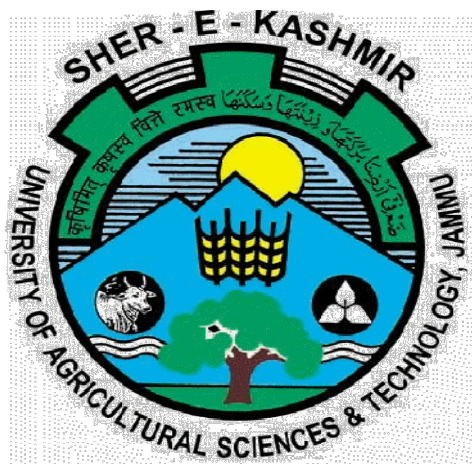


**EFFECT OF FOLIAR NUTRITION AND CROP  
GEOMETRY ON CULTIVARS OF BLACK GRAM IN  
*SHIWALIK* FOOTHILLS OF JAMMU**

**By**  
**Lalichetti Sagar**  
**(J-17-M-481)**

Thesis Submitted to Faculty of Postgraduate Studies  
in partial fulfilment of the requirements  
for the degree of


**MASTER OF SCIENCE IN AGRICULTURE  
AGRONOMY**



**Division of Agronomy**  
**Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu**  
**Main Campus, Chatha, Jammu 180009**  
**2019**

## CERTIFICATE-I

This is to certify that the thesis entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in Shiwalik foothills of Jammu**” submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Agronomy)** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is a record of bonafide research carried out by **Mr. Lalichetti Sagar**, Registration No. **J-17-M-481** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that such help and assistance received during the course of thesis investigation have been duly acknowledged.

  
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(Major Advisor)

**Place:** Jammu

**Date:** 29.07.2019

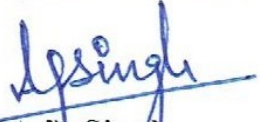
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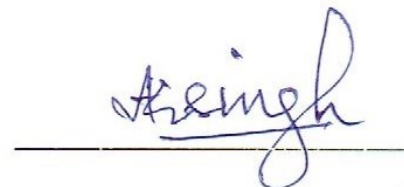
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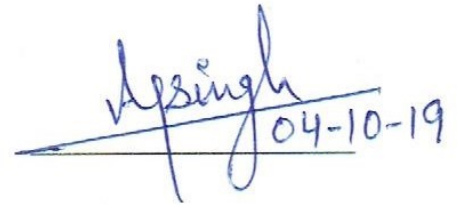
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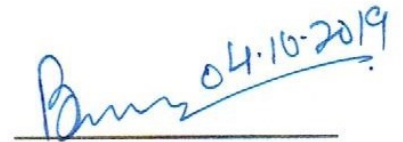
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Place: Jammu

Date: 29.07.2019

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## ABSTRACT

<b>Title of the thesis</b>	<b>Effect of foliar nutrition and crop geometry on cultivars of black gram in <i>Shivalik</i> foothills of Jammu</b>
<b>Name of the student</b>	<b>Lalichetti Sagar</b>
<b>Registration No.</b>	<b>J-17-M-481</b>
<b>Major subject</b>	<b>Agronomy</b>
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<b>Degree to be awarded</b>	<b>M.Sc. (Ag.) Agronomy</b>
<b>Year of award of degree</b>	<b>2019</b>
<b>Name of University</b>	<b>Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu</b>

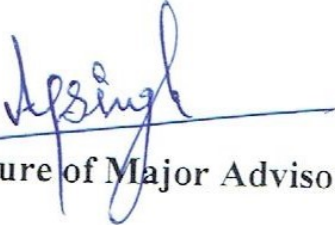
## ABSTRACT


An investigation entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shivalik* foothills of Jammu**” was conducted at Research Farm of Advanced Centre for Rainfed Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Rakh Dhiansar during *khariif* season of 2018. The soil of the experimental field was sandy loam in texture, slightly acidic in reaction (6.47), low in organic carbon (0.36 %) and available nitrogen (173.48 kg/ha) but medium in available phosphorus (14.21 kg/ha) and potassium (121.23 kg/ha) with electrical conductivity of 0.25 dS/m. The experiment consisting of three black gram cultivars viz., Uttara, PU-31 and Mash-114, two crop geometries (30×10 cm and 45×10cm) and three treatments on foliar nutrition viz., foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS, foliar spray of 1.5% KCl at flowering and foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering was laid out in factorial randomized block design with three replications. All the cultivars under investigation were grown as per the recommended package of practices except for imposition of treatments under investigation.

The experimental results revealed that all the cultivars differ significantly from one another with regard to growth, yield, quality and uptake of nutrients. Mash-114 proved to be superior followed by Uttara and PU-31, respectively. Among treatments on crop geometry, the 30×10 cm spacing found to be superior with respect to plant height (cm), crop growth rate (CGR), relative growth rate (RGR), pod yield (kg/ha), grain yield (kg/ha) and stover yield (kg/ha) which might be a reason for higher nutrient uptake at this spacing and to fetch higher gross returns. In case of 45×10 cm spacing, number of branches per plant, dry matter accumulation ( $\text{g/m}^2$ ), number of root nodules, number of pods per plant, pod weight per plant (g) and seed yield per plant (g) showed a significant increase except for test weight and number of seeds per pod. Foliar nutrition also caused significant variation on number of branches per plant, dry matter accumulation ( $\text{g/m}^2$ ), number of root nodules, number of pods per plant, pod weight per plant (g) and seed yield per plant (g) except on number of seeds per pod, 1000 grain weight (g) and in available N,P,K and molybdenum at harvest. Among different foliar nutrition treatments, the foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering found to be superior with respect to all growth parameter, yield and yield attributing characters, grain quality and nutrient uptake over alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering.

Based on the present study, it can be safely concluded that among the three black gram cultivars, two crop geometries and three foliar sprays, the Mash-114 with foliar application of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering when planted at 30×10 cm spacing could be a viable technological proposition under rainfed conditions of Jammu.

**Keywords:** Cultivars, crop geometry, foliar nutrition, molybdenum, potassium chloride

  
Signature of Major Advisor

  
Signature of Student

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## LIST OF ABBREVIATIONS

Abbreviation	Expansions
@	at the rate of
g	Gram
m <sup>2</sup>	Square meter
ha	Hectare
kg	Kilogram
cm	Centimeter
DAS	Days after sowing
%	Per cent
Viz.	Namely
B:C	Benefit cost ratio
₹	Rupees
DAP	Di-ammonium phosphate
MOP	Muriate of potash
SSP	Single super phosphate
RDF	Recommended dose of fertilizers
KCl	Potassium chloride
NAA	Naphthalene acetic acid
KNO <sub>3</sub>	Potassium nitrate
ZnSO <sub>4</sub>	Zinc Sulphate
FeSO <sub>4</sub>	Ferrous sulphate
WSF	Water soluble fertilizer
mm	Millimeters
°C	Degree Celsius
RH <sub>e</sub>	Relative humidity (evening)
RH <sub>m</sub>	Relative humidity (morning)
EC	Electrical conductivity
ppm	Parts per million
OC	Organic carbon
Mo	Molybdenum
fb	Followed by
CD	Critical difference
SE (d)	Standard error of difference of means
NS	Non-significant
Fig.	Figure
i.e.,	That is
No.	Number
L	Litre
PE	Pre-emergence
PoE	Post-emergence
G	Granules
SL	Soluble liquid

# Chapter-1

## *Introduction*

### INTRODUCTION

---

Pulses are important source of nutrition for billions of people in the world. Pulse crops are included in a cropping system for improving the cropping intensity, soil health and fertility status of the soil. Pulses are major source of food next to cereals. Pulses belong to the family *Leguminosae*. Pulses are excellent source of proteins, large number of people in the world consumed pulses as a staple food in combination with cereals to meet their protein requirement (Singh, 2017). India is world's largest producer and consumer of pulses. Despite, our country is also a leading importer of pulses this may be due to descend in per capita availability of pulses from 22.1 kg per year in 1951 to 16.9 kg per year respectively (Anonymous, 2016a). To overcome this, rainfed areas offer a huge potential niche for pulse production.

Rainfed area covers around 56% of total cultivated area in India (Suresh *et al.*, 2014). In Jammu 46.6% of total cultivated area is under rainfed agriculture (Anonymous, 2016). The important grain legumes grown in rainfed regions of India are chickpea, pigeon pea, green gram, black gram, cowpea, lentil and peas etc. Among these grain legumes, black gram (*Vigna mungo* L. Hepper), an ancient and well known leguminous crop of Asia is popular because of its nutritional quality, green manuring value, nitrogen fixing capacity and short duration. Higher drought tolerance index (7.48) made black gram most adaptable crop to rainfed areas (Baroowa and Gogoi, 2016). According to an estimate, 100 g of black gram provides 347 kcal energy, 24% protein (Gopalan *et al.*, 2004).

India ranks first in area and production of pulses with 23.55 million hectares and 17.15 million tonnes production (Anonymous, 2016). Black gram constitutes 3.06 million hectares area with 1.70 million tonnes production contributing 9.91% to total pulse production in the country (IIPR<sub>a</sub>, 2018). In Jammu and Kashmir, black gram constitutes 13.2 (000' ha) area and 5.1 (000' tonnes) production (IIPR<sub>b</sub>, 2018).

Selection of suitable varieties, correct crop spacing and fertilizer application are most important factors that affect the crop production. Optimum crop geometry favours growth of both aerial and underground parts resulting in better utilization of solar radiation and nutrients. This gives competitive advantage to crop favouring increase in grain yield. In a study on black gram 30×10 cm spacing showed good yield and quality response (Kumar *et al.*, 2018).

Foliar application of nutrients has been proved to be an asset in fertilizer application with a specific aim of increasing nutrient availability (Meena *et al.*, 2017). Foliar application of water soluble fertilizers is a preferred solution when quick supply of nutrients is hindered in the soil and not favourable for absorption (Das and Jana, 2015).

Potassium is third macro-nutrient required for the growth after nitrogen and phosphorus. Improved potassium application has significant impact on growth and yield of black gram (Kumar *et al.*, 2014). Potassium plays a major role in osmo-regulation in the plants since its deficiency prevents stomatal closure (Wang *et al.*, 2013). Potassium is a pre-requisite for drought adaptation as quick stomatal closure results in internal moisture preservation. This phenomenon signifies potassium's role in maintaining electrical potential gradients across cell membranes to maintain turgor in plant cells. Additionally, it activates many enzymes essential for photosynthesis and protein synthesis. In potassium deficient plants, the rate of photosynthesis and ATP production are reduced and all processes that depend on ATP are slowed down. Conversely, plant respiration increases contributing to slower growth and development (Prajapati and Modi, 2012). Favourable influence of potassium application on metabolism and biological activity and its stimulating effect on photosynthetic pigments which in turn encouraged vegetative growth, yield and protein percentage.

Trace elements play a considerable role in nutrition and metabolism of plants. Molybdenum is one of the important member of trace elements. Molybdenum is a constituent of nitrate reductase and nitrogenase enzymes involving in nitrate reduction, nitrogen fixation and nitrogen metabolism (Singh *et al.*, 2014) hence Mo directly influences metabolic processes such as purine metabolism, nitrate assimilation and phyto-hormones. Molybdenum is known to be a specific inhibitor of acid phosphatase.

Photosynthesis is reduced in molybdenum deficient plants since they failed to reduce nitrite and fix atmospheric nitrogen. Molybdenum deficiency also decreased concentration of reducing sugars suggesting involvement of molybdenum in carbohydrate metabolism (Malik *et al.*, 2015). Molybdenum availability depends on soil pH, soil colloids, adsorbing oxides and on extent of pH. In acidic soil availability of molybdenum decreases with the increase in anion adsorption to soil oxides (Brent *et al.*, 2005).

However, the information available on foliar sprays of potassium and molybdenum at various growth stages with respect to their independent effect and interaction effect on performance of different black gram cultivars grown under different crop geometries is meagre and thus keeping in view the facts as stated above a field experiment entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in Shivalik foothills of Jammu**” was carried out during *kharif* season of 2018 at Advanced Centre for Rainfed Agriculture, Rakh Dhiansar with following objectives:

- To assess the effect of foliar nutrition and crop geometry on growth and yield attributes of black gram cultivars.
- To study the effect of foliar nutrition of potassium and molybdenum on nutrient uptake in different black gram cultivars.
- To work out relative economics of different treatments.

## **Chapter-2**

### *Review of Literature*

REVIEW OF LITERATURE

---

Crop cultivars behave differently in expression of their traits when subjected to various levels of competition for growth factors. Susceptibility to competition not only depends on genetic makeup of the cultivars but also on the micro-environmental conditions and nutrient supplement which is supplied under specified climate and soil. An overall understanding of all these factors play a significant role in realizing the potential yield of a crop. An attempt has been made to compile the research work conducted in India and Abroad. The pertinent literature on the topic entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shivalik* foothills of Jammu**” has been reviewed in this chapter under following headings:

**2.1. INFLUENCE OF CULTIVARS**

- 2.1.1. Effect of cultivars on growth and development
- 2.1.2. Effect of cultivars on yield and yield attributes
- 2.1.3. Effect of cultivars on nutrient uptake
- 2.1.4. Effect of cultivars on quality
- 2.1.5. Effect of cultivars on relative economics

**2.2. INFLUENCE OF CROP GEOMETRY**

- 2.2.1. Effect of crop geometry on growth and development
- 2.2.2. Effect of crop geometry on yield and yield attributes
- 2.2.3. Effect of crop geometry on nutrient uptake
- 2.2.4. Effect of crop geometry on quality
- 2.2.5. Effect of crop geometry on relative economics

## **2.3. INFLUENCE OF FOLIAR NUTRITION**

2.3.1. Effect of foliar nutrition on growth and development

2.3.2. Effect of foliar nutrition on yield and yield attributes

2.3.3. Effect of foliar nutrition on nutrient uptake

2.3.4. Effect of foliar nutrition on quality

2.3.5. Effect of foliar nutrition on relative economics

## **2.1 INFLUENCE OF CULTIVARS**

Vegetative and reproductive growth of crop are influenced by many factors among them selection of right cultivar which is adaptable to given set of environments is one of the important aspect which play an important role in achieving good crop growth and development. Several cultivars were already released on the basis of different agro-climatic conditions. The literature assessing the performance of cultivars with that of recommended cultivars has been reviewed.

### **2.1.1. Effect of cultivars on growth and development**

Kumar *et al.* (2018) revealed that the growth characters were significantly influenced by cultivars and among different cultivars significantly higher number of branches per plant at 40, 60 and at harvest stage respectively was noted and the cultivar Indira Urd-1 was found superior over RU-03-16 and RU-03-52 in black gram under clay loam soil at Raipur, Chhattisgarh.

Panotra *et al.* (2016) observed that a significant increase in growth parameters viz. plant height and leaf area/plant was recorded at 60 DAS in variety T-9 as compared to other varieties of black gram under sandy loam textured soil at Baraut, U.P.

Choudhary *et al.* (2017) found significantly higher plant height, shoot fresh weight, shoot dry weight, number of nodules per plant were obtained with JU-86 variety of black gram over other varieties under sandy loam textured soil at Ajmer, Rajasthan.

Jadhav *et al.* (2014) reported significantly higher plant height and leaf area per plant with BDU-1 variety of black gram over other varieties under clayey textured soil at Parbhani, Maharashtra.

Aggarwal *et al.* (2014) realized that MASH 114 cultivar of black gram produced significantly higher root dry weight per plant, shoot dry weight per plant and number of nodules per plant and nodule dry weight per plant over MASH-338 under loamy sand soil at Ludhiana, Punjab.

Jadhav (2013) found that plant height, number of branches per plant were significantly higher in MASH 114 over Uttara cultivar in black gram under black soil at Navsari, Gujarat.

Bajpai and Srivastava (2013) observed that seedling fresh and dry weight was significantly higher with PU-31 over Uttara (IPU-94-1) under controlled condition *in-situ* at Lucknow.

Mane *et al.* (2018) recorded significantly higher plant height, number of branches per plant at harvest and number of nodules at 50 DAS per plant with BDU-1 variety of black gram over TAU-1 and AKU-15, respectively at Parbhani, Maharashtra.

### **2.1.2. Effect of cultivars on yield and yield attributes**

Singh *et al.* (2013) in an experiment to assess the performance of Pant U-19, Pant U-35 and NDU-1 concluded that grain yield per plant, grain yield and straw yield were found significantly higher with Pant U-35 over other varieties under sandy loam textured soil at semi-arid sub-tropical region of Modipuram, Meerut.

Sahu *et al.* (2018) in a cluster frontline demonstration observed 44.77 and 35.42 per cent increase in yield with Azad-3 and PU-31 varieties of black gram, respectively at Kashigarh, Chhattisgarh.

Panotra *et al.* (2016) found that grain yield (11.07 q/ha) and straw yield (26.58 q/ha) of PU-35 was significantly superior over PU-19 (10.67 and 25.49 q/ha) and T-9

(10.33 and 25.00 q/ha) varieties, respectively under sandy loam textured soil at Baraut, U.P.

Dodwadiaya and Sharma (2012) found that SML-668 variety performed better in both rainy and summer season over other varieties of green gram viz. Pusa Baisakhi, PS-16, Pusa 9531 and Pusa Vishal at New Delhi.

Dash and Rautaray (2017) in an evaluation of different green gram varieties found that number of pods per plant, pod length, number of seeds per pod, seed yield and stover yield of Pusa Vishal was significantly superior over other varieties viz. TARM-1, IPM-02-014, SML-668 and Local (Jhain Mung). Further, number of pods per plant, pod length, number of seeds per pod, seed yield and stover yield of IPM-02-014, SML-668 and Local (Jhain Mung) were at par with each other at Jagatsinghpur, Odisha.

Jitode *et al.* (2017) recorded significantly higher number of pods per plant (24.00), weight of seeds per plant (6.33g), test weight (41.75g), grain (833 kg/ha) and straw yield (1445 kg/ha) with PKV Green Gold-9911 over PKV Mung-8802 (23.17g, 6.17g, 40.83g, 829.00 and 1440.17 kg/ha) and Kopargaon (21.75, 5.58g, 40g, 676 and 1364 kg/ha) varieties of green gram, respectively.

Gangwar *et al.* (2012) reported PU-31 variety of black gram out yielded over other varieties under investigation with 831 kg/ha and the grain yield recorded was 11.6, 281.1, 86.3, 39.1 and 32.9 percent higher over T9, PU-40, WBU 109 and Shekar 2, respectively under silty clay loam soil at Pantnagar, Uttarakhand.

Siddikee *et al.* (2018) realized significantly higher pods per plant, pod length, seeds per pod, 1000 seeds weight and seed yield with BARI mash-3 over Bari mash-1, Bari mash-2 and local mash, respectively under silty clay soil at sub-tropical region of Dhaka, Bangladesh.

Choudhary *et al.* (2017) recorded highest length of the pod, number of seeds per plant and number of pods per plant with JU-86 variety of black gram which is in tune of 10.60cm, 8.42 and 28.60 respectively and the lowest was recorded with KU 96-3 variety

of black gram which is in tune of 8.60cm, 6.17 and 25.42 respectively under sandy loam textured soil at Ajmer, Rajasthan.

Ahmad *et al.* (2004) found significantly higher grain yield and harvest index with NM-92 cultivar of mung bean which is at par with NM-98 cultivar over NARC-Mung-1 and NM-92 showed significant superiority in 1000 grain weight over other cultivars, while mean values of number of grains per pod and number of pods per plant showed statistically non significant differences under sandy clay loam soil at Faisalbad, Pakistan.

### **2.1.3. Effect of cultivars on relative economics**

Panotra *et al.* (2016) observed that gross return (Rs. 57790), net return (Rs. 37778) and B.:C ratio (2.89) of PU-35 was higher compared to PU-19 (51342, 31330 and 2.57) and T-9 (47830, 27818 and 2.39) respectively and cost of cultivation of all the three varieties was same (Rs. 20012) under sandy loam textured soil at Baraut, U.P.

Dash and Rautaray (2017) found that Pusa Vishal variety of green gram fetched higher net and gross returns with higher B:C ratio over other varieties under evaluation viz. TARM-1, IPM-02-014, SML-668 and Local (Jhain Mung) at Jagatsinghpur, Odisha.

Jitode *et al.* (2017) revealed that increase in B:C ratio is due to significant increase in gross returns and recorded significantly higher B:C ratio with PKV Green Gold-9911 (3.22) over PKV Mung-8802 and Kopargaon varieties of green gram which were in tune of 3.20 and 2.66, respectively

Kumar *et al.* (2018) reported that maximum cost of cultivation (Rs. 14,392/ha) and gross returns (Rs 32,335/ha) was obtained with Indira Urd-1 followed by RU-03-52 and RU-03-16, respectively under rainfed clayey soil at Raipur, Chattissgarh.

Prabhamani and Potdar (2018) found significant differences with regard to economics of cowpea cultivation due to genotypes and the genotype DC 15 recorded significantly higher gross return, net return and B:C ration over C-152 in vertisols at Dharwad, Karnataka.

#### **2.1.4. Effect of cultivars on nutrient uptake**

Gorade *et al.* (2014) observed 74.80, 11.22 and 33.44 kg/ha N, P and K uptake with konkan trombay tampora variety of green gram which was found significantly superior over other varieties under investigation at Dapoli, Maharashtra.

Bortolon *et al.* (2018) observed significant differences within the cultivars under investigation and found that BRS 8180, BRS 8280, TMG 1180 and ST-820 presented lower nitrogen concentrations over other cultivars of soybean under clayey soil at Pedro Afonso, Brazil.

Singh *et al.* (2013) reported that nutrient uptake of N,P,K were significantly influenced by genotypes of black gram taken for investigation and Pant U-35 found to uptake higher amounts of N (76.2 kg/ha), P (14.4 kg/ha) and K (35.1kg/ha) over Pant U-19 and NDU-1, respectively under sandy loam textured soil Modipuram, U.P.

Kavitha *et al.* (2013) in a comparative study including twelve varieties of black gram revealed that VBN 5 (416 mg/100g) was significantly superior over other varieties with higher phosphorus intake at Coimbatore, Tamilnadu.

## **2.2. Influence of crop geometry**

Plant populations affect most growth parameters of black gram even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants and with the development of new cultivars to adapt to this varying environment there is a need for a viable crop geometry that is ideally fit to that newly released cultivar. The literature given below clearly reviewed the research on different crop geometry.

### **2.2.1 Effect of crop geometry on growth and development**

Daniel and Kumar (2015) found significantly higher plant height, number of leaves per plant and number of root nodules per plant with 30×15 cm spacing over 20×15 and 40×15 cm in rainfed black gram under sandy loam soil at Allahabad, U.P. However,

significantly higher number of branches and total dry weight per plant was reported with 40×15 cm spacing.

Amruta *et al.* (2015) also found that number of branches per plant, number of leaves per plant and number of nodules per plant were significantly higher with 45×10 cm over 30×10 cm spacing in *kharf* black gram at Bangalore, Karnataka.

Achakzai and Panizai (2007) observed significantly higher plant height at 30 cm row spacing over 40 and 45 cm row spacing at Quetta but higher number of branches were observed with 45 cm row spacing.

Amanullah *et al.* (2018) revealed significantly higher plant height and number of branches per plant were produced with 35 cm row spacing over 30 cm row spacing in irrigated black gram at Quetta, Balochistan.

Singh and Kumar (2014) reported significantly higher plant height with 35 cm row spacing but number of branches per plant and dry matter accumulation was found to be significantly higher with 30 cm row spacing in black gram under sandy loam texture at Amritsar, Punjab.

Gurjar *et al.* (2018) recorded higher plant height and number of branches with 45 cm row spacing over 30 cm in semi *rabi* sown green gram under sandy loam texture at Vadodara, Gujarat.

Kalsaria *et al.* (2017) found significantly higher number of branches per plant, dry matter accumulation and dry weight of root nodules per plant with 45×10 cm spacing over 30×10 cm spacing in summer green gram under medium black calcareous soil at Junagadh, Gujarat

Kadam and Khanvilkar (2015) reported significantly higher number of branches per plant and number of leaves per plant with 45×15 cm spacing over 30×15 cm in summer green gram under loam textured soils at Dapoli, Maharashtra. However, Plant height was found significantly higher with 30×15 cm spacing.

Sathyamoorthi *et al.* (2008) realized that the number of functional root nodules per plant increased with the increase in row spacing in green gram under red sandy loam soils at Kumulur, Tamil Nadu.

Prabhamani and Potdar (2018) observed that leaf area, leaf area index and total dry matter was significantly higher with 45 cm row spacing in cowpea over 30 and 60 cm, respectively in vertisolic soils at Dharwad, Karnataka.

### **2.2.2 Effect of crop geometry on yield and yield attributes**

Kumar *et al.* (2017) observed significant increase in yield with rectangular method of seeding over square method under semi-arid tropical climate with clay loam soil at Kallikulam, Tamil Nadu.

Murade *et al.* (2014) reported that biological and seed yield were significantly higher with 30×10 cm spacing over 45×10 cm in *kharif* black gram under clayey textured soil at Akola, Maharashtra.

Ihsanullah *et al.* (2002) revealed that significantly higher test weight, number of pods per plant, pod length, biological yield and grain yield with 20 cm row spacing over 30 and 43 cm row spacing in irrigated summer mung bean at Peshawar.

Sreemathi and Hemalatha (2018) found significantly higher seed and haulm yield was obtained with 30×15 cm spacing over 30×10 cm spacing in irrigated black gram under sandy clay loam soil at Killikulam, Tamil Nadu.

Lokanadhan (2015) in a study on seasonal and geometrical variation in black gram realized that adoption of closer spacing (30×10 cm) in variety Co BG 6 gives better grain yield in both *rabi and summer* seasons at Western Agro-climatic zone of Tamil Nadu.

Biswas *et al.* (2009) reported that number of pods per plant was significantly higher with wider row spacing (40×10 cm) whereas, grain yield was significantly higher with 30×10 cm row spacing in *kharif* black gram at Bangladesh.

Tungoe *et al.* (2018) observed that grain yield and stover yield was significantly higher with 30×10 cm spacing over 45×10 cm spacing in rainfed black gram under sandy loam soil at Medziphema, Nagaland.

Khan *et al.* (2017) in a study to assess the influence of plant densities on *kharif* green gram realized significantly maximum number of pods per plant and pod length with 30×10 cm spacing under sandy clay loam soil at Punjab.

Shukla *et al.* (2017) realized that pods per plant, straw weight per plant and seed weight per plant were significantly increased with 45×10 cm spacing over 30×10 cm spacing in chickpea under loam textured soil at sub-tropical and semi-arid zone of Kanpur, U.P.

Bhowmick *et al.* (2014) found that significantly higher number of pods per plant and test weight of seeds were obtained with 25×10 cm spacing over 30×10 cm in mung bean under sandy loam soil at Murshidabad, West Bengal.

Prabhamani and Potdar (2018) observed that number of pods per plant, seed weight per plant, seed and haulm yield were significantly higher with 45 cm row spacing in cowpea over 30 and 60 cm , respectively in vertisolic soils at Dharwad, Karnataka.

### **2.2.3 Effect of crop geometry on nutrient uptake**

Lone *et al.* (2009) in a study conducted to assess the influence of seed rate, row spacing and fertility levels in temperate conditions observed that uptake of nitrogen and phosphorus increased significantly with the increase in row to row distance in soybean under clay loam soil with medium available nitrogen and potassium and low available phosphorus at Shalimar, Srinagar.

Gohil *et al.* (2017) found that nitrogen and phosphorus uptake was significantly higher with 30×10 cm spacing over 30×20 cm spacing in green gram under neutral loamy sand textured soil with low available nitrogen and medium available phosphorus at Sardarkrushinagar, Gujarat.

Kumar *et al.* (2017) reported that uptake of nitrogen, phosphorus and potassium decreased significantly with the increase in spacing in semi-arid tropical black gram under sandy clay loam soil with low nitrogen and medium phosphorus and potassium at Killikulam, Tamil Nadu.

Tungoe *et al.* (2018) observed that nitrogen, phosphorus and potassium content in seed and stover increases with increase in row spacing in rainfed black gram under sandy loam soil at Medziphema, Nagaland.

Shweta and Amandeep (2017) reviewed that higher content of phosphorus and potassium was found at narrow row spacing. However the total uptake of nitrogen is higher with wider row spacing.

#### **2.2.4. Effect of crop geometry on quality parameters**

Anbarasu *et al.* (2018) realized that in castor plants sown at wider spacing of 150×120cm consists significantly higher chlorophyll content which is in tune of 3.28 mg/g and at par with those adopted 120×120 cm spacing under sandy clay loam soil at Madurai, Tamil Nadu.

Pavithra *et al.* (2018) found that there is crop geometry has no significant response during the course of study except at 45 DAS where the baby corn sown at 60×20 cm recorded significantly higher SPAD value over other treatments and the SPAD values were at par with 30×30 cm spacing under sandy clay loam soil at Coimbatore, Tamil Nadu.

#### **2.2.5. Effect of crop geometry on relative economics**

Jagadale *et al.* (2017) in a comparative study of different levels of fertilizers and plant geometry on rainfed cowpea found that gross monetary returns, Net monetary returns and benefit cost ratio is maximum with 45×10 cm spacing over 30×10 cm spacing under clayey textured soil at Latur, Maharashtra.

Kumar *et al.* (2018) observed that net returns and benefit cost ratio are significantly higher with 30×10 cm spacing over 45×10 cm spacing in rainfed black gram under black clay textured soil at Raipur, Chhattisgarh.

Gurjar *et al.* (2018) revealed that crop sown in September at narrow spacing of 30 cm remunerate maximum net profit with highest value of benefit cost ratio (BCR) in green gram under sandy clay loam soil vadodara, Gujarat.

Nayak *et al.* (2015) found that gross monetary returns, net monetary returns and benefit cost ratio was significantly superior with 30×10 cm spacing over rest of the plant spacing in *Kharif* black gram at Parbani, Maharashtra.

Prabhamani and Potdar (2018) observed that gross return, net return and B:C ratio were significantly higher with 45 cm row spacing in cowpea over 30 and 60 cm , respectively in vertisolic soils at Dharwad, Karnataka.

### **2.3. INFLUENCE OF FOLIAR NUTRITION**

Among the methods of fertilizer application, foliar nutrition is recognized as an important method of fertilization application. Foliar application is credited with remarkably rapid absorption and nearly complete utilization of nutrients, elimination of leaching losses and fixation and helps in regulating the uptake of nutrient by plants. Foliar feeding practice would be more useful in early maturing short duration crops, where the soil applied fertilizer may not become fully available before maturity of black gram crop. There the pertinent literature given below has reviewed the effect of foliar nutrition on growth, yield and yield attributes, nutrient uptake and relative economics of black gram.

#### **2.3.1. Effect of foliar nutrition on growth and development**

Biswas *et al.* (2009) realized that nodulation, dry matter accumulation and number of branches per plant were significantly superior with foliar spray of ammonium molybdate (0.05%) over water spray at 30, 45 and 60 DAS under sandy loam soils at Murshidabad, West Bengal.

Shinde *et al.* (2017) in an experiment conducted on chick pea found that two foliar sprays with zinc sulphate (0.5%) + borax (0.2%) + ammonium molybdate (0.1%) and ferrous sulphate (0.5%) at 10 days interval during flowering in addition to seed coating of same nutrients (2g/kg) by using a polymer was significantly superior with respect to plant height, number of branches and leaf area index over control at Raichur, Karnataka.

Kumar *et al.* (2018) observed that plant height, number of branches per plant, root nodules per plant were significantly superior with foliar spray of MOP (2%) solution at flowering stage over control (water spray) at 45, 60 DAS and at maturity under rainfed condition at Sehore, M.P. and similar findings were reported when foliar sprayed with microsol (Manivannan *et al.* 2002).

Ramesh and Thirumurugan (2001) reported that plant height (52.3 cm) in soybean significantly increased with foliar application of 2% DAP + 1% KCl + Benzyl adenine 25 ppm.

Praveena *et al.* (2018) found that among the treatments under investigation foliar spray of 0.2 % boron + 5kg/ha of zinc at 20 and 30 DAS produced significantly higher plant height (64.16 cm), number of branches per plant (7.80), number of nodules (20.60) at 60DAS and crop growth rate (0.33) at 30-45 DAS in green gram under sandy loam textured soil at SHUATS, Allahabad.

### **2.3.2. Effect of foliar nutrition on yield and yield attributes**

Thakur *et al.* (2017) indicated that yield components viz. number of pods per plant, number of seeds per pod, pod length etc. marked increase with foliar application of nutrients along with RDF (Recommended Dose of Fertilizers) in pulses under north eastern dry zone at Karnataka .

Steiner and Taigo (2015) found that foliar application of molybdenum @ 52 g/ha produced more number of achenes per capitulum and higher capitulum diameter but it is statistically at par with rest of the treatments in sunflower under clayey soil at Chavantes, Brazil.

Ningawale *et al.* (2016) reported significantly higher curd diameter and dry matter of curd (%) with foliar spray of ammonium molybdate @ 50 ppm, while yield per hectare (kg) was significantly higher with foliar spray of borax @ 100 ppm in cauliflower under mixed red black with clay loam soils at Jabalpur, M.P.

Kumar *et al.* (2013) realized that foliar application of 2% DAP produced significantly pod yield per plant (62.75) when applied twice at flowering and pod formation stage in soybean over other treatments under investigation and similar results were obtained by Togay *et al.* (2008) with foliar spray of molybdenum in lentil.

Biswas *et al.* (2009) found that foliar spray with ammonium molybdate was found superior to water spray with respect to seed yield to tune of 1269.50 kg/ha and 1164.50 kg/ha, respectively under sandy loam soils at Murshidabad, West Bengal.

### **2.3.3. Effect of foliar nutrition on nutrient uptake**

Geetha and Velayutham (2016) showed that all foliar spraying treatments were significantly varying in N uptake. Among the foliar spray of nutrients, foliar spray of 2% DAP + 1% KCl twice at flowering and 15 days after flowering registered higher N uptake (64.64 kg/ha). While, P and K uptake was not significantly influenced by foliar spray but foliar spray of 2% DAP + 1% KCl twice at flowering and 15 days after flowering registered higher P and K uptake to the tune of 6.75 and 46.51 kg/ha, respectively under clay loam textured soil at Coimbatore, Tamil Nadu.

Shashikumar *et al.* (2013) realized that significantly higher nitrogen, phosphorus and potassium (kg/ha) in soil as influenced by foliar application of growth regulator, organic and inorganic of nutrients uptake in soil with RDF + foliar spray of 40 ppm NAA+ 0.5% chelated micronutrient + 2% DAP over to other treatment under medium black clay soil at Annigeri, Gadag.

Lakshmi *et al.* (2018) reported that nitrogen, phosphorus and potassium uptake was significantly higher with 2% urea foliar spray to the tune of 98, 17, 115 kg /ha over other treatment 2% DAP, 1% KNO<sub>3</sub> and 2% 19-19-19 complex fertilizer, respectively under sandy loam soil at Jangamaheswarapuram.

Suhathiya and Ravichandran (2017) reported that nitrogen phosphorus and potassium uptake was significantly higher in grain and haulm with DAP 2 % + 0.05 % ZnSO<sub>4</sub> + 0.50 % FeSO<sub>4</sub> + 0.10 % Boric acid + 0.05 % Sodium molybdate + 0.05 % Cobalt chloride over other control under clay loam at Nagar.

Mudalagiriappa *et al.* (2016) realized that significantly higher nitrogen, phosphorus and potassium uptake at harvest with foliar application of 1.50% water soluble fertilizer (WSF) spray at flowering & pod development over other treatments viz. two water spray at flowering and pod development stage, 3.2 % DAP spray at flowering and pod development stage, 0.5 % WSF spray at flowering, 1% WSF spray at flowering, 1.50 % WSF spray at flowering, 2% WSF spray at flowering., 0.5 % WSF spray at pod development, 1% WSF spray at pod development, 1.50 % WSF spray at pod development, 2% WSF spray at pod development, 0.5 % WSF spray at flowering & pod development, 131% WSF spray at flowering & pod development and 1.50% WSF spray at flowering & pod development at Bengaluru, Karnataka.

Krishna and Kaleeswari (2018) reported that nitrogen, phosphorus and potassium uptake was significantly higher by applying 100 % RDF + 0.5% KNO<sub>3</sub> + 2% DAP (twice) + micronutrient spray (once) through foliar spray, over other control.

#### **2.3.4. Effect of foliar nutrition on quality**

Datta *et al.* (2011) reported that 7.5 ppm molybdenum treated plants recorded significantly higher chlorophyll-a, chlorophyll-b and total chlorophyll to the tune of 0.093, 0.090 and 0.348 mg/g fresh weight of leaf over control in bengal gram.

Amirani *et al.* (2015) in a pot experiment conducted foliar spray of micro-nutrients was adopted to tackle drought stress which was artificially created at flowering and grain filling stage showed increase in chlorophyll-a, chlorophyll-b and total chlorophyll content under silt loam soils at Iran.

Kurhade *et al.* (2015) realized that RDF + foliar spray with 1.5% KCl at flowering and 15 days after flowering recorded significantly higher protein content (20.47) over

RDF alone as control treatment under clayey textured soil at Akola, Maharashtra and these findings were in agreement with Ibrahim and Bassyuni (2012).

Meena *et al.* (2017) recorded the highest protein content of 23.3% with 2% urea + 2% SSP + 0.1% Zn EDTA + 0.2% B (Borax) followed by 2% urea while, lowest protein content of 21.9% was observed with control (water spray) under silty clay loam soil at Pantnagar, Uttarakhand.

### **2.3.5. Effect of foliar nutrition on relative economics**

Ganga *et al.* (2014) concluded that combined application of 2% urea + 0.25 % multiplex through foliar spray provided better net return (Rs 18,786) and B:C ratio (2.36) over individual application in late sown chick pea under sandy clay loam soil at BHU, Varanasi.

Devaraju and Senthivel (2018) realized that pulse wonder @ 5kg/ha at flowering and 15 days after 1<sup>st</sup> spray found to have more net returns (Rs. 22,149) and B:C (2.19) over other treatments under clay loam soils at Dindigul, Tamil Nadu.

Shashikumar *et al.* (2013) recorded higher gross returns and B:C ratio with RDF + foliar spray of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP in black gram crop over to other treatment under medium black clay soil at Agricultural Research Station, Annigeri, Gadag.

Kumar *et al.* (2013) realized higher gross returns, net returns and B:C ratio with 2% Di-ammonium phosphate (2.5kg/ha) over other water spray (control) under clay loam soil at Coimbatore.

Krishnaprabu (2015) reported that higher cost of cultivation, gross return with 5% Panchagavya while net return and B:C ratio was higher with foliar spray of nutrients over other treatments viz. 19:19:19 (1%), DAP (1%) over Urea (1%), Cow urine (5%), Jeevamruth (5%), micronutrients (1%), vermi-wash (5%) under clay loam soil at Annamalainagar, Tamil Nadu.

# Chapter-3

## *Materials and Methods*

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**MATERIALS AND METHODS**

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The present investigation entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shiwalik* foothills of Jammu**” was conducted at the Research farm, Advanced Centre for Rainfed Agriculture, SKUAST-Jammu, Rakh Dhiansar, during the *kharif* season of 2018-19. The details of the materials used, experimental procedures followed and techniques adopted during the course of investigation have been presented in this chapter.

**3.1 EXPERIMENTAL SITE****3.1.1 Location**

The field experiment was conducted during *kharif* season of 2018-2019 at the Research Farm, Advanced Centre for Rainfed Agriculture, SKUAST-Jammu, Rakh Dhiansar. Geographically, the experimental site was located at 32°-37' N latitude and 74°-55' E longitude with an altitude of 332 meters above mean sea level in the *Shiwalik* foothills of North-Western Himalayas.

**3.1.2 Climate and weather**

The climate of the experimental site was mainly sub-tropical in nature endowed with hot and dry early summers followed by hot and humid monsoon seasons and cold and dry winters. The mean annual rainfall of the location varies from 1050-1115 mm with an average of 1000 mm of which 70-80 % rainfall is received from June to September, whereas the remaining 20-30 % of rainfall is received in few scanty showers of winter rains from December to March due to western disturbances. The maximum temperature rises upto 45°C during summers (May-June) and maximum temperature falls to 10°C during winters. However, the total rainfall and its distribution are subjected to large variations.

The weather data for the crop season was recorded at the meteorological observatory located very close to the experimental site. During the crop growing season

July 16<sup>th</sup>, 2018 to October 27<sup>th</sup>, 2018 the weekly maximum and minimum temperature varied from 30.1 to 34.6°C and 11.19 to 25.3°C, respectively. The total rainfall recorded during the entire crop growth period was 547.4 mm. Moreover, there was uniform distribution of rainfall throughout the crop growing season with maximum of 151.7mm during meteorological week 32<sup>nd</sup> i.e. in the month of August. This has been graphically presented in Fig. 1 and numerically cited in Appendix-I.

### 3.2 SOIL CHARACTERISTICS

The composite soil samples from a depth of 0-15 cm were collected, air dried, processed and used for mechanical, physical and chemical analysis. Likewise, treatment wise soil sampling was done after harvesting of the crop during year of experimentation.

The data recorded in respect of physico-chemical properties of the experimental site revealed that the soil of the experimental site was sandy loam in texture, slightly acidic in reaction, low in organic carbon, available nitrogen but medium in available phosphorus and potassium as given in Table 1.

**Table 1: Initial physico-chemical properties of experimental site**

S. No.	Parameters	Value	Methods Employed
<b>A</b>	<b>Mechanical Properties</b>		
i)	Sand (%)	70.28	Bouyoucous Hydrometer method <b>(Piper, 1966)</b>
ii)	Silt (%)	18.32	
iii)	Clay (%)	11.40	
	<b>Textural Class</b>	<b>Sandy loam</b>	Textural Diagram <b>(Black, 1965)</b>

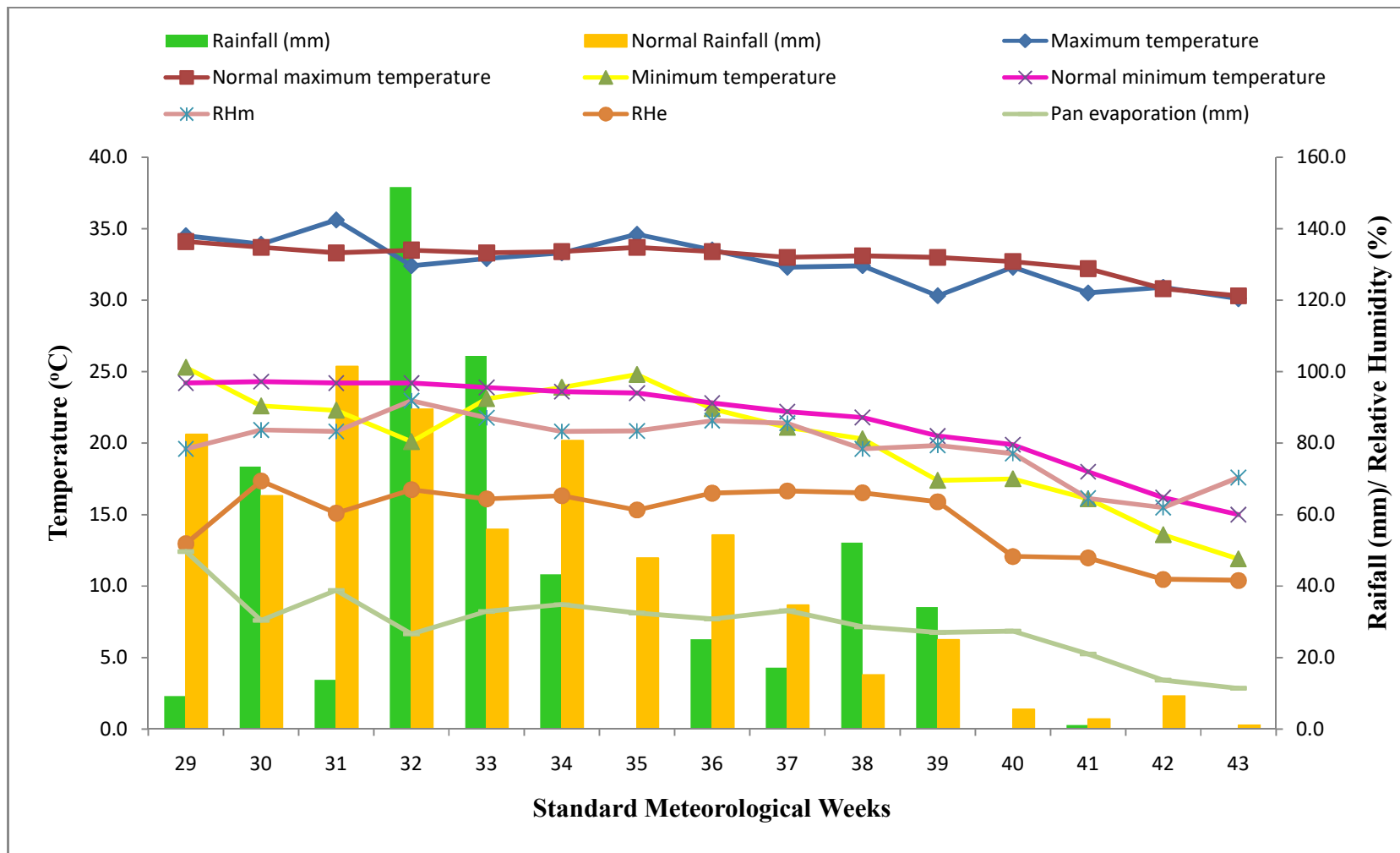


Fig. 1: Weather parameters during crop growing season (July 16 to Oct 27, 2018)

<b>B</b>	<b>Chemical Properties</b>		
i)	pH	6.47	1:2.5 Soil water suspension measured with Glass electrode pH ( <b>Jackson, 1973</b> )
ii)	EC (dS/m)	0.25	Salt bridge measurements from the suspension used for pH determination ( <b>Jackson, 1973</b> )
iii)	Organic Carbon (%)	0.36	Dichromate oxidation of organic matter ( <b>Jackson, 1973</b> )
iv)	Available N (kg/ha)	173.48	Alkaline Potassium Permanganate method ( <b>Subbiah and Asija, 1956</b> )
v)	Available P (kg/ha)	15.21	Sodium Bicarbonate method ( <b>Olsen <i>et al.</i>, 1954</b> )
vi)	Available K (kg/ha)	121.23	Ammonium Acetate method ( <b>Jackson, 1973</b> )
vii)	Available Mo (ppm)	0.087	Ammonium Oxalate method ( <b>Singh <i>et al.</i>, 1999</b> )

### 3.3 CROPPING HISTORY

The details of the crops and the cropping systems followed on the experimental field for the last few years prior to the start of the experiment are given in Table 2.

**Table2: Cropping history of the experimental site**

<b>Year</b>	<b><i>Kharif</i></b>	<b><i>Rabi</i></b>
2016-2017	-	-
2017-2018	-	Wheat
2018-2019	<b>Black gram (Experimental crop)</b>	

### 3.4 EXPERIMENTAL DETAILS

The experiment comprised of three factors- 3 black gram cultivars (Uttara, PU-31 and Mash-114), 2 crop geometries (30×10cm and 45×10 cm) and 3 foliar nutritions (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS, Foliar spray of 1.5% KCl at flowering and Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering) with eighteen treatment combinations was laid out in a factorial randomized block design in three replications at the Research Farm, Advanced Centre for Rainfed Agriculture, Rakh Dhiansar, SKUAST-Jammu.

#### 3.4.1 Treatment Details

The details of the treatments and symbols used as given in Table 3.

**Table 3. Details of Treatments:**

<b>Factor-1 (Cultivars)</b>	
C1 :	Uttara
C2 :	PU-31
C3 :	Mash-114
<b>Factor-2 (Crop geometry)</b>	
S1 :	30×10 cm
S2 :	45×10 cm
<b>Factor-3 (Foliar nutrition)</b>	
F1 :	Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS
F2 :	Foliar spray of 1.5% KCl at flowering
F3 :	Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering

### 3.4.2 Plot size and spacing

The gross and net plot sizes are given here in Table 4.

**Table 4: Gross and net plot size**

S.No.	Plot size	
1	Gross plot	4.5m×3m=13.5m <sup>2</sup>
2	Net plot	3.6m×2.6m=9.36m <sup>2</sup>

### 3.5 DETAILS OF FIELD CULTURAL OPERATIONS

The details of various cultural operations carried out during the crop growing periods have been given in Table 5.

**Table 5: Calendar of different cultural operations carried out during experimentation.**

Operation	Date of operation	Mode of execution
Field Preparation	16-7-18	Initially with tractor and manually later on
Layout	16-7-18	Manually
Sowing	16-7-18	Manually
Fertilizer Application	16-7-18	Manually
Herbicide application		
Pre- emergence herbicide	16-7-18	Application of pre-emergence herbicide (pendimethalin @1kg/ha) and post emergence herbicide (Imazethapyr @ 0.1kg/ha) through battery operated knapsack sprayer
Post-emergence herbicide	10-8-18	
Thinning	1-8-18	Manually
Foliar nutrition		
Sodium molybdate	5-8-18	Through battery operated knapsack sprayer
Potassium chloride on PU-31	1-9-18	

Potassium chloride on Uttara	5-9-18	
Potassium chloride on Mash-114	7-9-18	
<b>Physiological maturity</b>		
PU-31	7-10-18	
Uttara	12-10-18	
Mash-114	17-10-18	
<b>Harvesting</b>		
PU-31	14-10-18	Manually with sickles
Uttara	22-10-18	
Mash-114	27-10-18	
Threshing	7-12-18	Manually

### 3.5.1 Field preparation

Initially the field was prepared with the help of tractor drawn implements. After giving one deep ploughing the experimental field was cross harrowed and levelled properly to break the clods and bring the soil to the desired tilth. The plots were prepared manually.

### 3.5.2 Fertilizer Application

The application of the nutrients was done on the basis of nutrient recommendation in black gram. The recommended dose of 15 kg/ha of nitrogen and 40 kg/ha of phosphorus for black gram crop was applied through Diammonium phosphate as basal application at the time of sowing.

#### 3.5.2.1 Foliar Application

Foliar application of KCl @ 1.5 per cent is applied through Muriate of Potash (MOP) and Molybdenum is applied through Sodium molybdate @ 0.1 per cent at 20 DAS and at 50% flowering stage of different black gram cultivars as mentioned in Table 3.

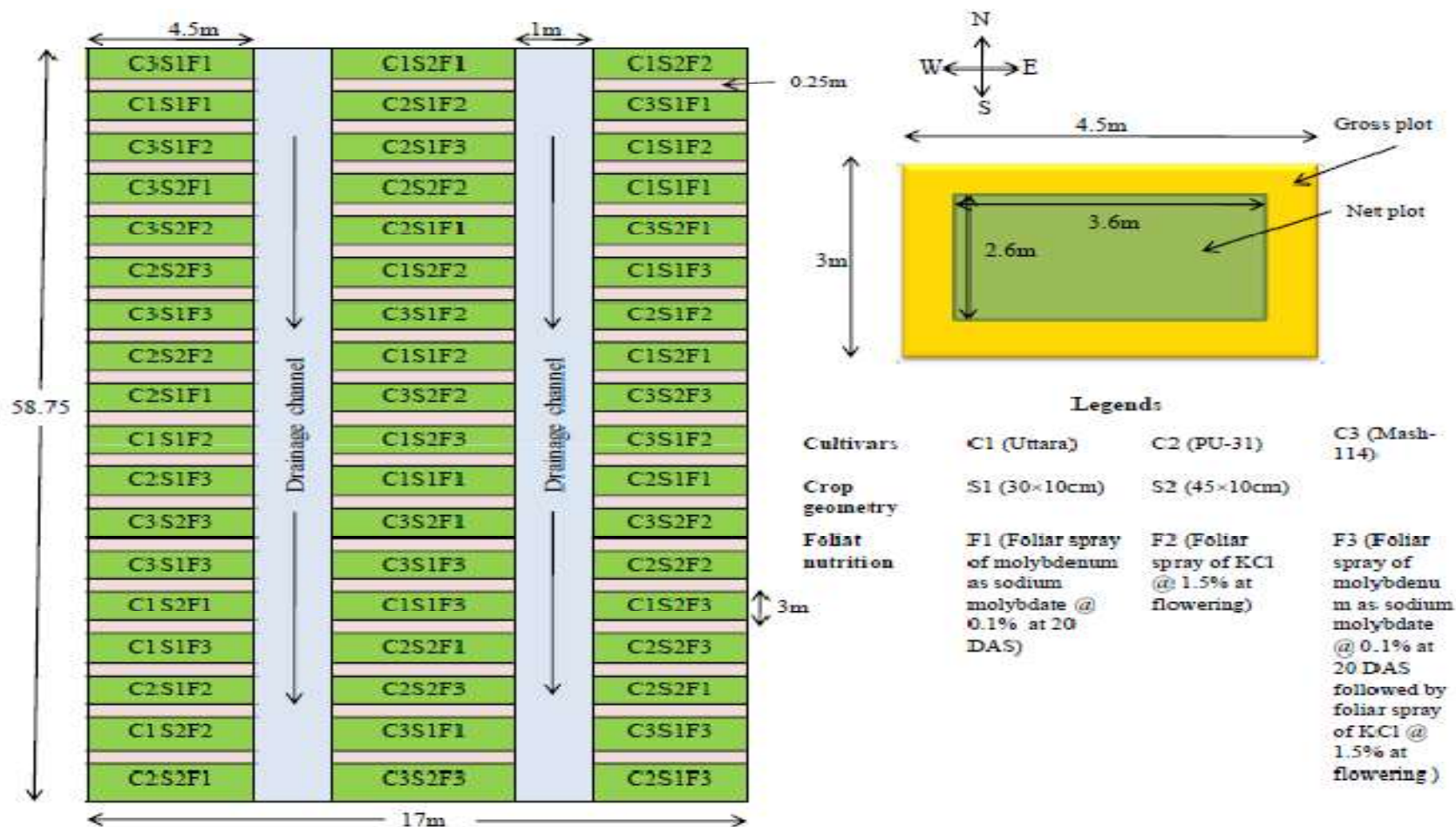


Fig. 2: LAYOUT OF FIELD EXPERIMENT

### **3.5.3 Sowing**

Furrows are opened manually with the help of liners at specified distance as given in Table 3. The seed rate of 20 kg/ha was used when sown at 30×10 cm spacing, while 13 kg/ha was used when sown at 45×10 cm spacing and seeds are sown by *kera* method. Immediately after sowing the lines are closed with soil and slightly pressed so as to have good seed-soil contact.

### **3.5.4 Thinning**

Thinning is a process of removal of extra plants to maintain ideal plant population by adjusting plant to plant distance of 10 cm as specified in Table 3. As far as possible efforts are made to save healthy plants and remove the weak plants during this operation.

### **3.5.5 Herbicide application**

For effective weed control, pre emergence application of pendimethalin @ 1kg/ha was applied immediately after sowing followed by post emergence application of Imazathapyr @ 0.1 kg/ha at 25 DAS with the help of battery operated knapsack sprayer fitted with flat fan T-jet nozzle using a spray volume of 500 litres/ha.

### **3.5.6 Harvesting and threshing**

#### **3.5.6.1 Harvesting of crop**

The crop was harvested manually with sickle when the 80-90% green pods turned black. The crop after cutting from the ground level were allowed for sun drying for 6-7 days. After drying, the harvested produce of net plot size was tied separately into bundles, labelled and bundle weight was recorded with the help of digital balance.

#### **3.5.6.2 Threshing of crop**

The sun dried produce of the crops from each plot was threshed manually by beating the bundles with wooden sticks. The grains of black gram were separated and cleaned with the help of hand fan and weight of grain was recorded on digital balance.

### **3.7 OBSERVATIONS RECORDED**

#### **3.7.1 Growth parameters**

For all the growth and development studies during the crop growth period five plants were selected randomly and tagged in each plot except for that of leaf area index, root nodule count, dry matter accumulation where plants from border rows were selected for recording observations. Initially the growth parameters were recorded at 20 days after sowing and subsequent observations were taken at an interval of 20 days and at harvest.

##### **3.7.1.1 Plant height (cm)**

The plant height from ground surface to the tip of the main stem was measured at 20,40, 60 days after sowing and at harvest. Average height of the randomly selected five plants was recorded and expressed as plant height in centimetres.

##### **3.7.1.2 Number of branches per plant**

The number of branches per plant were counted from five tagged plants and their mean was recorded as number of branches per plant at 20, 40 and 60 DAS and at harvest.

##### **3.7.1.3 Number of root nodules per plant**

The number of root nodules count was taken on 20, 40 and 60 days after sowing in randomly selected five plants. The plants were carefully taken out from the soil by keeping soil in the rhizosphere intact in order to avoid damage to the roots followed by dip the plants removed along with soil in a bucket containing tap water to remove the intact soil particles and then nodule count was performed.

##### **3.7.1.4 Dry matter accumulation (g/m<sup>2</sup>)**

Plant samples for dry matter accumulation were selected randomly from the experimental plot excluding the net plot, using 0.25 m<sup>2</sup> quadrat during different growth stages i.e. at 20, 40, 60 and at harvest. The plants were cut close to the ground level and washed to clean the dust particles and remove the excess moisture using a blotting paper and allow them to dry in shade for a day and then keep those plants in the oven to dry at a

temperature of  $65\pm 5^{\circ}\text{C}$  till a constant weight was attained and record this weight as oven dry weight.

### 3.7.1.5 Leaf area index (LAI)

Leaf area index was recorded at 20, 40 and 60 days after sowing. All the green leaves of randomly selected plants for dry matter accumulation were categorized into small, medium and large and leaf area was recorded using leaf area meter. The leaf area index of the leaves was calculated by using the following formulae (**Watson, 1947**)

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area (cm}^2\text{)}}$$

### 3.7.1.6 Crop growth rate (g/m<sup>2</sup>/day)

The increase in plant material per unit time or cumulative crop growth rate (CGR) was calculated as per the formula given by **Radford (1967)** and was expressed as gram per day:

$$\text{CGR} = \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where,  $W_1$  = total dry matter of crop per sq. meter at the time interval  $t_1$

$W_2$  = total dry matter of crop per sq. meter at the time interval  $t_2$

### 3.7.1.7 Relative growth rate (g/g/day)

The increase in plant material per unit dry matter per unit time (RGR) was calculated as per the formula given by **Radford (1967)** and was expressed as g/g/day:

$$\text{RGR} = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

Where,  $W_1$  = total weight of crop per sq. meter at the time interval  $t_1$

$W_2$  = total weight of crop per sq. meter at the time interval  $t_2$

### **3.7.2 Yield and yield attributes**

The plants selected for growth studies in each treatment were utilized at the time of harvest for recording the observations on the following yield components.

#### **3.7.2.1 Plant population per sq. meter**

An iron quadrat measuring 0.25 m<sup>2</sup> was thrown randomly at three different spots in each net plot and number of plants falling within each spot were counted and averaged to work out number of plants per sq. meter

#### **3.7.2.2 Number of pods per plant**

The pods of individual plants were counted and average of five plants was recorded as number of pods per plant.

#### **3.7.2.3 Number of seeds per pod**

The seeds from ten representative matured pods were separated and counted. The mean number of seeds per pod was calculated by dividing the number of seeds by the number of pods.

#### **3.7.2.4 Pod weight per plant (g)**

The pods of individual plants were weighed and average of five plants was recorded as weight of pods per plant.

#### **3.7.2.5 Seed yield per plant (g):**

The pods from randomly selected five plants were harvested and threshed and weighed separately and the average seed yield per plant was expressed in grams

#### **3.7.2.6 Thousand seed weight (g)**

From seed sample of each treatment, 1000 seeds were counted at random and weighed. The 1000 seed weight was expressed in grams (g).

### 3.7.2.7 Pod yield (kg/ha)

An iron quadrat measuring 0.25 m<sup>2</sup> was thrown randomly at three different spots in each net plot and pods are harvested separately from all the plants present in that area and averaged. This was used to work out pod yield per square meter and thereby it was used to estimate pod yield expressed in kg/ha.

### 3.7.2.8 Grain yield (kg/ha)

The pods collected for estimation of pod yield were threshed and seed yield per square meter is calculated and then it was used to work out grain yield expressed as kg/ha.

### 3.7.2.9 Stover yield (kg/ha)

The total biological portion from yield of above ground portion from net plot at harvest was recorded after complete sun drying and stover yield per ha was worked out by deducting the grain yield.

### 3.7.2.10 Harvest index (per cent)

The ratio of economic yield to the biological yield (harvest index) was computed using the following formula as given by **Nichiporovich (1967)**:

$$\text{Harvest index (per cent)} = \frac{\text{Economic yield (kg/ha)}}{\text{Biological yield (kg/ha)}} \times 100$$

## 3.8 SOIL STUDIES

### 3.8.1 Nutrient status of soil

After harvesting of the crop, individual soil samples from all the plots were taken from the surface for determination of pH, EC, OC, available nitrogen, phosphorus and potassium. The samples were dried under shade, grounded and passed through 2mm sieve and were analyzed.

### **3.8.1.1 Available nitrogen**

Available nitrogen was determined by modified alkaline permanganate method as described by **Subbiah and Asija (1956)** where processed soil is taken and added into the distillation flask along with 0.32%  $\text{KMnO}_4$  and 2.5% NaOH followed by collection of evolved ammonia in boric acid with mixed indicator of methyl red and bromocresol green adjusted to pH 8.5 which was titrated against a standard acid and the N estimated was expressed in kg/ha.

### **3.8.1.2 Available phosphorus**

Available phosphorus was determined using method described by **Olsen *et al.* (1954)**. The intensity of colour developed by stannous chloride was measured at 660 nm on spectrophotometer and was expressed as P kg/ha.

### **3.8.1.3 Available Potassium**

Available K was extracted with neutral normal ammonium acetate solution as described by **Jackson (1973)** and potassium was determined by flame photometer and expressed as K kg/ha.

### **3.8.1.3 Available Molybdenum**

Available molybdenum was extracted with Ammonium oxalate as described by **Singh *et al.* (1999)** and molybdenum was determined by spectrophotometer at 470 nm and was expressed as Mo ppm of soil.

## **3.9 Uptake studies in crop**

The plant samples were taken at 40 DAS and the time of harvesting for estimation of N, K and Mo concentration. The samples were oven dried, then finely ground with electric grinder and analyzed for nitrogen, phosphorus, potassium and molybdenum concentration. N and K uptake in plant samples were calculated by multiplying per cent nutrient content with their respective dry matter accumulation as per the formula given below:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{dry matter accumulation (kg/ha)}}{100}$$

### 3.9.1 Molybdenum estimation in plants

Molybdenum concentration is estimated as described by Ellis and Olsen (1950) where finely ground plant sample was taken and heated gently for 30 min after adding conc. nitric acid. Then cool it to room temperature and add per chloric acid and sulphuric acid and then continue heating for 15 min. After that cool and filter the solution, add 3ml hydrochloric acid and make the volume with distilled water. Transfer 10 ml of the solution to 25 ml flask and add 5 ml of HCl along with 1.5% potassium thiocyanate and 8ml acetone and then make the volume to 25 ml with distilled water. Then take the reading at 470 nm and was expressed as microgram per gram of sample.

$$\text{Molybdenum uptake (g/ha)} = \frac{\text{Molybdenum content (ppm)} \times \text{dry matter accumulation (kg/ha)}}{1000}$$

## 3.10 QUALITATIVE STUDIES

### 3.10.1 Protein Content (per cent)

Protein content of black gram seeds was estimated by micro-kjeldahl digestion to determine nitrogen content which is then converted to protein by multiplying respective nitrogen content in seed with a factor 6.25 (A.O.A.C, 1970).

### 3.10.2 Chlorophyll content

Five randomly selected plants from each plot were measured in the field and chlorophyll content was estimated with the help of SPAD (Soil Plant Analysis Development) chlorophyll meter make minolta.

### 3.11 ECONOMIC STUDIES

#### 3.11.1 Cost of cultivation (₹/ha)

Cost of different operations was calculated for different treatments on the basis of existing market prices of inputs and operations and the total cost was calculated by adding the expenditure involved in all kinds of operations as per treatment on per hectare basis was presented in Appendix-II.

#### 3.11.2 Gross returns (₹/ha)

Gross returns was calculated by multiplying the total grain yield with prevalent market prices of the items and then presented on per hectare basis as per treatments.

#### 3.11.3 Net returns (₹/ha)

Net returns were computed by deducting the total cost of cultivation from the gross returns as per treatments.

#### 3.11.4 Benefit: Cost Ratio (₹/₹ invested)

Benefit: Cost ratio was calculated by dividing net returns with the cost of cultivation for each treatment.

$$\text{Benefit: Cost Ratio} = \frac{\text{Net Returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

### 3.12 STATISTICAL ANALYSIS

The data presented in the thesis are the mean values. All the observations are statistically analyzed by using the Analysis of variance (ANOVA) for factorial randomized block design. The results were tested for the treatments mean by applying F-test of significance on the basis of null hypothesis (**Cochran and Cox, 1963**). Wherever necessary, standard errors along with critical difference at 5 per cent of significance were computed for discriminating the treatment effects for chance effects. The key for degrees of freedom used in analysis of variance (ANOVA) is given in below:

**Table 6: Analysis of Variance (ANOVA)**

<b>Sources of variation</b>	<b>Degree of freedom</b>
Replications (r-1)	$3-1 = 2$
Treatment combinations (t-1)	$18-1 = 17$
Error (r-1) (t-1)	$(3-1)(18-1) = 34$
<b>Total rt-1</b>	<b><math>54-1 = 53</math></b>

# Chapter-4

## *Experimental Results*

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**EXPERIMENTAL RESULTS**

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The Results obtained during the course of investigation entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shiwalik* foothills of Jammu**” conducted during *kharif* 2018-19 have been described in this chapter. The observations pertaining to different parameters of study were analyzed statistically and presented in this chapter through appropriate tables and graphs, wherever necessary. The mean weekly and monthly weather parameters, per cent nutrient contents, input-output costs have been appended in the appendices. The results of the study have been presented under the following heading:

**4.1 Growth studies**

The growth of black gram was measured in terms of plant height (cm), number of branches per plant, number of root nodules per plant, dry matter accumulation ( $\text{g/m}^2$ ), leaf area index (LAI), crop growth rate ( $\text{g/m}^2/\text{day}$ ) and relative growth rate ( $\text{g/g/m}^2/\text{day}$ ).

**4.1.1 Plant height (cm)**

Plant height is reliable index of growth and development representing infrastructure build up over a period of time. The data pertaining to plant height (cm) at different stages of crop growth as influenced by different cultivars, crop geometry and foliar spray treatments are summarized in Table 7.

Plant height increased with the advancement in the crop age upto harvest. The differences in plant height (cm) due to different cultivars, crop geometry and foliar spray treatments were found to be significant at all crop growth stages except at 20 DAS especially with crop geometry and foliar spray treatments.

Differences in plant height due to cultivars were found to be significant at all the stages of crop growth. Mash-114 recorded significantly taller plants as compared to Uttara and PU-31. While Uttara produced significantly taller plants than PU-31.

Among crop geometry treatments, 30×10 cm spacing recorded significantly higher plant height than 45×10 cm spacing at all crop growth stages except at 20 DAS.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl@ 1.5% at flowering recorded significantly higher plant height over alone application of foliar spray of KCl @ 1.5% at flowering at all the stages of crop growth except at 20 DAS. While produced similar results with alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS except at 20 and 40 DAS. However, foliar spray of Mo as sodium molybdate @ 0.1% at 20 DAS recorded taller plants than foliar spray of KCl @ 1.5% at flowering.

**Table 7: Effect of cultivars, crop geometry and foliar sprays on plant height (cm) of black gram**

Treatments	Plant Height (cm)			
	Days After Sowing (DAS)			
	20	40	60	At Harvest
<b>C (Cultivars)</b>				
C1 (Uttara)	23.01	35.84	52.86	53.78
C2 (PU-31)	21.71	34.29	47.31	48.30
C3 (Mash-114)	24.71	39.32	60.10	61.03
SE(d) ±	0.44	0.47	1.11	1.18
CD (5%)	0.89	0.94	2.26	2.40
<b>S (Crop geometry)</b>				
S1 (30×10cm)	23.32	36.87	54.46	55.46
S2 (45×10 cm)	22.97	36.09	52.39	53.28
SE(d) ±	0.36	0.38	0.91	0.96
CD (5%)	NS	0.77	1.84	1.96
<b>F (Foliar nutrition)</b>				
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	23.23	37.97	53.41	54.41
F2 (Foliar spray of 1.5% KCl at flowering)	22.93	33.29	51.13	51.86
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	23.28	38.18	55.73	56.84
SE(d) ±	0.44	0.47	1.11	1.18
CD (5%)	NS	0.94	2.26	2.40

**Interaction-** Non significant

#### 4.1.2 Number of branches per plant

The data pertaining to number of branches per plant at different growth stages of black gram were influenced by different black gram cultivars, crop geometry and foliar spray and statistically analysed and shown in Table 8.

Number of branches increased with the advancement in the crop age upto harvest however, the rate of increase was maximum between 40-60 days after sowing (DAS) and thereafter declined towards harvest irrespective of the treatments. The differences in number of branches due to different cultivars, crop geometry and foliar spray treatments were found to be significant at all crop growth stages except at 20 DAS in crop geometry and foliar spray treatments.

Differences in number of branches due to cultivars were found to be significant at all the stages of crop growth. Mash-114 recorded significantly more number of branches as compared to Uttara and PU-31. While Uttara produced significantly higher number of branches than PU-31.

Among crop geometry treatments, 45×10 cm spacing recorded significantly higher number of branches per plant than 30×10 cm spacing at all crop growth stages except at 20 DAS.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @ 1.5% at flowering recorded significantly higher number of branches to the tune of 1.46, 3.87, 8.86 and 9.39 at 20, 40, 60 DAS and at harvest over alone application of foliar spray of KCl @ 1.5% at flowering at all the stages of crop growth except at 20 DAS. While produced similar results with alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS except at 20 and 40 DAS. However, foliar spray of Mo as sodium molybdate @ 0.1% at 20 DAS recorded higher number of branches than foliar spray of KCl @ 1.5% at flowering.

The interaction effect of cultivars and foliar application of nutrients was found significant on number of branches per plant at 40, 60 DAS and at harvest which was exhibited in Table 8.1, 8.2 and 8.3. This interaction revealed that foliar spray of

molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering recorded significantly higher number of branches over foliar spray of KCl @ 1.5% at flowering with all the cultivars taken for investigation. While foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering was statistically at par with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS with respect to Uttara and Mash-114 at 40 DAS. At 60 DAS and at harvest the interaction effect of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering was significantly higher over alone application with all cultivars taken for comparison.

**Table 8: Effect of cultivars, crop geometry and foliar sprays on number of branches of black gram**

Treatments	No. of Branches			
	Days After Sowing (DAS)			
	20	40	60	At Harvest
<b>C (Cultivars)</b>				
C1 (Uttara)	1.24	3.59	8.14	8.60
C2 (PU-31)	1.16	3.26	7.60	8.00
C3 (Mash-114)	1.83	4.16	9.09	9.95
SE(d) ±	0.06	0.07	0.08	0.09
CD (5%)	0.11	0.15	0.16	0.18
<b>S (Crop geometry)</b>				
S1 (30×10cm)	1.39	3.61	8.14	8.70
S2 (45×10 cm)	1.43	3.73	8.47	8.99
SE(d) ±	0.05	0.06	0.07	0.07
CD (5%)	NS	0.12	0.13	0.15
<b>F (Foliar nutrition)</b>				
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	1.44	3.86	8.37	8.91
F2 (Foliar spray of 1.5% KCl at flowering)	1.33	3.30	7.61	8.25
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	1.46	3.87	8.86	9.39
SE(d) ±	0.06	0.07	0.08	0.09
CD (5%)	NS	0.15	0.16	0.18
C × F	NS	0.26	0.28	0.31
S × F	NS	NS	NS	NS
C × S	NS	NS	NS	NS
C×S×F	NS	NS	NS	NS

**Table 8.1: Number of branches per plant as affected by interaction between cultivars and foliar sprays at 40 DAS in black gram**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	3.87	3.48	4.23	3.86
F2 (Foliar spray of 1.5% KCl at flowering)	3.07	2.80	4.03	3.30
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering)	3.89	3.49	4.23	3.87
Mean of C	3.59	3.26	4.16	
SE(d) ±	0.13			
CD (5%)	0.26			

**Table 8.2: Number of branches per plant as affected by interaction between cultivars and foliar sprays at 60 DAS in black gram**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	8.37	7.80	8.93	8.37
F2 (Foliar spray of 1.5% KCl at flowering)	7.30	6.90	8.64	7.61
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	8.77	8.10	9.70	8.86
Mean of C	8.14	7.60	9.09	
SE(d) ±	0.14			
CD (5%)	0.28			

**Table 8.3: Number of branches per plant as affected by interaction between cultivars and foliar sprays at harvest in black gram**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	8.77	8	9.97	8.91
F2 (Foliar spray of 1.5% KCl at flowering)	7.90	7.30	9.56	8.25
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	9.13	8.70	10.33	9.39
Mean of C	8.6	8	9.95	
SE(d) ±	0.15			
CD (5%)	0.31			

#### 4.1.3 Number of root nodules per plant

The data related to number of nodules per plant at 20, 40 and 60 DAS as influenced by different black gram cultivars, crop geometries and foliar sprays were statistically analyzed and presented in Table 9.

It is evident from the data that number of root nodules per plant increased with the advancement in the crop age upto 60 DAS. The differences in number of root nodules due to different cultivars, crop geometry and foliar spray treatments were found to be significant at all crop growth stages except at 20 DAS in crop geometry and foliar spray treatments.

Among the cultivars, Mash-114 registered significantly maximum number of root nodules per plant over Uttara and PU-31. While significantly lower number of root nodules was recorded by PU-31 over other cultivars under comparison.

Among crop geometry treatments, 45×10 cm spacing recorded significantly higher number of root nodules per plant than 30×10 cm spacing at all stages where observations with respect to root nodules except at 20 DAS.

Application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @ 1.5% at flowering had registered maximum number of root nodules per plant over alone application of foliar spray of KCl @ 1.5% at flowering at all stages where observations with respect to root nodules are made except at 20 DAS. While produced similar results with alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS except at 20 and 40 DAS. However, foliar spray of Mo as sodium molybdate @ 0.1% at 20 DAS recorded higher number of root nodules per plant than foliar spray of KCl @ 1.5% at flowering.

Significant interaction of cultivars and foliar spray was recorded for number of root nodules per plant is exhibited in Table 9.1 and 9.2. At 40 DAS the foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering was found statistically at par with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS irrespective of cultivars. However, at 60 DAS the interaction effect of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering was significantly higher over alone application with all cultivars under investigation.

**Table 9: Effect of cultivars, crop geometry and foliar sprays on number of nodules per plant of black gram.**

Treatment	Days After Sowing (DAS)		
	20	40	60
<b>C (Cultivars)</b>			
C1 (Uttara)	10.04	19.71	35.02
C2 (PU-31)	8.80	17.45	32.78
C3 (Mash-114)	11.41	24.79	38.70
SE(d) ±	0.12	0.49	0.36
CD (5%)	0.23	1.00	0.73
<b>S (Crop geometry)</b>			
S1 (30×10cm)	10.02	20.01	35.01
S2 (45×10 cm)	10.15	21.36	36.44
SE(d) ±	0.09	0.40	0.30
CD (5%)	NS	0.82	0.60
<b>F (Foliar nutrition)</b>			
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	10.10	22.18	35.98
F2 (Foliar spray of 1.5% KCl at flowering)	10.02	17.55	32.25
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	10.13	22.22	38.27
SE(d) ±	0.12	0.49	0.36
CD (5%)	NS	1.00	0.73
C × F	NS	1.74	1.24
S × F	NS	NS	NS
C × S	NS	NS	NS
C×S×F	NS	NS	NS

**Table 9.1: Number of nodules per plant as affected by interaction between cultivars and foliar sprays at 40 DAS in black gram.**

<b>Factors</b>	<b>C1 (Uttara)</b>	<b>C2 (PU-31)</b>	<b>C3 (Mash-114)</b>	<b>Mean of F</b>
<b>F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)</b>	21.73	19.20	25.60	22.18
<b>F2 (Foliar spray of 1.5% KCl at flowering)</b>	15.70	13.93	23.03	17.55
<b>F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )</b>	21.70	19.23	25.73	22.22
<b>Mean of C</b>	19.71	17.45	24.79	
<b>SE(d) ±</b>	<b>0.85</b>			
<b>CD (5%)</b>	<b>1.74</b>			

**Table 9.2: Number of nodules per plant as affected by interaction between cultivars and foliar sprays at 60 DAS in black gram**

<b>Factors</b>	<b>C1 (Uttara)</b>	<b>C2 (PU-31)</b>	<b>C3 (Mash-114)</b>	<b>Mean of F</b>
<b>F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)</b>	35.98	33.54	38.41	35.98
<b>F2 (Foliar spray of 1.5% KCl at flowering)</b>	31.39	29.67	35.70	32.25
<b>F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )</b>	37.70	35.12	41.99	38.27
<b>Mean of C</b>	35.02	32.78	38.70	
<b>SE (d) ±</b>	<b>0.61</b>			
<b>CD (5%)</b>	<b>1.24</b>			

#### 4.1.4 Leaf Area Index

Leaf area index (LAI) is an important component which determines the amount of solar radiations intercepted by crop canopy to be utilized for normal metabolic activities of the plants. A pre-usual of data with regard to leaf area index are summarized in Table 10.

The differences in leaf area index due to different cultivars, crop geometry and foliar spray treatments were found to be significant at all crop growth stages except at 20 DAS in crop geometry and foliar spray treatments.

Differences in LAI due to cultivars were found to be significant at all the stages of crop growth. Mash-114 recorded significantly higher leaf area index as compared to Uttara and PU-31. While Uttara produced significantly more number of leaf area index than PU-31.

Among crop geometry treatments, 30×10 cm spacing recorded significantly higher leaf area index than 45×10 cm spacing at all crop growth stages except at 20 DAS.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @ 1.5% at flowering recorded significantly higher LAI over alone application of foliar spray of KCl @ 1.5% at flowering at all the stages of crop growth except at 20 DAS. While produced similar results with alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS except at 20 and 40 DAS. However, foliar spray of Mo as sodium molybdate @ 0.1% at 20 DAS recorded higher LAI than foliar spray of KCl @ 1.5% at flowering.

The interaction effect of varieties and foliar application of nutrients was found significant on leaf area index at 40 DAS and 60 DAS and the relevant data are presented in Table- 10.1 and 10.2. Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering recorded significantly higher leaf area index over foliar spray of 1.5% KCl at flowering with all the varieties taken for investigation. While foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering was statistically at par with foliar spray of molybdenum as sodium

molybdate @ 0.1% at 20 DAS with respect to Uttara and Mash-114 at 40 DAS. At 60 DAS interaction effect foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering with all varieties taken for comparison.

**Table 10: Effect of cultivars, crop geometry and foliar sprays on leaf area index of black gram.**

Treatment	Days after Sowing		
	20	40	60
<b>C (Cultivars)</b>			
C1 (Uttara)	0.251	0.998	1.504
C2 (PU-31)	0.220	0.736	0.993
C3 (Mash-114)	0.285	1.302	1.757
SE(d) ±	0.003	0.052	0.059
CD (5%)	0.006	0.106	0.120
<b>S (Crop geometry)</b>			
S1 (30×10cm)	0.254	1.063	1.530
S2 (45×10 cm)	0.251	0.939	1.282
SE(d) ±	0.002	0.043	0.048
CD (5%)	NS	0.087	0.098
<b>F (Foliar nutrition)</b>			
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	0.253	1.192	1.443
F2 (Foliar spray of 1.5% KCl at flowering)	0.251	0.645	1.034
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	0.253	1.199	1.776
SE(d) ±	0.003	0.052	0.059
CD (5%)	NS	0.106	0.120
C × F	NS	0.184	0.208
S × F	NS	NS	NS
C × S	NS	NS	NS
C×S×F	NS	NS	NS

**Table 10.1: Leaf area index as affected by interaction between cultivars and foliar sprays at 40 DAS in black gram.**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	1.208	0.945	1.422	1.192
F2 (Foliar spray of 1.5% KCl at flowering)	0.573	0.315	1.048	0.645
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	1.212	0.948	1.437	1.199
Mean of C	0.998	0.736	1.302	
SE (d) ±	0.09			
CD (5%)	0.184			

**Table 10.2: Leaf area index as affected by interaction between cultivars and foliar sprays at 60 DAS in black gram.**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	1.518	0.980	1.832	1.443
F2 (Foliar spray of 1.5% KCl at flowering)	1.078	0.735	1.290	1.034
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	1.915	1.263	2.150	1.776
Mean of C	1.504	0.992	1.757	
SE(d) ±	0.10			
CD (5%)	0.208			

#### 4.1.5 Dry Matter Accumulation ( $\text{g/m}^2$ )

Dry matter accumulation is an important index indicating photosynthetic efficiency of the crop which ultimately influences the crop yield. It is a direct index of plant proliferation. Dry matter accumulation progressively increased with advancement of crop age as presented in Table 11 and depicted in Fig. 3, 4 and 5. Dry matter accumulation varied significantly in response to different cultivars, crop geometry and foliar spray except at 20 DAS in crop geometry and foliar spray treatments.

Among the cultivars Mash-114 recorded significantly higher accumulation of dry matter as compared to Uttara and PU-31. While Uttara accumulated significantly higher dry matter than PU-31.

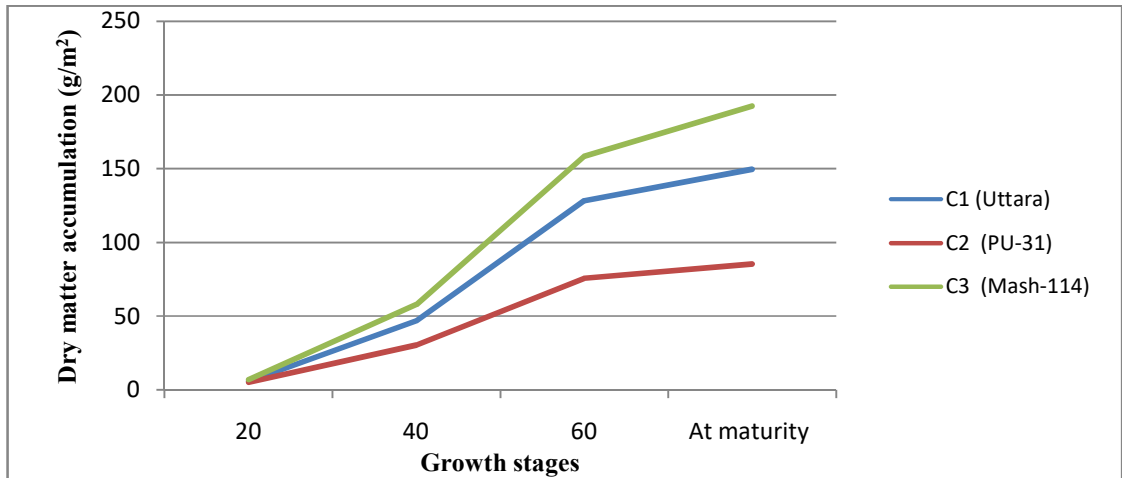
Among crop geometry treatments,  $30 \times 10$  cm spacing recorded significantly more accumulation of dry matter over  $45 \times 10$  cm spacing at all crop growth stages except at 20 DAS.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @ 1.5% at flowering recorded significantly more accumulation of dry matter over alone application of foliar spray of KCl @ 1.5% at flowering at all the stages of crop growth except at 20 DAS. While produced similar results with alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS except at 20 and 40 DAS. However, foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS recorded more dry matter accumulation than foliar spray of KCl @ 1.5% at flowering.

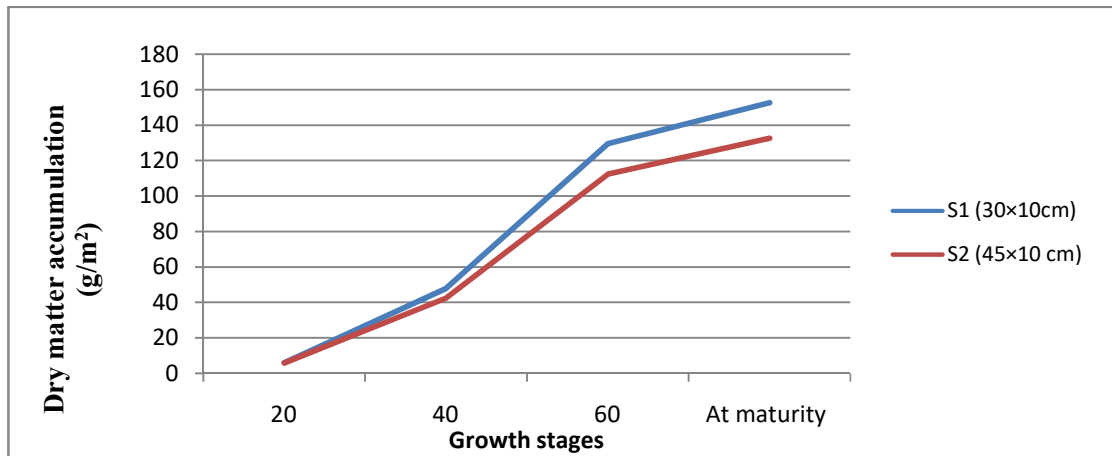
**Table 11: Effect of cultivars, crop geometry and foliar sprays on periodic dry matter accumulation (g/m<sup>2</sup>) of black gram**

Treatments	Dry Matter Accumulation (g/m <sup>2</sup> )			
	Days After Sowing (DAS)			
	20	40	60	At maturity
<b>C (Cultivars)</b>				
C1 (Uttara)	5.71	46.90	128.30	149.64
C2 (PU-31)	5.22	30.58	75.66	85.38
C3 (Mash-114)	7.03	57.99	158.56	192.53
SE(d) ±	0.24	1.78	5.53	6.45
CD (5%)	0.49	3.62	11.23	13.09
<b>S (Crop geometry)</b>				
S1 (30×10cm)	6.08	47.81	129.39	152.47
S2 (45×10 cm)	5.89	42.50	112.29	132.56
SE(d) ±	0.20	1.46	4.52	5.26
CD (5%)	0.40	2.96	9.17	10.69
<b>F (Foliar nutrition)</b>				
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	5.99	46.05	122.52	144.48
F2 (Foliar spray of 1.5% KCl at flowering)	5.84	40.38	106.01	124.59
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	6.12	49.04	133.98	158.48
SE(d) ±	0.24	1.78	5.53	6.45
CD (5%)	0.49	3.62	11.23	13.09

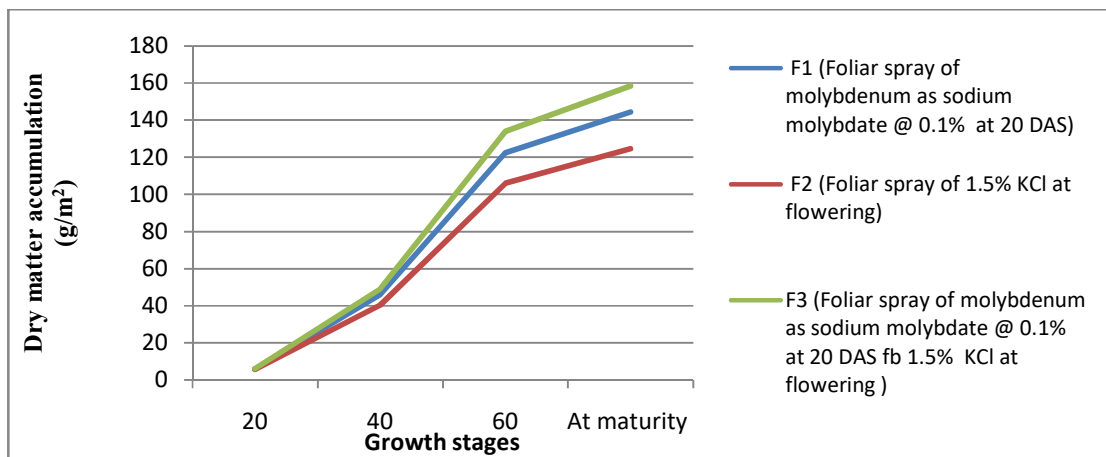
**Interaction-** Non significant



**Fig. 3: Effect of cultivars on dry matter accumulation of black gram**



**Fig. 4: Effect of crop geometry on dry matter accumulation of black gram**



**Fig. 5: Effect of foliar nutrition on dry matter accumulation of black gram**

#### 4.1.6 Crop growth rate (g/m<sup>2</sup>/day)

The crop growth rate increased with the advancement of the crop age upto 60 DAS and thereafter showed a declining trend. Different cultivars, crop geometries and foliar sprays under investigation significantly influenced the crop growth rate is presented in the Table 12.

The data pertaining to CGR reveals that rate of growth in Mash-114 was significantly more rapid than Uttara and PU-31. While Uttara grows significantly at a faster rate than PU-31.

Among crop geometry treatments, the data recorded revealed that wider spacing of 45×10 cm spacing caused significant increase in crop growth rate at all stages upto 60 DAS except at 20 DAS.

Among crop geometry treatments, 30×10 cm spacing recorded significantly more accumulation of dry matter over 45×10 cm spacing at all crop growth stages except at 20 DAS.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @ 1.5% at flowering recorded significantly more rapid growth rate over alone application of foliar spray of KCl @ 1.5% at flowering at all the stages of crop growth except at 20 DAS. While produced similar results with alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS except at 20 and 40 DAS. However, foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS recorded more growth rate than foliar spray of KCl @ 1.5% at flowering.

**Table 12: Effect of cultivars, crop geometry and foliar sprays on crop growth rate (g/m<sup>2</sup>/day) of black gram.**

Treatment	Days After Sowing		
	20-40	40-60	60-maturity
<b>C (Cultivars)</b>			
C1 (Uttara)	2.06	4.07	0.79
C2 (PU-31)	1.27	2.25	0.42
C3 (Mash-114)	2.55	5.03	1.03
SE(d) ±	0.08	0.19	0.03
CD (5%)	0.17	0.39	0.07
<b>S (Crop geometry)</b>			
S1 (30×10cm)	2.09	4.08	0.80
S2 (45×10 cm)	1.83	3.49	0.70
SE(d) ±	0.07	0.16	0.03
CD (5%)	0.14	0.32	0.06
<b>F (Foliar nutrition)</b>			
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	2.00	3.82	0.75
F2 (Foliar spray of 1.5% KCl at flowering)	1.73	3.28	0.64
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	2.15	4.25	0.85
SE(d) ±	0.08	0.19	0.03
CD (5%)	0.17	0.39	0.07
<b>Interaction- Non significant</b>			

#### 4.1.7 Relative growth rate (g/g/m<sup>2</sup>/day)

The data pertaining to relative growth rate presented in the Table 13. It is evident from the data that cultivars like Mash-114 and Uttara has relative growth rate at par with each other at 20-40 DAS and 40-60 DAS, respectively. However, both these cultivars significantly differ in their relative growth with that of PU-31. In case of crop geometries adopted the data recorded revealed that wider spacing of 45×10 cm spacing caused significant increase in relative growth rate at 20-40 DAS and 40-60 DAS. The foliar spray treatments revealed that foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering has significant influence on relative growth rate of black gram plants over alone application between 40 and 60 DAS.

**Table 13: Effect of cultivars, crop geometry and foliar sprays on relative growth rate of black gram**

Treatment	RGR (g/g/m <sup>2</sup> /day)		
	Days After Sowing		
	20-40	40-60	60-maturity
<b>C (Cultivars)</b>			
C1 (Uttara)	0.0457	0.0217	0.0025
C2 (PU-31)	0.0381	0.0195	0.0023
C3 (Mash-114)	0.0457	0.0218	0.0026
CD (5%)	0.0016	0.0005	0.0001
<b>S (Crop geometry)</b>			
S1 (30×10cm)	0.0442	0.0213	0.0024
S2 (45×10 cm)	0.0421	0.0207	0.0024
CD (5%)	0.0013	0.0004	0.0001
<b>F (Foliar nutrition )</b>			
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	0.0435	0.0208	0.0024
F2 (Foliar spray of 1.5% KCl at flowering)	0.0412	0.0206	0.0024
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	0.0447	0.0216	0.0025
CD (5%)	0.0016	0.0005	0.0001

**Interaction-** Non significant

## 4.2 Yield and Yield attributes

After harvest, the yield attributes viz. 1000 grain weight, number of seeds per pod, pod weight per plant, number of pods per plant, seed yield per plant were recorded.

### 4.2.1 1000 grain weight (g)

Thousand grain weight indicates the nature and extent of grain development. It is a function of various production factors that influences grain development and filling pattern. The data presented in Table 14 showed that different varieties, crop geometry and foliar spray treatments could not bring about statistical differences in 1000 grain weight of black gram. However, it is observed that among varieties Mash-114 recorded numerically higher grain weight with 1000 seeds followed by utara and PU-31, respectively.

Among crop geometry, it is observed that crop grown with wider row spacing of 45×10 cm recorded numerically higher 1000 grain weight over closer row spacing of 30×10 cm.

Though, foliar spray treatments could not play a significant role with respect to 1000 grain weight but numerical variation observed clearly such that foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering realized comparatively higher 1000 grain weight followed by alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering.

### 4.2.2 Number of seeds per pod

It is evicted from the data presented in Table 14 shows that cultivars, crop geometry and foliar sprays could not bring about statistical differences in number of seeds per pod but the numerical differences among them are quite clear. However, it is observed that among varieties Mash-114 recorded numerically higher number of seeds per pod followed by utara and PU-31, respectively.

Among crop geometry treatments it is observed that crop grown with wider spacing of 45×10 cm recorded more number of seeds per pod over 30×10 cm spacing.

Among foliar spray treatments, foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering recorded numerically more number of seeds per pod followed by alone application of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering.

#### **4.2.3 Number of pods per plant**

The data pertaining to number of pods per plant as influenced by different black gram cultivars, crop geometries and foliar sprays were statistically analyzed and presented in Table 14.

The perusal of data in Table 14 clearly reveals that the number of pods per plant was significantly affected by different black gram cultivars. The Black gram cultivar Mash-114 produced significantly higher number of pods and the significantly lowest number of pods per plant was recorded by PU-31.

Spacing being an important factor of crop growth and development had impacted the number of pods per plant significantly and when recorded higher number of pods when planted at 45×10 cm over 30×10 cm.

The foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering recorded significantly higher pod weight per plant over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering, among the foliar spray treatments.

A significant interaction has been found between cultivars and foliar nutrition which was presented in Table 14.1. It was found that Mash-114 when sprayed with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering was significantly recorded higher number of pods per plant over other combination under comparison.

#### **4.2.4 Pod weight per plant (g)**

The data pertaining to pod weight per plant as influenced by different black gram cultivars, crop geometries and foliar sprays were statistically analyzed and presented in Table 14.

Among the cultivars, Mash-114 registered significantly higher pod weight per plant over Uttara and PU-31. While significantly lower number of pod weight per plant was recorded by PU-31 over other cultivars under comparison.

Among crop geometry treatments it is observed that crop grown with wider spacing of 45×10 cm recorded significantly higher pod weight per plant over 30×10 cm spacing.

Among foliar spray treatments, foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering recorded significantly higher pod weight per plant over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering. In the same time foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS recorded significantly higher pod weight over foliar spray of KCl @ 1.5% at flowering.

The interaction effect between cultivars and foliar nutrition showed significant results with respect to the pod weight per plant was presented in Table 14.2. It followed the similar trend as that of number of pods per plant.

#### **4.2.5 Seed yield per plant (g)**

The perusal of data related to seed yield per plant presented in Table 14 clearly reveals that different black gram cultivars, crop geometries and foliar sprays were significantly influenced seed yield per plant. The Black gram cultivar Mash-114 produced significantly more seed yield per pod in comparison to other cultivars under investigation. In case of crop geometry, being an important factor determining the competition effect within the planting community wherein the 45×10cm spacing recorded significantly higher seed yield per plant over 30×10 cm.

Among the foliar spray treatment foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering recorded significantly higher pod weight per plant over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering,

Interaction effect of cultivars and foliar nutrition was found to be significant with respect to seed yield per plant and it was presented in Table 14.3. It was evident from the data that the best combination with respect to seed yield per plant was foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering on Massh-114 whose response was significantly superior to the combined application of molybdenum and KCl over other combinations, respectively.

**Table 14: Effect of cultivars, crop geometry and foliar sprays on plant population per m<sup>2</sup> and yield attributes of black gram**

Treatments	Plant population / m <sup>2</sup>	Pods/ plant	Pod wt/ plant (g)	Seed yield / plant (g)	Seeds/ pod	1000 seed wt (g)
<b>C (Cultivars)</b>						
C1 (Uttara)	27.61	23.54	4.43	3.92	7.04	30.94
C2 (PU-31)	27.78	22.57	4.21	3.74	7.01	30.76
C3 (Mash-114)	26.56	25.32	4.80	4.28	7.59	33.29
SE(d) ±	0.96	0.16	0.03	0.03	0.27	1.38
CD (5%)	NS	0.33	0.07	0.06	NS	NS
<b>S (Crop geometry)</b>						
S1 (30×10cm)	32.26	23.53	4.42	3.92	7.15	31.26
S2 (45×10 cm)	22.37	24.15	4.57	4.04	7.28	32.06
SE(d) ±	0.78	0.13	0.03	0.02	0.22	1.13
CD (5%)	1.59	0.27	0.06	0.05	NS	NS
<b>F (Foliar nutrition )</b>						
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	27.72	23.95	4.52	4.00	7.09	31.30
F2 (Foliar spray of 1.5% KCl at flowering)	27.67	22.53	4.19	3.75	7.10	30.33
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	26.56	24.94	4.73	4.19	7.46	32.85
SE(d) ±	0.96	0.16	0.03	0.03	0.27	1.38
CD (5%)	NS	0.33	0.07	0.06	NS	NS
C × F	NS	0.58	0.12	0.11	NS	NS
S × F	NS	NS	NS	NS	NS	NS
C × S	NS	NS	NS	NS	NS	NS
C×S×F	NS	NS	NS	NS	NS	NS

**Table 14.1: Number of pods per plant as affected by interaction between cultivars and foliar sprays at harvest in black gram.**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
<b>F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)</b>	23.93	22.90	25.03	23.95
<b>F2 (Foliar spray of 1.5% KCl at flowering)</b>	21.97	21.20	24.44	22.53
<b>F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )</b>	24.73	23.60	26.50	24.94
<b>Mean of C</b>	23.54	22.57	25.32	
<b>SE(d) ±</b>	<b>0.28</b>			
<b>CD (5%)</b>	<b>0.58</b>			

**Table 14.2: Pod weight per plant (g) as affected by interaction between cultivars and foliar sprays at harvest in black gram.**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
<b>F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)</b>	4.53	4.29	4.75	4.52
<b>F2 (Foliar spray of 1.5% KCl at flowering)</b>	4.09	3.92	4.56	4.19
<b>F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )</b>	4.68	4.43	5.08	4.73
<b>Mean of C</b>	4.43	4.21	4.80	
<b>SE(d) ±</b>	<b>0.05</b>			
<b>CD (5%)</b>	<b>0.12</b>			

**Table 14.3: Seed yield per plant (g) as affected by interaction between cultivars and foliar sprays at harvest in black gram**

Factors	C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
<b>F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)</b>	4.00	3.80	4.20	4.00
<b>F2 (Foliar spray of 1.5% KCl at flowering)</b>	3.62	3.48	4.14	3.75
<b>F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )</b>	4.14	3.93	4.50	4.19
<b>Mean of C</b>	3.92	3.74	4.28	
<b>SE (d) ±</b>	<b>0.05</b>			
<b>CD (5%)</b>	<b>0.11</b>			

#### 4.2.6 Pod yield (kg/ha)

The data pertaining to pod yield is influenced by different cultivars, crop geometry and foliar spray treatments are summarized in Table 15 and depicted in Fig, 6, 7 and 8.

A difference in pod yield due to varieties was found to be significant and Mash-114 recorded significantly higher pod yield as compared to Uttara and PU-31. While Uttara produced significantly higher pod yield than PU-31.

Among crop geometry, 30×10 cm spacing recorded significantly higher pod yield than 45×10 cm spacing.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering recorded significantly higher pod yield over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and foliar spray of 1.5% KCl at flowering. While foliar spray of molybdenum sodium molybdate @ 0.1% at 20 DAS recorded significantly higher pod yield over foliar spray of KCl @ 1.5% at flowering.

Interaction effect of cultivars and foliar nutrition was found to be significant with respect to pod yield (kg/ha) and it was presented in Table 15.1 It was evident from the data that the best combination with respect to pod yield (kg/ha) was foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering on Massh-114 whose response was significantly superior to the combined application of molybdenum and KCl over other combinations, respectively.

#### 4.2.7 Grain yield (kg/ha)

The data pertaining to grain yield is influenced by different cultivars, crop geometry and foliar spray treatments are summarized in Table 15 depicted in Fig, 6, 7 and 8.

A difference in grain yield due to varieties was found to be significant and Mash-114 recorded significantly higher grain yield as compared to Uttara and PU-31. While Uttara produced significantly higher grain yield than PU-31.

Among crop geometry, 30×10 cm spacing recorded significantly higher grain yield than 45×10 cm spacing.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering recorded significantly higher grain yield over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and foliar spray of 1.5% KCl at flowering. While foliar spray of molybdenum sodium molybdate @ 0.1% at 20 DAS recorded significantly higher grain yield over foliar spray of KCl @ 1.5% at flowering.

Interaction effect of cultivars and foliar nutrition was found to be significant with respect to grain yield (kg/ha) and it was presented in Table 15.2 It was evident from the data that the best combination with respect to grain yield (kg/ha) was foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering on Massh-114 whose response was significantly superior to the combined application of molybdenum and KCl over other combinations, respectively.

#### 4.2.8 Stover yield (kg/ha)

The data pertaining to stover yield is influenced by different cultivars, crop geometry and foliar spray treatments are summarized in Table 15 depicted in Fig, 6, 7 and 8. A difference in stover yield due to varieties was found to be significant and Mash-114 recorded significantly higher stover yield as compared to Uttara and PU-31. While Uttara produced significantly higher stover yield than PU-31.

Among crop geometry, 30×10 cm spacing recorded significantly higher stover yield than 45×10 cm spacing.

Among foliar spray treatments, spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering recorded significantly higher stover yield over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and foliar spray of 1.5% KCl at flowering. While foliar spray of molybdenum sodium molybdate @ 0.1% at 20 DAS recorded significantly higher stover yield over foliar spray of KCl @ 1.5% at flowering.

#### 4.2.9 Harvest index (%)

The data pertaining to harvest index influenced by different black gram cultivars, crop geometries and foliar sprays were statistically analyzed and presented in Table 15.

Among the cultivars, Mash-114 registered significantly higher harvest index over Uttara and PU-31. While significantly lower number of harvest index was recorded by PU-31 over other cultivars under comparison.

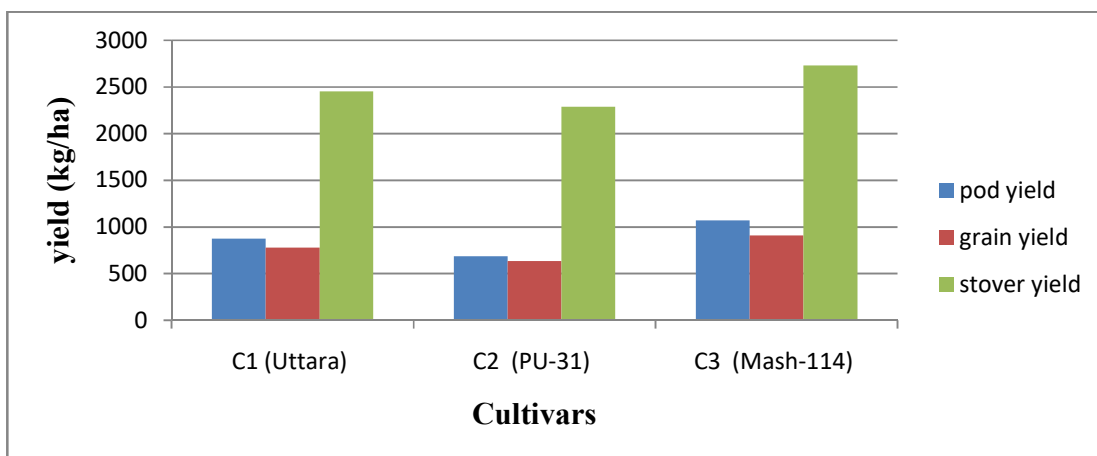
Among crop geometry treatments it is observed that crop grown with wider spacing of 30×10 cm recorded significantly higher harvest index over 45×10 cm spacing.

Among foliar spray treatments, foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering recorded significantly higher harvest index over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering. In the same time foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS recorded significantly higher pod weight over foliar spray of KCl @ 1.5% at flowering.

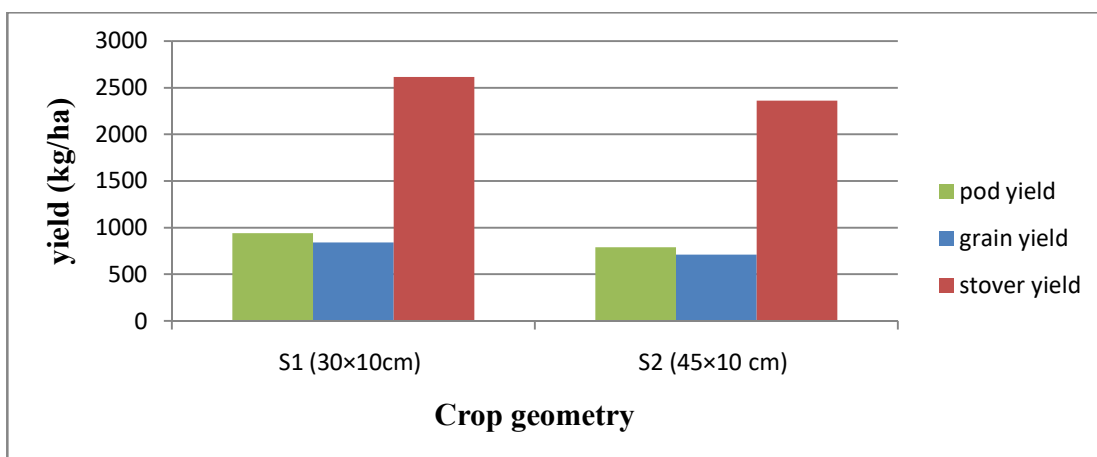
The interaction effect of varieties and foliar application of nutrients was found significant on pod and grain yield and the data are presented in Table- 10.1. Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering recorded significantly higher harvest index over foliar spray of 1.5% KCl at flowering with all the varieties taken for investigation. While foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering was statistically at par with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS with respect to Uttara and Mash-114 at 40 DAS. At 60 DAS interaction effect foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering with all varieties taken for comparison was significantly.

**Table 15: Effect of cultivars, crop geometry and foliar sprays on pod yield, grain yield, stover yield and harvest index of black gram**

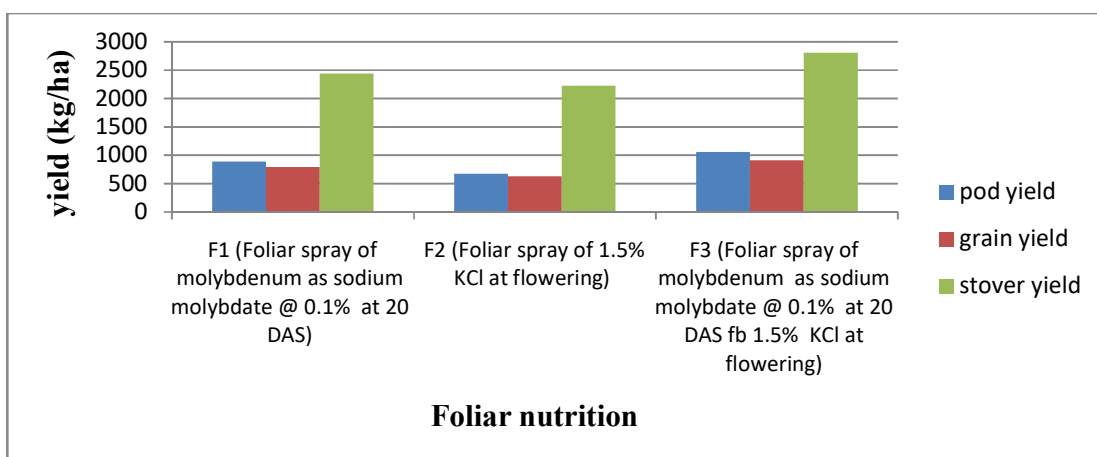
Treatments	Pod yield (kg/ha)	Grain yield (kg/ha)	Stover yield (kg/ha)	Harvest Index (%)
<b>C (Cultivars)</b>				
C1 (Uttara)	875	779	2453	24.10
C2 (PU-31)	684	636	2288	21.75
C3 (Mash-114)	1069	909	2728	24.99
SE(d) ±	44	31	60	0.71
CD (5%)	89	62	122	1.45
<b>S (Crop geometry)</b>				
S1 (30×10cm)	941	842	2616	24.34
S2 (45×10 cm)	793	712	2363	23.15
SE(d) ±	36	25	49	0.59
CD (5%)	72	51	100	NS
<b>F (Foliar nutrition )</b>				
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	891	789	2439	24.44
F2 (Foliar spray of 1.5% KCl at flowering)	678	624	2223	21.92
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering)	1059	912	2807	24.65
SE(d) ±	44	31	60	0.71
CD (5%)	89	62	122	1.45
C × F	154	108	NS	NS
S × F	NS	NS	NS	NS
C × S	NS	NS	NS	NS
C×S×F	NS	NS	NS	NS



**Fig. 6: Effect of cultivars on pod yield, grain yield and stover yield**



**Fig. 7: Effect of crop geometry on pod yield, grain yield and stover yield**



**Fig. 8: Effect of foliar nutrition on pod yield, grain yield and stover yield**

**Table 15.1: Pod yield as affected by interaction between cultivars and foliar sprays at harvest in black gram.**

Factors		C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)		890	728	1054	891
F2 (Foliar spray of 1.5% KCl at flowering)		676	521	837	678
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering)		1058	802	1316	1059
Mean of C		875	684	1069	
SE(d) ±	76				
CD (5%)	154				

**Table 15.2: Grain yield as affected by interaction between cultivars and foliar sprays at harvest in black gram.**

Factors		C1 (Uttara)	C2 (PU-31)	C3 (Mash-114)	Mean of F
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)		789	677	900	789
F2 (Foliar spray of 1.5% KCl at flowering)		615	506	752	624
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering)		936	725	1075	912
Mean of C		779	636	909	
SE(d) ±	53.2				
CD (5%)	108				

### 4.3 Nutrient Studies

#### 4.3.1 Available nutrients in the soil after harvest

The available N, P, K and molybdenum status of the soil as recorded after the harvest of the crop is presented in the Table 16 shows that cultivars, crop geometry and foliar sprays could not bring about statistical differences but the numerical differences among them are quite clear. The highest available soil nitrogen, phosphorus, potassium and molybdenum were recorded in the plots which were under PU-31 followed by Uttara and Mash-114.

Among the crop geometry, the plots where sowing was done at 45×10 cm registered higher status of N, P, K and molybdenum followed by those sown at 30×10cm spacing.

Among the foliar spray treatments, the plots that were sprayed with KCl @ 1.5% at flowering recorded higher status of N, P, K and molybdenum after harvest followed by foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering. While least was registered with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering.

**Table 16: Effect of cultivars, crop geometry and foliar sprays on available nutrients in soil at harvest in black gram**

Treatments	Available Nutrients			
	N (kg/ha) at harvest	P (kg/ha) at harvest	K(kg/ha) at harvest	Mo(ppm) at harvest
<b>C (Cultivars)</b>				
C1 (Uttara)	174.66	12.15	116.39	0.077
C2 (PU-31)	175.68	13.17	117.41	0.079
C3 (Mash-114)	174.58	12.07	116.31	0.074
SE(d) ±	0.52	0.60	0.70	0.010
CD (5%)	NS	NS	NS	NS
<b>S (Crop geometry)</b>				
S1 (30×10cm)	174.84	12.33	116.57	0.074
S2 (45×10 cm)	175.10	12.59	116.83	0.079
SE(d) ±	0.43	0.49	0.57	0.008
CD (5%)	NS	NS	NS	NS
<b>F (Foliar nutrition)</b>				
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	174.75	12.24	116.48	0.082
F2 (Foliar spray of 1.5% KCl at flowering)	175.49	12.98	117.22	0.084
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	174.68	12.17	116.41	0.074
SE(d) ±	0.52	0.60	0.70	0.010
CD (5%)	NS	NS	NS	NS
<b>Initial status</b>	173.48	14.21	121.23	0.087
<b>Interaction-Non significant</b>				

### 4.3.2 Nutrient uptake

The data presented in the Table 17 with respect to nitrogen, phosphorus, potassium and molybdenum uptake registered significant variations among the different cultivars, crop geometry and foliar sprays. The significantly highest N, P, K and molybdenum was recorded by Mash-114 both at 40 DAS and at physiological maturity which was significantly superior over other cultivars under comparison at both the intervals. Among the crop geometry the uptake was maximum with 30×10cm spacing over 45×10cm spacing both at 40 DAS and at harvest.

Among foliar sprays, it is evident from the data that application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering registered significantly maximum uptake of nutrients viz. N, P, K and molybdenum at harvest while the same treatment showed to be at par with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS at 40 DAS.

**Table 17: Effect of cultivars, crop geometry and foliar sprays on nutrient uptake of black gram**

Treatments	Nitrogen (kg/ha)		Potassium (kg/ha)		Molybdenum (g/ha)	
	40 DAS	At maturity	40 DAS	At maturity	40 DAS	At maturity
<b>C (Cultivars)</b>						
C1 (Uttara)	6.47	29.42	4.64	18.81	0.21	1.02
C2 (PU-31)	4.37	17.54	3.13	11.86	0.14	0.63
C3 (Mash-114)	7.70	37.15	5.60	24.11	0.25	1.29
SE(d) ±	0.61	2.51	0.47	1.62	0.02	0.12
CD (5%)	1.23	5.10	0.95	3.28	0.04	0.24
<b>S (Crop geometry)</b>						
S1 (30×10cm)	5.65	25.87	4.85	16.67	0.22	0.87
S2 (45×10 cm)	6.71	30.20	4.07	19.84	0.18	1.09
SE(d) ±	0.50	2.05	0.38	1.32	0.02	0.10
CD (5%)	1.01	4.17	0.78	2.68	0.03	0.20
<b>F (Foliar nutrition )</b>						
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	7.36	28.23	5.32	18.11	0.24	0.95
F2 (Foliar spray of 1.5% KCl at flowering)	3.70	22.61	2.63	14.07	0.12	0.67
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	7.49	33.27	5.42	22.60	0.24	1.33
SE(d) ±	0.61	2.51	0.47	1.62	0.02	0.12
CD (5%)	1.23	5.10	0.95	3.28	0.04	0.24

**Interaction-** Non significant

## 4.4 Quality Parameters

### 4.4.1 Chlorophyll content

Chlorophyll content in the black gram is significantly influenced by cultivars, crop geometry and foliar spray treatments is evident from the Table 18. Chlorophyll content recorded by SPAD meter showed significantly higher values with Mash-114 at all the growth stages. It is apparent from the table that wider spacing has significantly contributed in getting higher SPAD readings over closer recommended spacing under comparison. Among the foliar spray treatments, foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering registered higher SPAD values over alone application of foliar spray of Mo as sodium molybdate @ 0.1% at 20 DAS and foliar spray of KCl @ 1.5% at flowering. However, the SPAD values of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb KCl @1.5% at flowering showed at par results with foliar spray of Mo as sodium molybdate @ 0.1% at 20 DAS during 20 and 40 DAS but significantly differ with alone application of KCl @ 1.5% at flowering at all stages except 20 DAS.

**Table 18: Effect of cultivars, crop geometry and foliar sprays on SPAD values in black gram**

Treatment	SPAD values		
	Days After Sowing		
	20	40	60
<b>C (Cultivars)</b>			
C1 (Uttara)	29.51	31.54	36.74
C2 (PU-31)	27.70	29.99	33.19
C3 (Mash-114)	31.48	35.02	39.98
SE(d) $\pm$	0.60	0.43	1.08
CD (5%)	1.23	0.86	2.19
<b>S (Crop geometry)</b>			
S1 (30 $\times$ 10cm)	29.53	31.79	35.60
S2 (45 $\times$ 10 cm)	29.60	32.57	37.67
SE(d) $\pm$	0.49	0.35	0.88
CD (5%)	NS	0.71	1.79
<b>F (Foliar nutrition)</b>			
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	29.65	33.67	36.63
F2 (Foliar spray of 1.5% KCl at flowering)	29.35	28.99	34.35
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	29.70	33.88	38.94
SE(d) $\pm$	0.60	0.43	1.08
CD (5%)	NS	0.86	2.19

**Interaction-** Non significant

#### 4.4.2 Protein content (%)

Protein is one of the most important determinants of grain quality in black gram. Data pertaining to protein content (%) as influenced by cultivars, crop geometry and foliar spray treatments is presented in the Table 19.

The perusal data in relation to protein content was significantly influenced by cultivars alone and among the cultivars Mash-114 registered significantly higher protein content over Uttara and PU-31. While Uttara registered significantly higher protein content over PU-31.

Crop geometry and foliar sprays have no significant impact on protein content of black gram.

**Table 19: Effect of cultivars, crop geometry and foliar sprays on protein content of black gram**

Treatment	Protein Content (%)
<b>C (Cultivars)</b>	
C1 (Uttara)	20.16
C2 (PU-31)	18.49
C3 (Mash-114)	22.32
SE(d) ±	0.18
CD (5%)	0.36
<b>S (Crop geometry)</b>	
S1 (30×10cm)	20.18
S2 (45×10 cm)	20.46
SE(d) ±	0.15
CD (5%)	NS
<b>F (Foliar nutrition)</b>	
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	20.36
F2 (Foliar spray of 1.5% KCl at flowering)	20.13
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	20.47
SE(d) ±	0.18
CD (5%)	NS

**Interaction-** Non significant

#### 4.5 Relative Economics

Relative economics was worked out by calculating cost of cultivation of individual treatment and estimating the gross returns using economical yield of the crop. The data presented in Table 20 revealed that cultivars, crop geometry and foliar spray treatments influenced the cost of cultivation, gross returns, net returns and B: C ratio. The details of the cost of various inputs used in the experiment is presented in appendix III.

However, among different cultivars even though their cost of cultivation is same Mash-114 fetched maximum net returns and B:C ratio over Uttara and PU-31. It is evident from the data that Mash-114 fetches a profit of 1.83 per rupee invested. While the Uttara fetched better returns over PU-31.

Among, different crop geometry taken for comparison the cost of cultivation to raise a black gram crop at wider spacing is lower compared to growing at closer spacing. However, the black gram crop grown in closer spacing of 30×10 cm fetched more net returns due more plant population attributing towards achieving higher yield which is thereby contributing towards getting higher B:C ratio over crop grown at wider spacing of 45×10 cm.

Among various foliar spray treatments, higher cost of cultivation was incurred with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering while cost of cultivation was minimum with foliar spray of 1.5% KCl at flowering. However, due to positive influence of spray on black gram the foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering fetched maximum returns over alone application of molybdenum and KCl.

**Table 20: Effect of cultivars, crop geometry and foliar sprays on relative economics of black gram**

Treatments	Cost of Cultivation (₹/ha)	Gross Returns (₹/ha)	Net Returns (₹/ha)	B:C (₹/₹invested)
<b>C (Cultivars)</b>				
C1 (Uttara)	18461	54530	36069	1.95
C2 (PU-31)	18461	44520	26059	1.41
C3 (Mash-114)	18461	63630	45169	2.45
<b>S (Crop geometry)</b>				
S1 (30×10cm)	18461	58940	40479	2.19
S2 (45×10 cm)	17728	49840	32112	1.81
<b>F (Foliar nutrition)</b>				
F1 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS)	23661	55230	31569	1.33
F2 (Foliar spray of 1.5% KCl at flowering)	19011	43680	24669	1.30
F3 (Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering )	23811	63840	40029	1.68

# Chapter-5

## *Discussion*

## DISCUSSION

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The experimental results emanating from the field investigation entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shivalik* foothills of Jammu**” conducted at the Research Farm, Advanced Center for Rainfed Agriculture, SKUAST-Jammu, Rakh Dhiansar during the *kharif* season of 2018-19 have been described in the previous chapter. The significant experimental findings emerged during the course of experimentation are discussed below with possible explanations and scientific evidences in order to determine the cause and effect relationship among different treatments in relation to various attributes studied and to sort the information of practical significance.

### 5.1 Weather and crop growth

In addition to crop management practices, the growth and development of a crop is also influenced by pertaining weather during the crop growth period. The meteorological data recorded during the *kharif* season 2018-19 depicted in Fig.1 and embodied in Appendix-I indicated that a well distributed rainfall of 547.4 mm was received during the crop growth season which was more than the water requirement of black gram. At no stage the crop is subjected to drought stress which might have affected the overall performance of black gram cultivars irrespective of the treatments. It was also observed that the minimum temperature recorded was lower than the normal from flowering till harvesting which might be a probable reason for prolonged growth period in all the cultivars of black gram. Similar findings about the influence of temperature on crop have also been reported by Hatfield and Prueger (2015).

### 5.2 Growth parameters

Plant growth is manifested in many ways. Though growth parameters *viz.* plant height (cm), number of branches per plant, number of root nodules per plant, dry matter accumulation ( $\text{g/m}^2$ ), leaf area index (LAI), crop growth rate ( $\text{g/m}^2/\text{day}$ ) and relative growth rate ( $\text{g/g/m}^2/\text{day}$ ) presented in (Tables 7,8,9,10,11,12 and 13) are largely

controlled by genetic makeup of the plant but they can also be altered agronomically by manipulating their environment.

Growth attributes of a cultivar is largely dependent on genetic makeup of that cultivar and its capacity to adapt to that particular environmental condition in which it getting established.

The plant height was not affected due to crop geometry and foliar nutrition at 20 DAS. However, an increasing trend with 30×10 cm spacing was noticed during all growth stages This may be due to the inter row competition between the plants for sun light, water, nutrients and space at closer spacing which encouraged self-thinning of branches and enhanced vertical growth of the plant rather than horizontal growth as that observed with 45×10 cm spacing. Similar findings were reported by Daniel and Kumar (2015), Achakzai and Panizai (2007). The Crop geometry of 45×10 cm produced significantly higher number of branches per plant over 30×10 cm spacing this may be due to more space for nutrient absorption in the presence of ideal soil moisture content during the crop growing period. Similar results were reported by Gurjar *et al.* (2018). Greater root proliferation with decreasing plant densities might be playing a role in increasing number of root nodules per plant. The results are in confirmation with Sathyamoorthi *et al.* (2008) in green gram.

Plant spacing significantly affected the dry matter accumulation from 20 DAS onwards up to harvest. However, closer spacing of 30x10 cm caused significantly increase in dry matter accumulation from 20 DAS onwards up to harvest as compared to wider spacing of 45x10 cm. The dry matter production of a crop reflects its efficiency in utilizing the available resources. Dry matter production increased steadily with advancing growth stages and reached the maximum at harvest. The Dry matter production was found to be more with closer spacing of 30 × 10 cm, which could be attributed to higher population and accumulation of nutrients per unit area compared to wider spacing. Crop growth rate makes the assessment of crop productivity per unit land. Similarly, crop growth rate was recorded significantly higher with closer crop geometry of 30 × 10 cm all the growth stages, which was mainly due to more population per unit area. Plants grown at wider spacing observed to have broader leaves than those grown at closer

spacing. Even though broader leaves and better plant stature have direct relationship with leaf area index but however, it could not compensate the cumulative leaf area obtained from more number of plants per unit area in closer spacing of 30×10 cm. These findings are in conformity with Kalsaria *et al.* (2017), Prabhamani and Potdar (2018).

Foliar nutrition showed significant variation on growth parameters and the foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering found to be superior with respect to growth parameters of black gram over alone application. The probable reason for this might be because of the fact that molybdenum is a structural component of nitrogenase and this enzyme actively involved in nitrogen fixation by root nodule bacteria of leguminous crop and followed by application of potassium at reproductive stage might have helped in strengthening the stalk and known to improve the plant vigour by its role in activation of enzymes and its involvement in ATP production which is probably more important in regulating the rate of photosynthesis further added to the effect caused by molybdenum.

### **5.3 Yield and yield attributes**

Pod yield, grain yield, stover yield and harvest index obtained from cultivar Mash-114 was found to be significantly higher as compared to Uttara while the cultivar Uttara was significantly higher over PU-31. This might be due to greater vegetative growth and better light interception which is resulted due to higher leaf area index and later on contributing towards higher dry matter partitioning towards economic part.

Number of pods per plant, pod weight per pod and seed yield per pod was significantly higher with plants grown under wider spacing of 45×10 cm this might be due to better crop growth, more space available for plants, lesser competition for moisture and nutrients within the rows. In case of closer spacing mortality caused by mutual shading during pre-flowering stage of the crop may also have a negative impact on yield attributing characters. This is in conformity with findings of Tungoe *et al.* (2018).

Crop geometry at 30 × 10 cm recorded higher seed and stover yield as compared to wider spacing, which might be due to more plant population per unit area which would

have contributed to more biomass. Similar results were also reported by Lokanadhan (2015), Sreemathi and Hemalatha (2018).

The data pertaining to yield and yield attributes in Table 14 and 15 revealed that foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering performed better and played a significant role in obtaining higher seed and stover yield. The probable reason may be that the spray of molybdenum helps in differed metabolic process which also helps in more productive organs. Besides this, application of KCl at flowering might resulted in greater accumulation of carbohydrates, protein and their translocation to productive organs which in turn improved all growth and yield attributing characters, resulting in more seed and stover yield. The findings confirm the results of Mastkar and Sirothiya (2017).

#### **5.4 Nutrient uptake**

Highest N, K and molybdenum uptake was found by the cultivar Mash-114 followed by Uttara and PU-31 cultivars. Nutrient uptake is a product of nutrient concentration and dry matter accumulation which was significantly related to the total biomass produced by the cultivar. These results are in agreement with Choudhary *et al.* (2017)

Crop geometry of 30 × 10 cm enhanced the uptake of N, K and molybdenum compared to wider spacing of 45×10cm as depicted in Table 17. Better nutrient uptake improved the vegetative growth as indicated by higher dry matter accumulation, resulting in higher dry matter production with 30 × 10 cm spacing. This might due to increase in root length that which attributed to increase the root activity, under higher plant population, which enables increased absorption of nutrients from soil. These results are in line with Gohilet *al.* (2017) in green gram.

The data pertaining to nutrient uptake in the previous chapter revealed that foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering has reported higher nutrient uptake *viz.* nitrogen, potassium and molybdenum. This might be probably due to due to efficient functioning of root system and higher rate of nitrogen

fixation. Similar type of findings was obtained by Ranaweera (1992) in soybean with foliar application of nitrogen and molybdenum.

### 5.5 Relative economics

The practicability and usefulness of treatment is judged ultimately in terms of net returns. The economics worked out is presented in Table 20 revealed that the cost of cultivation of all the black gram cultivars take for study was same while difference in net returns and benefit cost ratio among the cultivars was due to higher gross returns which might have obtained due to significant variation in grain yield. Mash-114 cultivar which has highest grain yield fetched higher gross returns which is further responsible to get higher net returns and B: C ratio. Similar results were reported by Panotra *et al.* (2016).

Among the crop geometry, the net returns and benefit cost ratio are significantly higher with 30×10 cm spacing over 45×10 cm spacing this might be due to more number of plants per unit area which fetches higher grain yield there by more gross returns. Though the cost of cultivation at closer spacing is more than that at wider spacing but it was compensated by more grain yield which was obtained from 30×10 cm spacing. The results were in agreement with Kumar *et al.* (2018).

Among the foliar nutrition, the higher monetary returns was obtained with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering which might be due to more grain yield which have even compensated the higher cost of cultivation and thereby achieved higher net returns and B: C ratio thereby proved to be a viable option over alone application of sodium molybdate @ 0.1% at 20 DAS and KCl @ 1.5% at flowering, respectively.

# Chapter-6

## *Summary and Conclusions*

SUMMARY AND CONCLUSION

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The present investigation entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shivalik* foothills of Jammu**” was conducted at the Research Farm, Advanced Center for Rainfed Agriculture, SKUAST-Jammu, Rakh Dhiansar during the *kharif* season of 2018-19 with the following objectives:

- To assess the effect of foliar nutrition and crop geometry on growth and yield attributes of black gram cultivars.
- To study the effect of foliar nutrition of potassium and molybdenum on nutrient uptake in different black gram cultivars.
- To work out relative economics of different treatments.

To achieve these objectives, a field experiment with eighteen treatment combinations comprised of three cultivars (Uttara, PU-31 and Mash-114), two crop geometries (30×10 cm and 45×10 cm) and three foliar sprays (foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS, foliar spray of 1.5% KCl at flowering and foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering) were laid out in factorial randomized block design with three replications. The experimental soil was slightly acidic in reaction (6.47), low in organic carbon (0.36%), available nitrogen (173.48 kg/ha) and medium in available phosphorous (14.21 kg/ha) and potassium (121.23 kg/ha) having sandy loam in texture. The effects of these treatments were recorded on growth parameters (plant height (cm), number of branches per plant, number of root nodules per plant, dry matter accumulation ( $\text{g/m}^2$ ), leaf area index (LAI), crop growth rate ( $\text{g/m}^2/\text{day}$ ) and relative growth rate ( $\text{g/g/m}^2/\text{day}$ ), yield and yield attributes, quality parameters (protein content and SPAD readings), nutrient studies (N, P, K and molybdenum in soil and plant) and relative economics. Findings obtained from the present investigation are summarized as under:

## 6.1 Growth characters

- Among the cultivars, Mash-114 recorded significantly higher plant height, number of branches per plant, number of root nodules per plant, dry matter accumulation ( $\text{g/m}^2$ ), leaf area index (LAI), crop growth rate ( $\text{g/m}^2/\text{day}$ ) and relative growth rate ( $\text{g/g/m}^2/\text{day}$ ) at all the growth stages.
- Among the crop geometry, the  $45 \times 10$  cm recorded significantly higher number of branches per plant, number of root nodules per plant while plant height, dry matter accumulation ( $\text{g/m}^2$ ), leaf area index (LAI), crop growth rate ( $\text{g/m}^2/\text{day}$ ) and relative growth rate ( $\text{g/g/m}^2/\text{day}$ ) were recorded highest with  $30 \times 10$  cm spacing.
- The growth parameters like plant height, number of branches per plant, number of root nodules per plant, dry matter accumulation ( $\text{g/m}^2$ ), leaf area index (LAI), crop growth rate ( $\text{g/m}^2/\text{day}$ ) and relative growth rate ( $\text{g/g/m}^2/\text{day}$ ) were recorded highest in treatment where foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering was applied.

## 6.2 Yield and yield attributes

- Among the cultivars, the Mash-114 registered significantly higher number of pods per plant, pod weight per plant (g), seed yield per plant (g) which thereby attributed to record higher pod yield (kg/ha), stover yield (kg/ha), grain yield (kg/ha) and harvest index (%) over other cultivars taken under investigation.
- Among different crop geometry, the yield attributes like number of pods per plant, pod weight per plant (g), seed yield per plant (g) were recorded significantly higher with  $45 \times 10$  cm. However, the closer spacing of  $30 \times 10$  cm found to report higher pod yield (kg/ha), stover yield (kg/ha), grain yield (kg/ha).
- Among different foliar sprays, number of pods per plant, pod weight per plant (g), seed yield per plant (g), 1000-grain weight (g), number of seeds per pod, pod yield (kg/ha), grain yield (kg/ha), stover yield (kg/ha) recorded highest by foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering.

### **6.3 Nutrient studies**

#### **a) Soil studies**

- The properties of soil after the harvest of the crop with respect available N, P and K and molybdenum did not changed significantly by cultivars, crop geometry and foliar nutrition. However, the available N was numerically higher over initial status in all the treatments.

#### **b) Nutrient uptake studies**

- The significantly higher N, K and molybdenum uptake was recorded with Mash-114 both at 40 DAS and at harvest.
- Among the crop geometry, the 30×10 cm spacing found to have higher nutrient uptake over 45×10 cm spacing.
- Foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering recorded higher N, K and molybdenum uptake over alone application of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and foliar spray of 1.5% KCl at flowering

### **6.4 Quality parameters**

- Among the cultivars, Mash-114 recorded significantly higher SPAD readings while protein content with respect to cultivars did not vary significantly.
- The irrespective of cultivars those planted at wider crop spacing of 45×10 cm recorded higher SPAD readings over closer spacing
- The highest SPAD readings was recorded with foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering. Protein content also recorded to be higher with the same treatment but the content was non significant with respect to foliar nutrition.

### **6.5 Relative economics**

- Among the cultivars, all the three cultivars incurred same cost of cultivation while difference in their net returns and benefit cost ratio was due to difference in their

gross returns and since Mash-114 recorded higher grain yield it recorded higher gross returns, net returns and B:C ratio followed by Uttara and PU-31.

- Among the crop geometry, the cost of cultivation of 45×10 was lower than that of 30×10 spacing. However, the higher grain yield contributed to achieve the higher gross returns, net returns and B:C ratio.
- Among the foliar nutrition, although the cost of cultivation of foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering was higher but higher gross returns compensated the cost of cultivation thereby help in achieving higher net returns and B:C ratio.

## CONCLUSION

On the basis of the results of present investigation the following conclusions can be drawn:-

- Among the different black gram cultivars, Mash-114 proved to be more suitable cultivar than Uttara and PU-31.
- Among different crop geometry, seeds sown at 30×10 cm spacing found to be more effective with respect to higher grain yield and monetary returns.
- Among the foliar nutrition, the foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering proved superior in terms of growth, yield, quality, nutrient uptake and fetched more economic returns reflected in terms of net returns and B: C ratio followed by foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS and foliar spray of 1.5% KCl at flowering.

Hence, based on the present study, it can be safely concluded that among the three black gram cultivars, two crop geometries and three foliar sprays, Mash-114 with foliar application of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering when planted at 30×10 cm spacing could be a viable technological proposition under rainfed conditions of Jammu.

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# *Appendices*

## APPENDIX-I

**Mean weekly meteorological data during the crop growing season (16<sup>th</sup> July – 27<sup>th</sup> October, 2018)**

<b>SMW*</b>	<b>Date &amp; month</b>	<b>Maximum Temperature (°C)</b>	<b>Normal Maximum Temperature (°C)</b>	<b>Minimum Temperature (°C)</b>	<b>Normal Minimum Temperature (°C)</b>	<b>RH% (Morning)</b>	<b>RH% (evening)</b>	<b>Rainfall (mm)</b>	<b>Normal Rainfall (mm)</b>	<b>Pan evaporation (mm)</b>
<b>29</b>	16 -22 July	34.5	34.1	25.3	24.2	78.4	51.9	9.2	82.5	49.7
<b>30</b>	23-29	33.90	33.7	22.60	24.3	83.70	69.40	73.5	65.3	30.4
<b>31</b>	30-05 Aug.	35.60	33.3	22.30	24.2	83.30	60.40	13.8	101.5	38.8
<b>32</b>	6-12 Aug.	32.40	33.5	20.10	24.2	91.90	67.00	151.7	89.5	26.6
<b>33</b>	13-19 Aug.	32.90	33.3	23.10	23.9	87.10	64.40	104.4	55.9	32.9
<b>34</b>	20-26 Aug	33.30	33.4	23.90	23.6	83.30	65.30	43.3	80.7	34.8
<b>35</b>	27-2 Sep.	34.60	33.7	24.80	23.5	83.40	61.30	0.0	47.8	32.5
<b>36</b>	3-9 Sep.	33.50	33.4	22.40	22.8	86.30	66.00	25.1	54.3	30.8
<b>37</b>	10-16 Sep.	32.30	33	21.10	22.2	85.60	66.60	17.2	34.7	33.1
<b>38</b>	17-23 Sep.	32.40	33.1	20.30	21.8	78.40	66.10	52.2	15.2	28.6
<b>39</b>	24-30 Sep.	30.30	33	17.40	20.5	79.40	63.60	34.1	25	27
<b>40</b>	1-7 Oct.	32.30	32.7	17.50	19.9	77.10	48.30	0.0	5.5	27.4
<b>41</b>	8-14 Oct.	30.50	32.2	16.10	18	64.60	47.90	1.2	2.8	21
<b>42</b>	15-21 Oct	30.90	30.8	13.60	16.2	62.00	41.90	0.0	9.3	13.7
<b>43</b>	22-28 Oct.	30.10	30.3	11.90	15	70.40	41.60	0.0	1.1	11.4

**SMW\* Standard Meteorological Week**

**Source: Agro met Observatory, ACRA, Rakh Dhiansar.**

## APPENDIX-II

### Cost of cultivation of cultivar Uttara

Input	Quantity/ha	Unit	Rate (₹/unit)	Total cost (₹/ha)
Land preparation	3.36	Hour	1050	3528
Seed rate				
Uttara	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
Fertilizers				
DAP	90	kg	22	1980
Basal Fertilizer application	4	man days	200	800
Herbicides				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
Insecticides				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid	8	g	14	112
Insecticide application	2	man days	200	400
Harvesting	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>18461</b>

**Cost of cultivation of black gram cultivar PU-31**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate				
PU-31	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
Fertilizers				
DAP	90	kg	22	1980
Basal Fertilizer application	4	man days	200	800
Herbicides				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
Insecticide				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid	8	g	14	112
Insecticide application	2	man days	200	400
Harvesting	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>18461</b>

**Cost of cultivation of black gram cultivar Mash-114**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate				
Mash-114	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
Fertilizers				
DAP	90	kg	22	1980
Basal Fertilizer application	4	man days	200	800
Herbicides				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
Insecticide				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid	8	g	14	112
Insecticide application	2	man days	200	400
Harvesting	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>18461</b>

**Cost of cultivation of black gram cultivars sown at 30×10 cm spacing**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
<b>Fertilizers</b>				
DAP	90	kg	22	1980
Basal Fertilizer application	4	man days	200	800
<b>Herbicides</b>				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
<b>Insecticide</b>				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid (2)	8	g	14	112
Insecticide application	2	man days	200	400
Harvesting	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>18461</b>

**Cost of cultivation of black gram cultivars sown at 45×10 cm spacing**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate	13.34	kg	110	1467.4
Sowing	4	man days	200	800
Thinning	4	man days	200	800
<b>Fertilizers</b>				
DAP	90	kg	22	1980
Basal Fertilizer application	4	man days	200	800
<b>Herbicides</b>				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
<b>Insecticide</b>				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid (2)	8	g	14	112
Insecticide application	2	man days	200	400
Harvesting	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>17728</b>

**Cost of cultivation of black gram under foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
<b>Fertilizers</b>				
DAP	90	kg	22	1980
Sodium molybdate	600	g	8	4800
Foliar spray application	2	man days	200	400
Basal Fertilizer application	4	man days	200	800
<b>Herbicides</b>				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
<b>Insecticide</b>				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid	8	g	14	112
Insecticide application	2	man days	200	400
Harvesting	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>23661</b>

**Cost of cultivation of black gram under foliar spray of 1.5% KCl at flowering**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
<b>Fertilizers</b>				
DAP	90	kg	22	1980
MOP	9	kg	16.7	150.3
Foliar spray application	2	man days	200	400
Basal Fertilizer application	4	man days	200	800
<b>Herbicides</b>				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
<b>Insecticide</b>				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid	8	g	14	112
Insecticide application	2	man days	200	400
Harvesing	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>19011</b>

**Cost of cultivation of black gram under foliar spray of molybdenum as sodium molybdate @ 0.1% at 20 DAS fb 1.5% KCl at flowering**

<b>Input</b>	<b>Quantity/ha</b>	<b>Unit</b>	<b>Rate (₹/unit)</b>	<b>Total cost (₹/ha)</b>
Land preparation	3.36	Hour	1050	3528
Seed rate	20	kg	110	2200
Sowing	4	man days	200	800
Thinning	4	man days	200	800
<b>Fertilizers</b>				
DAP	90	kg	22	1980
Sodium molybdate	600	g	8	4800
MOP	9	kg	16.7	150.3
Foliar spray application	2	man days	200	400
Basal Fertilizer application	4	man days	200	800
<b>Herbicides</b>				
Pendimethalin (PE)	3.33	L	330	1098.9
Imazethapyr 10% SL (PoE)	1	L	1392	1392
Herbicide Application	2	man days	200	400
<b>Insecticide</b>				
Chloropyriphos+cypermethrin	1	L	1150	1150
Imidachloprid	8	g	14	112
Insecticide application	2	man days	200	400
Harvesing	7	man days	200	1400
Threshing and winnowing	8	man days	200	1600
Miscellaneous				800
<b>Total</b>				<b>23811</b>

**Sale price of the produce**

<b>Cultivars</b>	<b>₹/quintal</b>
Uttara, PU-31 and Mash-114	7000

### APPENDIX-III

**Nitrogen, potassium and molybdenum content in black gram cultivars planted at different crop geometry under different foliar nutrition**

S.No.	Treatments	Nutrient concentration					
		Nitrogen (%)		Potassium (%)		Molybdenum (ppm)	
		40 DAS	at harvest	40 DAS	at harvest	40 DAS	at harvest
1	C1S1F1	1.33	1.99	0.97	1.29	0.058	0.062
2	C1S2F1	1.75	1.90	0.96	1.20	0.041	0.071
3	C2S1F1	1.64	2.01	0.96	1.31	0.053	0.065
4	C2S2F1	1.65	2.00	0.94	1.30	0.053	0.066
5	C3S1F1	1.55	1.96	0.93	1.26	0.054	0.056
6	C3S2F1	1.66	1.91	0.90	1.21	0.051	0.071
7	C1S1F2	0.94	1.80	0.89	1.10	0.026	0.052
8	C1S2F2	0.80	1.80	0.91	1.10	0.030	0.052
9	C2S1F2	1.14	1.90	0.94	1.20	0.039	0.059
10	C2S2F2	1.22	1.94	0.95	1.24	0.036	0.055
11	C3S1F2	0.80	1.80	0.96	1.10	0.025	0.052
12	C3S2F2	0.80	1.80	1.02	1.10	0.025	0.052
13	C1S1F3	1.66	2.12	1.10	1.42	0.050	0.081
14	C1S2F3	1.58	2.10	1.09	1.40	0.053	0.084
15	C2S1F3	1.43	2.29	1.06	1.59	0.046	0.086
16	C2S2F3	1.43	2.22	1.08	1.52	0.046	0.094
17	C3S1F3	1.43	2.02	1.11	1.42	0.055	0.079
18	C3S2F3	1.57	2.07	0.99	1.37	0.044	0.084

#### APPENDIX-IV

**Per cent nitrogen (N) content in grains of black gram cultivars planted at different crop geometry under different foliar nutrition**

<b>S.No</b>	<b>Treatments</b>	<b>Per cent nitrogen content in grain</b>
1	C1S1F1	3.20
2	C1S2F1	3.21
3	C2S1F1	2.88
4	C2S2F1	2.93
5	C3S1F1	3.54
6	C3S2F1	3.57
7	C1S1F2	3.21
8	C1S2F2	3.24
9	C2S1F2	2.91
10	C2S2F2	3.06
11	C3S1F2	3.56
12	C3S2F2	3.58
13	C1S1F3	3.23
14	C1S2F3	3.28
15	C2S1F3	2.97
16	C2S2F3	3.00
17	C3S1F3	3.57
18	C3S2F3	3.60

# *Vita*

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## CERTIFICATE-IV

Certified that all the necessary corrections as suggested by external examiner and advisory committee have been duly incorporated in the thesis entitled “**Effect of foliar nutrition and crop geometry on cultivars of black gram in *Shiwalik* foothills of Jammu**” submitted by **Mr. Lalichetti Sagar**, Registration No. **J-17-M-481**

  
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