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Research Article

Assessing growth performance and agro-meteorological indices of green gram (*Vigna radiata* L.) varieties influenced by soil amendments and foliar application under sodic soil in Cauvery delta zone of Tamil Nadu

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Abstract
Green gram prefers neutral soil reactions and is sensitive to saline and alkaline soil conditions. Around 2.1 % of the country's geographical area is salt-affected, of which 3.77 million ha is sodic soil. Rehabilitation of salt-affected soil using drainage is expensive and leaching with good quality water is not feasible. To overcome this, a field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, during summer 2022 to study the effect of soil amendments and foliar nutrition under sodic soil. The experiment was laid out in a split-plot design with three replications. The treatments comprised of different varieties in main plots (M_1, M_2, M_3, M_4, M_5 and M_6) and different soil amendments with foliar application in sub plots (S_1, S_2 and S_3). The results showed that VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm (M_4S_1) registered higher plant height (18.31, 31.52 & 60.63 cm), DMP (907, 1932 & 2969 kg ha^{-1}), CGR (3.02, 6.83 & 4.15 g m^{-2} d^{-1}) and SPAD value (37.56, 41.62 & 30.57) at 30, 45 DAS and harvest. The same treatments increased grain and haulm yield of 997 and 2232 kg ha^{-1}. It also increased all agro-meteorological indices *viz.,* GDD, HTU, PTU, RTD and HUE of green gram. However, comparable results were obtained with VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm (M_4S_2).

Keywords: Agro-meteorological indices, Foliar nutrition, Green gram, Sodicity, Soil amendments

INTRODUCTION

The deterioration of soil brought on by salinization and sodification is a widespread worry. Salinity and sodicity-related soil degradation pose a serious environmental risk to soil fertility and agricultural productivity in arid and semiarid regions of the world. High pH (>8.2) and high ESP (>15) are two characteristics of sodic soil, often known as alkali soils or solonetz. Due to the concomitant effects of salt and sodicity, saline-sodic soils are formed, leading to soil dispersion due to high Na^+ concentrations in the soil solution or at the exchange phase and loss of soil physical structure due to clay swelling. In addition to these physicochemical consequences, this results in the loss of biological properties such as microbial respiration and biomass (Wong *et al.,*2008). However, salinity limits morphological, histological, chemical, biochemical, and metabolic processes by causing osmotic imbalances and specific ion toxicities, adversely affecting plant growth (Aslam *et al*., 2017).

Gypsum is the most often used amendment for sodic soil reclamation. Due to its limited solubility, it is difficult to increase the efficacy of applied gypsum in the absence of adequate moisture, whether from irrigation or rainfall. Addition of organic sources performs a dual role in these situations, enhancing gypsum solubility there by helping to improve the soil physico-chemical characteristics. Pressmud, an industrial by-product that is commonly available, is used to hasten the solubilization of gypsum by organic acids created during decomposition (Sundhari *et al.,* 2018). It is a good source of organic manure and can be utilised to improve the soil and as a substitute supply of plant nutrients (Kumar and Chopra, 2016). Microbial culture of CSR GROMOR coupled with gypsum as soil application and foliar spray improved water absorption, nutritional uptake and crop yield (Chatterjee *et al*., 2012). For enhancing crop development and productivity, additional foliar feeding is essential. Moreover, it boosts the pace of photosynthetic growth and nutrient transfer from leaves to emerging seeds (Sridhar *et al*., 2020). Brassinosteroid (BRs) is also an antioxidant. BR is a pleiotropic plant hormone that influences a variety of physiological and developmental processes including growth, seed germination, rhizogenesis and senescence. Also, it stimulates plant development and protects against water stress, salt stress and pathogen attack (Praveena *et al.,* 2020).

Because the complex process occurring in various parts of the plant including many physiological changes due to environmental conditions prevalent at various stages of crop growth, influences the growth and yield of green gram varieties. It is important to find a suitable green gram variety that will perform well in sodic soil with regard to soil amendments and foliar nutrition. An earlier study conducted in this region with green gram varieties viz., VBN 2, ADT 3 and CO 8 found that VBN 2 performed well with better yield under sodic soil conditions (Nithila *et al.,* 2002). So, identifying the response of newly developed synchronized green gram varieties to different soil amendments and foliar nutrition that may sustain green gram yield in sodic soil is not attempted. Hence, this experiment was conducted to study the different soil amendments and foliar nutrition on different green gram varieties under sodic soil conditions.

MATERIALS AND METHODS

Experimental site

The field experiment was carried out in field No. D_2b at Anbil Dharmalingam Agricultural College and Research Institute, Manikandam Block of Tiruchirappalli, during the summer season of 2022 (February to May). The experimental site is situated 85 m above mean sea level (MSL) at 11° 32' North latitude and 78° 83' East longitude. Meteorological data of the experiment is given in Fig. 1. Initial soil characteristics of the experimental site are depicted in Table 1.

Treatment details

The field trial was laid out in a split-plot design with three replications. The treatments comprised different green gram varieties *viz.,* M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 and M_6 - CO 8, in main plots and soil amendments with foliar nutrition in subplots *viz.,* S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + Brassinosteroid @ 0.2 ppm (FN) @ 30 DAS, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + Brassinosteroid @ 0.2 ppm (FN) @ 30 DAS and S_3-Farmers practice. Sowing was done on 23 February 2022. Individual plot size was 20 m^2, spacing adopted was 30 cm x 10 cm. The statistical analysis was carried out by AGRES software at 5 % level of significance.

Gypsum requirement

For a 30-cm soil matrix, gypsum requirements (GR) were calculated to lower the initial Exchangeable Sodium Percentage (ESP) from 36.40 to 10%. The following equation was used to determine how much gypsum the soil needed (USSL, 1954):

$$GR = \frac{ESP_i - ESP_f}{100} \times CEC \times 1.72 \qquad \text{Eq. 1}$$

Where, GR is the net gypsum requirement of the soil (t ha^{-1})

ESP_i = initial exchangeable sodium percentage

ESP_f = final exchangeable sodium percentage

CEC = cation exchangeable capacity (c mol (p$^+$) kg^{-1})

Gypsum was mixed into the soil using a rotavator 20 days prior to sowing at 20 cm soil depth, and the soil moisture was monitored up to the field capacity to aid in leaching. Following gypsum leaching, modifications were made in accordance with the treatment schedule. Foliar spray of Brassinosteroid was given at the vegetative (30 DAS) stage.

Chemical analysis

Chemical analyses were performed for measuring pH, EC, ESP, soil exchangeable cations (Ca^{2+}, Mg^{2+}, Na^+ & K^+) and soil available NPK. Using a 1:2 soil and water extraction, soil pH and EC were assessed (Jackson, 1973). The ESP was determined using the following equation proposed by (Gardner and Miller, 2004; USSL, 1954) and expressed as %

$$ESP\ (\%) = \frac{Exchangeable\ sodium}{Cation\ exchange\ capacity} \times 100 \qquad \text{Eq. 2}$$

Jackson (1973) suggested utilising the Versenate titration method for analysis of exchangeable Ca^+ and Mg^+.

The results were represented as c mol (p^+) kg^{-1}. Exchangeable Na^+ and K^+, were analysed using the flame photometry technique and given as c mol (p^+) kg^{-1} (Toth and Prince 1949). The Flame photometry method was used to analyse exchangeable Na^+ and K^+ suggested by Toth and Prince (1949) and expressed as c mol (p^+) kg^{-1}. Soil available N (kg ha^{-1}) analysis by alkaline permanganate method (Asija and Subbiah, 1956), available P (kg ha^{-1}) by colorimetric method (Olsen (1954) and available K (kg ha^{-1}) by flame photometer (Stanford and English, 1949) were used.

Agro-meteorological indices

Agro-meteorological indices were computed for different phenophases of green gram, which was determined using the following equations.

Growing degree days (GDD)

GDD concept was proposed to explain the relationship between growths that occurred during the specific temperature. It was calculated as per the formula suggested by Iwata (1975): GDD was calculated by using the following formula

$$\text{GDD (°C days)} = \frac{T_{max} + T_{min}}{2} - T_{base} \qquad \text{Eq. 3}$$

Where

T_{max} = maximum temperature

T_{min} = minimum temperature

T_{base} = base temperature (10 °C)

Helio thermal units (HTU)

The product of GDD and the actual number of hours of bright sunshine for a given day is the helio-thermal unit for that day. Using the formula, the total HTU for each phenophase was calculated and reported as °C days hour (Srivastava, 2011).

HTU (°C days hr) = GDD x Actual bright sunshine (hr) Eq.4

Photothermal units (PTU)

The PTU was obtained by multiplying the GDD with the day length. It is expressed in °C days hour (Srivastava, 2011)

PTU (°C days hr) = GDD x maximum possible day length (hr) Eq.5

Relative thermal disparity (RTD)

The RTD was calculated by the formula suggested by Rajput (1980)

$$\text{RTD (°C days)} = \frac{T_{max} + T_{min}}{T_{base}} \times 100 \qquad \text{Eq.6}$$

Where

T_{max} = maximum temperature

T_{min} = minimum temperature

T_{base} = base temperature (10 °C)

Heat use efficiency (HUE)

The heat use efficiency is the amount of above ground dry matter produced per degree day suggested by Haider *et al.* (2003) and expressed as kg ha^{-1} °C $days^{-1}$.

HUE (kg ha^{-1} °C $days^{-1}$)= Total dry matter (g $hill^{-1}$) / Accumalated growing degree days (°C days) Eq. 7

RESULTS AND DISCUSSION

Plant height

Green gram varieties, soil amendments and foliar nutrition had no significant differences in plant height at 30 and 45 DAS. However, a significant effect was found at the harvest stage, which is presented in Fig. 2. Higher plant height was recorded in VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) produced 60.63 cm, respectively which was on par with VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2 - 58.69 cm) and VBN (Gg) 3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1) (58.63 cm). Increased plant height might be due to the additional supply of major, micronutrients and growth hormones through soil amendments and foliar spray. These findings were well supported by Nagpal *et al*. (2022) in green gram. VRM (Gg) 1 + farmers practice (M_1S_3) and CO 8 + farmers practice (M_6S_3) recorded significantly lower plant height of 39.96 and 41.95 cm at the harvest stage.

Dry matter production

Significant differences in DMP were recorded only at 45 DAS and harvest stages (Table 2). At 45 DAS, a higher amount of DMP was recorded in VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) with a DMP of 1932 kg ha^{-1} which was statistically comparable with VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2) produced 1881 kg ha^{-1}. This may be related to improved nutrient availability to plants, which resulted in maximum plant growth in terms of plant height and leaf area, which in turn helped to boost the production of DMP. These results also agreed with the findings of Shahid *et al*. (2020). Significantly lowest DMP was produced in VRM (Gg) 1 + farmers practice (M_1S_3) which recorded 1272 kg ha^{-1}. At harvest, higher amount of DMP was recorded in VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) with a DMP of 2969 kg ha^{-1} followed by VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2- 2871 kg ha^{-1}) and VBN (Gg)

3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1) (2849 kg ha^{-1}). Increase in all growth parameters due to the application of CSR-Bio microbial culture could be attributed to the expected increase in the available nitrogen, phosphorus and potassium, which were continuously available to the plants (Kumar *et al.,* 2019). Significantly lower and similar DMP was recorded in VRM (Gg) 1 + farmers practice (M_1S_3) and CO 8 + farmers practice (M_6S_3) recorded 1656 and 1696 kg ha^{-1}, respectively.

Crop growth rate

Effect of soil and crop management practices on CGR of green gram varieties is presented in Table 3. At 30-45 DAS, VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) and VBN (Gg) 3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1) comparatively produced higher CGR of 6.83 and 6.15 g m^{-2} day^{-1}. It was on par with VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2). The longer vegetative phase and improved photosynthetic capacity of the plant may have been caused by the foliar application of nitrogen, which also increased the accumulation and transfer of nutrients. These findings were also supported by the work of Amutha *et al*. (2012) in black gram, Matwa *et al*. (2017) in green gram and Mondal *et al*. (2013) in green gram. Lesser CGR was observed in VRM (Gg) 1 + farmers practice (M_1S_3) with 4.37 g m^{-2} day^{-1}. At 45 DAS-harvest, VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) and VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2) similarly recorded higher CGR of 4.15 and 3.96 g m^{-2} day^{-1}, respectively. It was followed by VBN (Gg) 3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1 - 4.13 g m^{-2} day^{-1}). Lesser CGR was observed in VRM (Gg) 1 + farmers practice (M_1S_3) with 2.56 g m^{-2} day^{-1}.

SPAD value

Effect of soil amendments and foliar nutrition on SPAD value of green gram varieties is presented in Fig. 3. At 30 DAS, higher SPAD meter reading was recorded in VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) which recorded 37.56. It was comparable with VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2), which recorded 37.21. The lowest SPAD value was produced in VRM (Gg) 1 + farmers practice (M_1S_3 - 23.52). At 45 DAS and harvest, higher and comparable SPAD meter reading was recorded in VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1 - 41.62 and 30.57) and VBN (Gg) 3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1) which recorded 41.38 and 30.22. It was followed by VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2 - 39.27 and 28.56) and VBN (Gg) 3 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_2 - 39.07 and 27.91) at 45 DAS and harvest, respectively. Inhibition of senescence activators been identified as one of the reasons contributing to an increase in chlorophyll content following brassinosteroid treatment (Gomes *et al*., 2013). The lowest SPAD value was recorded in VRM (Gg) 1 + farmers practice (M_1S_3 - 26.62 and 18.21).

Grain yield

Effect of soil amendments and foliar nutrition on grain yield of green gram varieties is presented in Table 4. VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t

Table 1. Physico-chemical properties of initial soil

A. Mechanical analysis	**Values**
Coarse sand fraction (%)	63.03
Fine sand fraction (%)	27.53
Silt fraction (%)	8.55
Textural class	Sandy clay loam
B. Soil physical properties	
Bulk density (Mg m^{-3})	1.28
Particle density (Mg m^{-3})	2.25
Pore space (%)	30
C. Electro-chemical properties	
pH	8.98
EC (dS m^{-1})	0.45
CEC (cmol (p^+) kg^{-1})	20.96
ESP (%)	35.70
D. Chemical properties	
Organic Carbon (%)	0.46
Available N (kg ha^{-1})	216.2
Available P (kg ha^{-1})	14.61
Available K (kg ha^{-1})	280.1
Exchangeable Ca^+ (c mol (p^+) kg^{-1})	10.22
Exchangeable Mg^+(c mol (p^+) kg^{-1})	7.33
Exchangeable Na^+(c mol (p^+) kg^{-1})	6.31
Exchangeable K^+(c mol (p^+) kg^{-1})	2.54

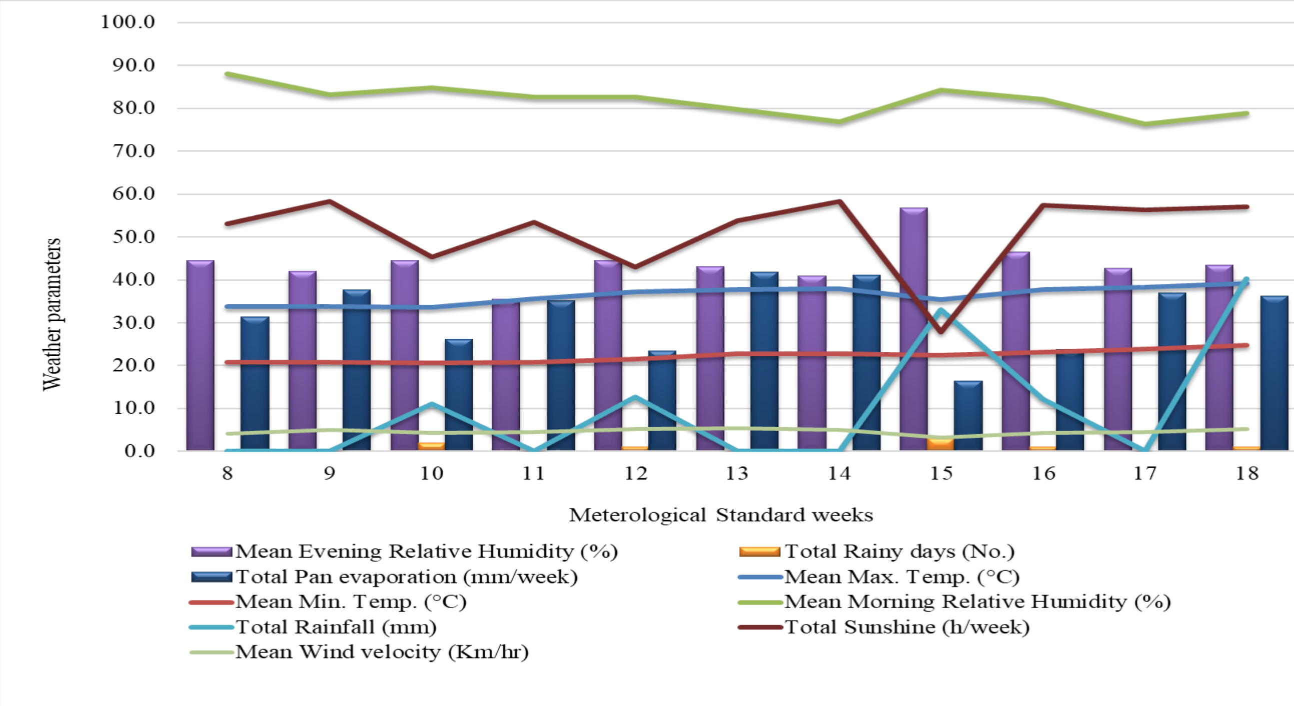

Fig. 1. *Weekly weather data of during the cropping period of February 2022 - April 2022*

ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) registered incresaed grain yield of 997 kg ha^{-1}, it was followed by VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2) and VBN (Gg) 3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1) with the grain yield of 930 and 894 kg ha^{-1}. It may also be attributed to the favorable Ca^{2+}/Na^{+} ratio in soil coupled with favourable effect of Ca^{2+} probably in maintaining cell membrane integrity and plant metabolism (Ashraf, 2004). The balanced growth habit, which increased the production of flowers and fruiting bodies while providing nutrients at the right time through foliar spray, may have decreased flower and fruit shedding while, on the other hand, causing a positive source-sink gradient of photosynthates translocation because of growth regulator. These beneficial impacts might have contributed to greater production under the foliar spray of nutrients and growth regulators. This finding aligns with the results of Manivannan *et al*. (2003). VRM (Gg) 1 + farmers practice (M_1S_3) recorded a significantly lower grain yield of 527 kg ha^{-1}.

Haulm yield

Effect of soil amendments and foliar nutrition on haulm yield of green gram varieties is presented in Table 4. Among that, VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) resulted in maximum haulm yield of 2232 kg ha^{-1}. However, it was statistically comparable with VBN (Gg) 4 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_2), VBN (Gg) 3 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_1) and VBN (Gg) 3 + gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_3S_2) which registered the haulm yield of 2164, 2111 and 2095 kg ha^{-1}, respectively. The generation of such response in the plants is by cumulative expression on accelerated rate of nitrate assimilation, protein synthesis, preferential translocation of photosynthates to the sink and delayed leaf senescence by applied inputs (Hayat *et al*., 2001 and Fujii and Saka, 2001). VRM (Gg) 1 + farmers practice (M_1S_3) recorded lower haulm yield of 1491 kg ha^{-1} which was on par with CO 8 + farmers practice (M_6S_3) recorded 1541 kg ha^{-1}.

Agro-meteorological indices

Growing degree days (GDD)

GDD varied considerably due to different green gram varieties, soil amendments and foliar nutrition which was presented in Table 5. Among different varieties, VBN (Gg) 4 (M_4) was accumulated maximum GDD of 531°C days at 50 % flowering as compared to other varieties. The next higher GDD were found in CO 8 (M_6) and VBN (Gg) 3 (M_3) accumulated 495 and 488 °C days, respectively. The lowest GDD was recorded in VRM (Gg) 1 (M_1) (451 °C days). At pod formation stage, VBN (Gg) 4 (M_4) was accumulated higher GDD (1126 °C days) followed by VBN (Gg) 3 (M_3) accumulated 1069 °C days and VBN (Gg) 2 (M_2) recorded 1033 °C days. This might be due to better growing conditions such as temperature, light, humidity and rainfall to fully exploit genetic potentiality of crop (Bahar *et al*., 2015). While, lowest value was found in VBN (Gg) 5 (M_5 - 955 ° days). Likewise, at physiological maturity, VBN (Gg) 4 (M_4) recorded higher GDD of 1527 °C days followed by VBN (Gg) 3 (M_3 -1506 °C days) and CO 8 (M_6 -1465 °C days). While, lowest GDD was found in VRM (Gg) 1 (M_1) accumulated 1419 °C days at physiological maturity. Among different soil amendments with foliar nutrition, gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (S_1) has accumulated higher GDD of 506, 1087 and 1536 °C days at 50 % flowering, pod formation and physiological maturity stages, respectively followed by gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} with FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2 - 487, 1048 and 1510 °C days). Lower values were recorded in farmers practice (S_3 - 436, 976 and 1362 °C days).

Helio-thermal units (HTU)

Effect of soil and crop management practices on HTU of green gram varieties is presented in Fig. 4. The accumulated HTU required for attaining different pheno-

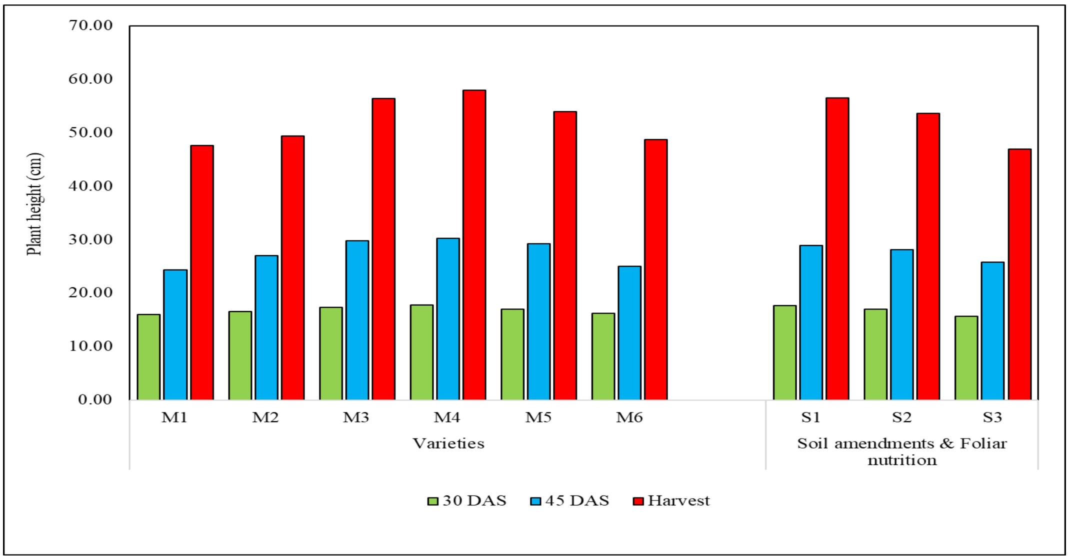

Fig. 2. *Effect of soil amendments and foliar nutrition on plant height of green gram varieties; M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3- Farmers practice*

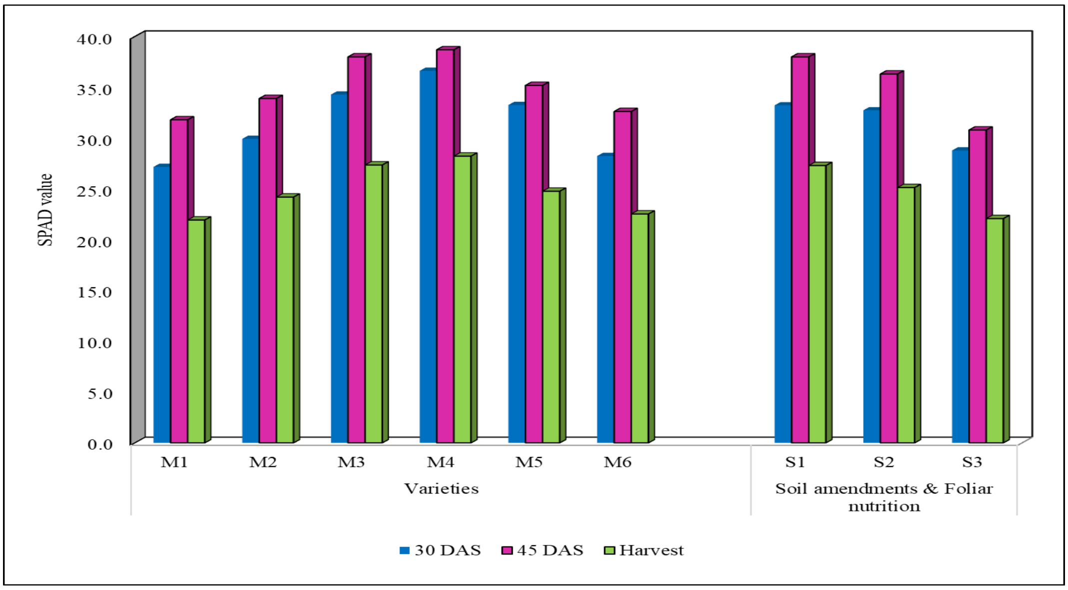

Fig. 3. *Effect of soil amendments and foliar nutrition on SPAD value of green gram varieties; M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8 S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice*

Table 2. Effect of soil amendments and foliar nutrition on dry matter production of green gram varieties

Dry matter production (kg ha^{-1})														
30 DAS					45 DAS					At harvest				
Treatments	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**
M_1	778	764	617	720	M_1	1561	1499	1272	1444	M_1	2042	1972	1656	1890
M_2	810	794	665	756	M_2	1727	1606	1347	1560	M_2	2419	2249	1901	2190
M_3	895	827	701	808	M_3	1817	1706	1498	1674	M_3	2849	2672	2274	2598
M_4	907	858	710	825	M_4	1932	1881	1526	1780	M_4	2969	2871	2377	2739
M_5	822	806	691	773	M_5	1729	1661	1397	1596	M_5	2694	2497	2112	2434
M_6	791	775	625	730	M_6	1672	1572	1304	1516	M_6	2172	2049	1696	1972
Mean	834	804	668		Mean	1740	1654	1391		Mean	2524	2385	2003	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M
SEd	9.21	6.99	16.75	17.13	Sed	17.78	10.91	28.15	26.72	Sed	21.18	14.26	35.53	34.94
CD (P=0.05%)	20.53	14.43	NS	NS	CD (P=0.05%)	39.63	22.51	59.94	55.15	CD(P=0.05%)	47.19	29.44	75.41	72.11

M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3- Farmers practice

Table 3. Effect of soil amendments and foliar nutrition on crop growth rate of green gram varieties

Crop growth rate (g m^{-2} d^{-1})														
0-30 DAS					30-45 DAS					45 DAS-Harvest				
Treatments	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**
M_1	2.59	2.55	2.06	2.40	M_1	5.22	4.90	4.37	4.83	M_1	3.21	3.15	2.56	2.97
M_2	2.70	2.65	2.22	2.52	M_2	6.11	5.41	4.55	5.36	M_2	3.46	3.22	2.77	3.15
M_3	2.98	2.76	2.34	2.69	M_3	6.15	5.86	5.31	5.77	M_3	4.13	3.86	3.10	3.70
M_4	3.02	2.86	2.37	2.75	M_4	6.83	6.82	5.44	6.36	M_4	4.15	3.96	3.40	3.84
M_5	2.74	2.69	2.30	2.58	M_5	6.05	5.70	4.71	5.49	M_5	3.86	3.34	2.86	3.35
M_6	2.64	2.58	2.08	2.43	M_6	5.87	5.31	4.53	5.24	M_6	3.33	3.18	2.61	3.04
Mean	2.78	2.68	2.23		Mean	6.04	5.67	4.82		Mean	3.69	3.45	2.88	
	M	S	M at S	S at M		M	S	M at S	S at M		M	S	M at S	S at M
SEd	0.03	0.02	0.05	0.06	SEd	0.03	0.04	0.08	0.09	SEd	0.04	0.02	0.06	0.06
CD (P=0.05%)	0.06	0.05	NS	NS	CD (P=0.05%)	0.08	0.08	0.18	0.20	CD (P=0.05%)	0.08	0.05	0.14	0.13

M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice logical stages of green gram was maximum in VBN (Gg) 4 (M_4) with 5250, 7386 and 12516 °C days hrs at 50 % flowering, pod formation and at physiological maturity stages. This was followed by VRM (Gg) 1 (M_1 - 4813, 6808 and 11501 °C days hrs) and VBN (Gg) 2 (M_2 - 4656, 6791 and 11327 °C days hrs) at all three stages whereas, at 50 % flowering stage lowest HTU was observed in CO 8 (M_6 - 4386l °C days hrs). At pod formation and physiological maturity stages lowest values were found in VBN (Gg) 5 (M_5) with 6152 and 10431°C days hrs, respectively. Among sub plot treatments, gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (S_1) has higher HTU of 5247, 7132 and 12243 °C days hrs at 50 % flowering, pod formation and physiological maturity stages, respectively followed by gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} with FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2 - 4629, 6659 and 11167 °C days hrs). Lower HTU was recorded in farmers practice (S_3 - 4234, 6063 and 10128 °C days hrs).

Photo thermal units (PTU)

Effect of soil and crop management practices on PTU of green gram varieties was presented in Fig 5. Among different green gram varieties, at 50 % flowering stage, VBN (Gg) 4 (M_4) attained maximum PTU of 6067 °C days hours. The next higher PTU was found in VRM (Gg) 1 (M_1 - 5713 °C days hrs) and VBN (Gg) 2 (M_2 - 5388 °C days hrs), respectively. The PTU was lowest under CO 8 (M_6) with 5079 °C days hrs. At pod formation stage, VBN (Gg) 4 (M_4) recorded higher PTU (10279 °C days hrs) followed by VBN (Gg) 3 (M_3) and VBN (Gg) 5 (M_5) recorded 9695 and 9478 °C days hrs), respectively. While, lowest PTU was found in VRM (Gg) 1 (M_1) with 8686 °C days hrs. At physiological maturity stage, VBN (Gg) 3 (M_3) recorded higher PTU of 15674 °C days hrs followed by VBN (Gg) 4 (M_4) and VBN (Gg) 5 (M_5) recorded 15345 and 14281 °C days hrs, respectively. Whereas, lowest PTU was found in VBN (Gg) 2 (M_2) with 13381°C days hrs. Likewise, gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (S_1) has higher PTU of 5969, 9712 and 16515 °C days hrs at 50 % flowering, pod formation and physiological maturity stages, respectively followed by gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} with FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2 - 5600, 9431 and 15448 °C days hrs). Lower PTU was recorded in farmers practice (S_3 – 4746, 9084 and 11113 °C days hours), respectively.

Relative temperature disparity (RTD)

RTD varied considerably due to different green gram varieties, soil amendments and foliar nutrition, is shown in Table 6. Among different varieties, VBN (Gg) 4 (M_4) was recorded higher RTD (3158 and 6380 °C days) at 50 % flowering and pod formation stages as compared to other varieties. The next higher RTD were found in VBN (Gg) 3 (M_3) which registered 2962 and 5783 °C days. At physiological maturity stage, VBN (Gg) 4 (M_4) recorded higher RTD of 9328 °C days followed by VRM (Gg) 1 (M_1 - 8877 °C days). The RTD value was lowest in VRM (Gg) 1 (M_1 - 2458, 4834 and 7992 °C days). Whereas, VRM (Gg) 1 (M_1) recorded lowest

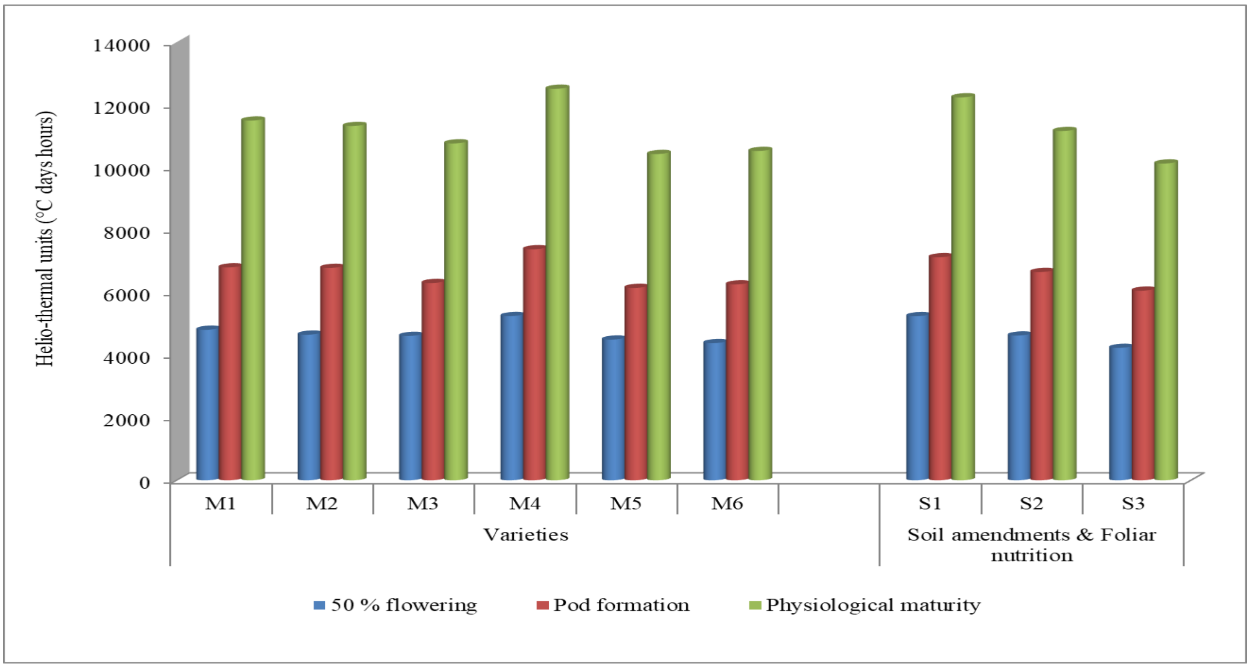

Fig 4. *Effect of soil amendments and foliar nutrition on helio-thermal units (°C days hours) of green gram varieties; M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice*

Table 4. Effect of soil amendments and foliar nutrition on grain yield and haulm yield of green gram varieties

	Grain yield (kg ha^{-1})					Haulm yield (kg ha^{-1})			
Treatments	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**
M_1	744	722	527	664	M_1	1701	1701	1491	1631
M_2	799	786	685	757	M_2	1897	1796	1775	1823
M_3	894	847	741	827	M_3	2111	2095	1762	1989
M_4	997	930	799	909	M_4	2232	2164	1798	2065
M_5	834	804	702	780	M_5	1942	1901	1770	1871
M_6	781	778	561	707	M_6	1797	1774	1541	1704
Mean	842	811	669		Mean	1947	1905	1690	
	M	S	M at S	S at M		M	S	M at S	S at M
Sed	6.78	4.93	11.97	12.08	SEd	31.13	15.23	43.54	37.30
CD (P=0.05%)	15.11	10.18	25.34	24.94	CD (P=0.05%)	69.36	31.43	93.54	76.99

M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice

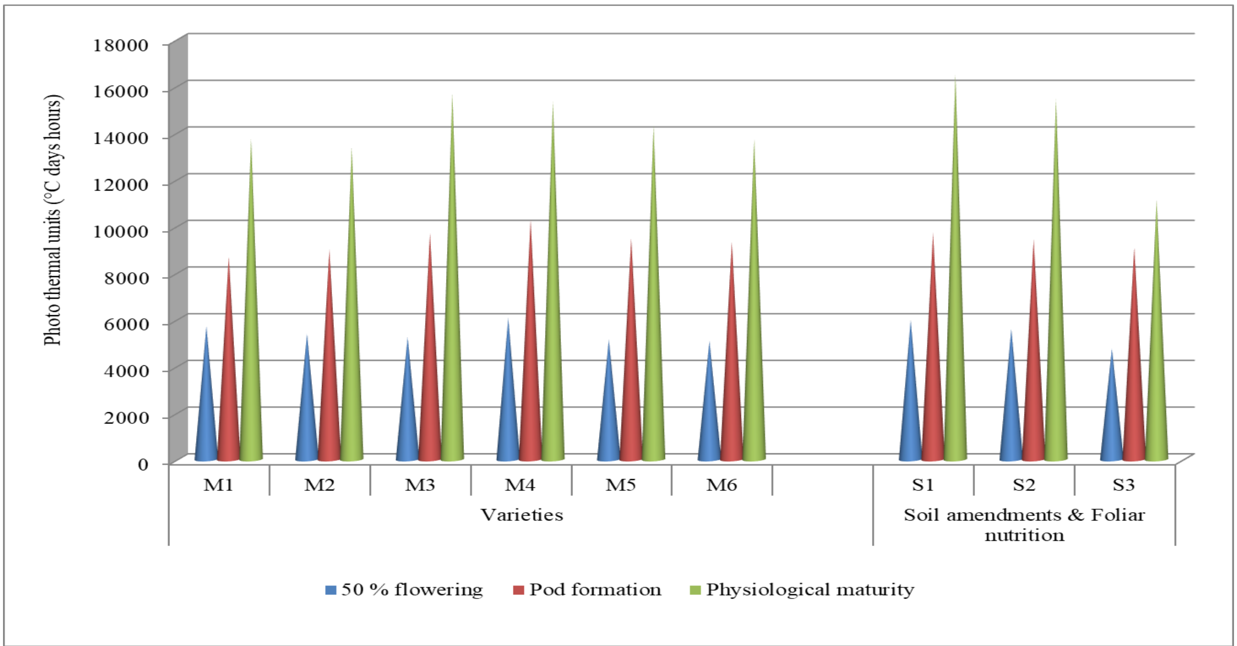

Fig. 5. *Effect of soil amendments and foliar nutrition on photo thermal units (°C days hours) of green gram varieties; M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice*

RTD of 2517 °days at 50 % flowering stage and CO 8 (M_6) recorded lowest RTD values of 5092 and 8152 °C days at pod formation and physiological maturity stages, respectively. Among different soil amendments with foliar nutrition, gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (S_1) has accumulated higher RTD of 3098 and 9455 °C days at 50 % flowering and physiological maturity stages, respectively. Lower values were recorded in farmers practice (S_3 - 2283 and 7863 °C days). At pod formation stage, gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} with FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2) recorded higher RTD value of 5985 °C days followed by gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (S_1 - 5584 °C days). Lower values were recorded in farmers practice (S_3 - 5324 °C days). The lower values might be due to higher temperature remained during reproductive phase causing detrimental effect on dry matter accumulation and grain yield. Similar results in chickpea were also observed by Pandey (2013).

Heat use efficiency (HUE)

HUE was calculated by total GDD accumulated to produce unit amount of grain yield is shown in Table 7. The maximum HUE for grain, haulm and biological yield were 0.60, 1.35 and 1.95 kg ha^{-1} °C days^{-1}, respectively as compared to other varieties. The next higher HUE was found in VBN (Gg) 3 (M_3 - 0.55, 1.32 and 1.87 kg / ha / °C days) and VBN (Gg) 5 (M_5 - 0.54, 1.30 and 1.84 kg / ha / °C days), respectively. The HUE was lowest under VRM (Gg) 1 (M_1) with 0.47, 1.15 and

Table 5. Effect of soil amendments and foliar nutrition on growing degree days of green gram varieties

Growing degree days (°C days)														
50 % flowering					Pod formation					Physiological maturity				
Treatments	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**
M_1	495	452	407	451	M_1	1068	1025	961	1018	M_1	1513	1427	1318	1419
M_2	538	495	385	472	M_2	1133	1028	939	1033	M_2	1621	1473	1273	1455
M_3	516	495	452	488	M_3	1133	1089	985	1069	M_3	1599	1534	1387	1506
M_4	560	538	495	531	M_4	1134	1176	1068	1126	M_4	1604	1664	1313	1527
M_5	452	429	385	422	M_5	1006	962	896	955	M_5	1408	1491	1431	1443
M_6	474	516	495	495	M_6	1047	1008	1007	1020	M_6	1471	1474	1451	1465
Mean	506	487	436		Mean	1087	1048	976		Mean	1536	1510	1362	
SEd	14.29	14.13	14.97	13.17	SEd	20.81	19.12	27.50	24.96	Sed	29.72	26.58	32.69	30.96
CD (P=0.05%)	21.27	18.56	28.56	26.53	CD (P=0.05%)	41.69	37.56	53.69	50.23	CD (P=0.05%)	59.23	53.14	64.52	61.42

M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice

Table 6. Effect of soil amendments and foliar nutrition on relative temperature disparity of green gram varieties

Relative temperature disparity														
50 % flowering					Pod formation					Physiological maturity				
Treatments	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**	**Treatments**	**S_1**	**S_2**	**S_3**	**Mean**
M_1	3375	2910	1265	2517	M_1	4325	6060	5625	5337	M_1	9790	8760	8080	8877
M_2	3025	2785	1965	2592	M_2	5975	6035	4725	5578	M_2	8990	8610	8180	8593
M_3	2985	2965	2935	2962	M_3	6140	5815	5395	5783	M_3	9715	8270	7620	8535
M_4	3415	3150	2910	3158	M_4	6870	6400	5870	6380	M_4	10075	9340	8570	9328
M_5	3275	3025	2185	2828	M_5	6025	5785	5040	5617	M_5	9490	8100	7215	8268
M_6	2510	2665	2435	2537	M_6	4170	5815	5290	5092	M_6	8670	8270	7515	8152
Mean	3098	2917	2283		Mean	5584	5985	5324		Mean	9455	8558	7863	
SEd	90.56	86.75	97.56	92.51	SEd	167.5	150.6	166.9	155.6	SEd	275.4	270.6	283.5	272.6
CD (P=0.05%)	182.1	172.3	194.6	185.6	CD (P=0.05%)	312.4	309.5	333.5	310.6	CD (P=0.05%)	550.8	545.6	567.9	545.2

M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice

Table 7. Effect of soil amendments and foliar nutrition on heat use efficiency (kg / ha / °C days) of green gram varieties

Heat use efficiency (kg / ha / °C days)														
	Grain yield (Kg/ ha)					Haulm yield (Kg/ ha)					Biological yield (Kg/ ha)			
Treatments	S_1	S_2	S_3	Mean	Treatments	S_1	S_2	S_3	Mean	Treatments	S_1	S_2	S_3	Mean
M_1	0.49	0.51	0.40	0.47	M_1	1.12	1.19	1.13	1.15	M_1	1.62	1.70	1.53	1.62
M_2	0.49	0.53	0.54	0.52	M_2	1.17	1.22	1.39	1.26	M_2	1.66	1.75	1.93	1.78
M_3	0.56	0.55	0.53	0.55	M_3	1.32	1.37	1.27	1.32	M_3	1.88	1.92	1.81	1.87
M_4	0.62	0.56	0.61	0.60	M_4	1.39	1.30	1.37	1.35	M_4	2.01	1.86	1.98	1.95
M_5	0.59	0.54	0.49	0.54	M_5	1.38	1.27	1.24	1.30	M_5	1.97	1.81	1.73	1.84
M_6	0.53	0.53	0.39	0.48	M_6	1.22	1.20	1.06	1.16	M_6	1.75	1.73	1.45	1.64
Mean	0.55	0.54	0.49		Mean	1.27	1.26	1.24		Mean	1.82	1.80	1.74	
SEd	0.01	0.01	0.02	0.01	SEd	0.02	0.02	0.04	0.03	SEd	0.04	0.03	0.04	0.03
CD (P=0.05%)	0.02	0.02	0.04	0.03	CD (P=0.05%)	0.05	0.04	0.07	0.06	CD (P=0.05%)	0.07	0.05	0.09	0.06

M_1 - VRM (Gg) 1, M_2 - VBN (Gg) 2, M_3 - VBN (Gg) 3, M_4 - VBN (Gg) 4, M_5 - VBN (Gg) 5 & M_6 - CO 8, S_1- Gypsum @ 50 % GR + Pressmud @ 10 t ha^{-1} + BRs @ 0.2 ppm, S_2- Gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} + BRs @ 0.2 ppm & S_3-Farmers practice

1.62 kg / ha / °C days, respectively. Among sub plot treatments, gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (S_1) has higher HUE of 0.55, 1.27 and 1.82 kg / ha / °C days for grain, haulm and biological yield followed by gypsum @ 50 % GR + CSR GROMOR @ 25 kg ha^{-1} with FS of brassinosteroid 0.2 ppm @ 30 DAS (S_2 - 0.54, 1.26 and 1.80 kg / ha / °C days). Lower HUE was recorded in farmers practice (S_3 - 0.49, 1.24 and 1.74 kg / ha / °C days), respectively. When the temperature was at its ideal level throughout the growth season, the crop used heat more effectively and biological activity increased, resulting in higher yield. Similar relationship was expressed by Thavaprakash *et al.* (2007)

Conclusion

The study revealed that the addition of gypsum and organic amendments (pressmud, CSR GROMOR) acted as an ameliorant to sodic soil. The combined effect of gypsum with organic amendments was more effective in increasing growth and physiological parameters along with green gram yield. VBN (Gg) 4 + gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS (M_4S_1) registered significantly higher plant height, DMP, CGR and SPAD value at 30, 45 DAS and at harvest stages. It also increased grain yield, haulm yield and agro-meteorolof green gram. Hence it is concluded that application of gypsum @ 50 % GR + pressmud @ 10 t ha^{-1} + FS of brassinosteroid 0.2 ppm @ 30 DAS in VBN (Gg) 4 variety (M_4S_1) had a remarkable effect in reducing soil sodicity with enhancing green gram productivity under sodic soil condition.

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Conflict of interest

The authors declare that they have no conflict of interest.

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