively). Among interactions. at 30-45 DAS, highest CGR was recorded in S_1F_4 and the lowest was observed in S_4F_2. At 45-60 DAS, S_1F_4 recorded highest CGR and the lowest CGR was observed in S_4F_1.

S_1 recorded higher values of RGR 0.029 and 0.016 g g^{-1} d^{-1}, respectively at 30-45 and 45-60 DAS. F_4 recorded higher RGR (0.026 g g^{-1} d^{-1}) and was at par with F_1 and lower RGR (0.022 g g^{-1} d^{-1}) were recorded in F_2 and F_3. At 45 DAS, higher RGR was recorded with the treatment combination of S_1F_4 and lower RGR were observed with S_4F_2. At 45-60 DAS, higher RGR was recorded with S_3F_1 and lowest RGR with S_4F_1.

The results revealed that, NAR showed a decreasing trend with increasing crop duration. At 30-45 DAS, S_1 recorded the highest NAR (4.20 g cm^{-2} d^{-1}). At 45-60 DAS, higher NAR (3.47 g cm^{-2} d^{-1}) was recorded with S_3 and it was at par with S_1 and S_2. At 15-30 DAS, higher NAR (12.41 g cm^{-2} d^{-1}) was recorded with F_3 and it was on par with F_2 and F_4. At 45-60 DAS, F_4 recorded higher NAR (3.23 g cm^{-2} d^{-1}) and it was on par with F_3. Interaction effect of spacing and foliar nutrition found to be significant during all growth stages.

The results revealed that at 30 DAS, 45 and 60 DAS, S_1 recorded higher LAI (0.6, 3.00 and 1.54, respectively) and the lower LAI (0.29, 1.26 and 0.69, respectively) was observed with S_4. LAI was significantly influenced by foliar nutrition only at 45 DAS. The highest LAI (2.16) was recorded in F_4. The treatments F_3 and F_1 were at par. The lowest value was recorded in F_2. Interaction effect of spacing and foliar nutrition is significant at 45 DAS, the treatment combination S_1F_2 recorded higher LAI and lower LAI was observed with S_4F_3.

The results revealed that yield parameters as well as yield were influenced by spacing and foliar nutrition. S_3 recorded highest number of pods (27.06) and the lower number of pods were observed in double seedlings per hill treatments (S_2 and S_4). Among the foliar nutrition treatments higher number of pods (17.19) was recorded in F_3 and was at par with F_4.

Higher pod length (7.99 cm) was observed with S_1 and S_3 (on par). S_2 and S_4 recorded lower mean pod length. F_3 recorded the highest value of pod length (8.15 cm) and was superior to all other treatments. Among the interaction effects, S_1F_3 recorded higher pod length. More number of seeds pod^{-1} was observed in S_3 and at par with S_2 and S_1. Among the foliar application treatments, F_3 recorded the highest number of seeds per pod (12.25) and was found superior to all other treatments. The results revealed that influence of spacing and foliar nutrition on 100 seed weight was not significant.

A critical perusal of data revealed that higher seed yield (899.44 kg ha^{-1}) was observed in S_3 and it was at par with S_1 and these two were significantly superior over other two methods of spacing. S_4 recorded the lowest (555.70 kg ha^{-1}) grain yield. Foliar spray with F_3 recorded higher grain yield (880.85 kg ha^{-1}) and it was on par with F_4. The haulm yield was higher (1911.28 kg ha^{-1}) with S_1 and was at par with S_3. Among the foliar nutrition treatments, F_3 recorded higher haulm yield (1854.29 kg ha^{-1}) and was at par with F_4. F_1 recorded lower haulm yield (1399.76 kg ha^{-1}) and was at par with F_2. There were no significant difference in harvest index and crude protein content due to spacing and foliar nutrition.

The results revealed that weed density and dry weight varied with spacing and foliar nutrition. S_3 recorded more weed density and dry weight. Among the foliar nutrition treatments F_1 recorded more weed density and dry weight, and the lowest was observed in F_2. Twelve weed species were observed in experimental field. The predominant weed species were grasses.

Spacing and foliar nutrition had a significant influence on organic carbon, NPK content of soil after the experiment. S_1 recorded higher organic carbon, N and

K, but phosphorus content was higher in S_3. Among the foliar nutrition treatments, F_2 recorded higher organic carbon and N whereas, F_4 recorded higher available P and K. Among the interaction effects, the highest available N content of soil was recorded in S_1F_2, available P and K was more in S_2F_4.

Higher NPK uptake was seen in S_1. Among the foliar nutrition treatments, N and P uptake was higher with F_4, whereas F_3 recorded the higher K uptake. Among the interaction effects, S_1F_4, S_3F_4 and S_1F_1 recorded higher NPK uptake, respectively.

The economics of cultivation varied with spacing and foliar nutrition treatments. Spacing of 25 cm x 25 cm with one seedling $hill^{-1}$ (S_3) along with foliar nutrition of KNO_3 at 0.5% (F_3) at 15 and 30 DAS recorded higher net returns (₹ 43868 ha^{-1}) and benefit cost ratio (1.75).

Future line of work

1. Performance of other pulses under system of crop intensification.
2. Effect of potassium nitrate on drought management in summer fallows.
3. Foliar application of organic source of nutrients for productivity enhancement in pulses.

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APPENDIX

APPENDIX -I

Weather parameters during the cropping period

February 2022 to May 2022

Standard weeks	Temperature (° C)		Relative Humidity (%)		Rainfall (mm)	Evaporation (mm)
	Maximum	Minimum	Maximum	Minimum		
7	31.9	21.5	93.2	78.4	14.80	17.4
8	32.2	21.5	91.3	77.1	5.60	27
9	32.7	22.1	91.6	74.7	0.00	27.1
10	32.8	24.1	90.1	78.1	0.80	28.5
11	33.4	24.4	89.3	75.7	0.00	30.1
12	33.9	25.3	87.7	76.4	0.00	32.4
13	33.8	25.2	87.7	75.7	0.00	32.3
14	33.5	23.4	89.1	83.7	40.00	25.3
15	32.5	21.3	91.9	89.3	41.20	15.9
16	32.7	21.6	90.3	80.7	5.90	25.6
17	33.4	23.3	87.4	76.6	26.00	27
18	33.9	23.9	89.7	75.4	21.30	26.9
19	33.6	23.8	89.3	81.3	21.80	25.8

PRODUCTIVITY ENHANCEMENT OF GREEN GRAM (*Vigna radiata* (L.) WILCZEK) UNDER SYSTEM OF CROP INTENSIFICATION (SCI)

by

KODURU SOWMYA

(2020-11-125)

ABSTRACT

Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF AGRONOMY

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2022

ABSTRACT

The study entitled "Productivity enhancement of green gram (*Vigna radiata* (L.) Wilczek) under system of crop intensification (SCI)" was conducted at College of Agriculture, Vellayani during 2020-2022. The objectives were to standardize the plant population and to assess the effect of foliar nutrition in enhancing the productivity of green gram in summer fallows through a system of crop intensification.

The field experiment was conducted from February 2022 to May 2022, in farmer's field at Southern Coastal Plain (AEU 1), Varkala, Thiruvananthapuram district, Kerala. The experiment was laid out in split plot design with 16 treatment combinations and four replications. The main plot treatment was spacing (S_1- spacing of 25 cm x 15 cm with single seedling hill^{-1}, S_2 - spacing of 25 cm x 15 cm with double seedling hill^{-1}, S_3 -spacing of 25 cm x 25 cm with single seedling hill^{-1}, S_4- spacing of 25 cm x 25 cm with double seedling hill^{-1}) and the sub plot treatment was foliar application (F_1 - Urea @ 2%, F_2 - DAP @ 2%, F_3 - KNO_3 @ 0.5%, F_4 - DAP @ 2% + KNO_3 @ 0.5% at 15 and 30 DAS). All other management practices were followed as per Package of Practices Recommendations of Kerala Agricultural University (KAU, 2016). The green gram variety, CO 8 was used for the experiment.

The growth attributes of green gram *viz.*, plant height, number of leaves plant^{-1}, number of branches plant^{-1}, leaf area and dry matter production were recorded at 15 DAS, 30 DAS, 45 DAS, 60 DAS and at harvest. The growth attributes were significantly higher with single seedling (S_1 and S_3) compared to double seedling hill^{-1} (S_2 and S_4) at all the growth stages. Among the foliar application treatments, F_3 and F_4 recorded significantly superior growth attributes. The physiological parameters, *viz.*, CGR, RGR, NAR and LAI also varied significantly with spacing and foliar application.

The results indicated that the yield attributes *viz.*, number of pods plant^{-1} (27.06), and number of seeds pod^{-1} (12.25) were higher with S_3 whereas length of

pod (7.99 cm) was higher with S_1. Among the foliar nutrition treatments, higher yield components were recorded in F_3. Spacing of 25 cm x 25 cm with single seedling hill^{-1} (S_3) recorded higher seed yield (899.44 kg ha^{-1}) and it was at par with S_1 and significantly superior to the other two spacings. Single seedling treatments (S_1 and S_3) showed a yield increase of 10.7 per cent and 38.2 per cent, over double seedling treatments (S_2 and S_4). Haulm yield was higher with S_1 and it was on par with S_3. Foliar nutrition with KNO_3 at 0.5% (F_3) at 15 and 30 DAS recorded higher grain yield and haulm yield (880.85 and 1854.29 kg ha^{-1}, respectively) and remained at par with F_4.

Weed density and weed dry weight were lower (9.75 m^{-2} and 18.54 g m^{-2}, respectively) in S_2 than S_3 (15.94 m^{-2} and 28.92 g m^{-2}, respectively). Weed density and weed dry weight were significantly lower in F_2 and higher in F_1.

Higher uptake of N, P and K were observed with S_1 and S_3. Among the foliar nutrition treatments, higher N (49.60 kg ha^{-1}) and P uptake (10.11 kg ha^{-1}) were observed with F_4. K uptake (27.07 kg ha^{-1}) was higher with F_3 and was at par with F_4. Post-harvest analysis of soil revealed higher available N (378.06 kg ha^{-1}) and available K (193.60 kg ha^{-1}) in S_1 and it was at par with S_2. Available P was higher (112.42 kg ha^{-1}) in S_3 and was comparable with S_2. Among the foliar nutrition treatments, higher status of available N and P were observed with F_4 and available K with F_3.

The economics of cultivation varied with spacing and foliar nutrition treatments. Spacing of 25 cm x 25 cm with one seedling hill^{-1} (S_3) along with foliar nutrition of KNO_3 at 0.5% (F_3) at 15 and 30 DAS recorded higher net returns (₹ 43868 ha^{-1}) and benefit cost ratio (1.75).

From the study it could be concluded that, planting green gram at a spacing of 25 cm x 25 cm with single seedling hill^{-1} with recommended dose of fertilizers, supplemented with foliar application of KNO_3 at 0.5% at 15 and 30 DAS could be recommended for higher productivity and profitability of the crop in summer rice fallows under the system of crop intensification.