RESPONSE OF BLACK GRAM [*Vigna mungo* (L.)] CULTIVARS TO FERTILIZER LEVELS

by

Mr. Sarwade Vishal Raghunath
(Reg. No. 2020/006)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST-AHMEDNAGAR,
MAHARASHTRA, INDIA.

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRONOMY

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POST GRADUATE INSTITUTE
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APPROVED BY

Dr. S.S. Ilhe
(Chairman and Research Guide)

Dr. A.D. Tumbare
(Committee Member)

Dr. A.G. Durgude
(Committee Member)

Dr. M.R. Patil
(Committee Member)

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POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
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2023

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part

there of has not been submitted

by me or other person to any

other University or Institute

for a Degree or

Diploma

Place : M.P.K.V., Rahuri (V.R. Sarwade)

Date : / /2023

Dr. S.S. Ilhe
Associate Professor,
Department of Agronomy,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413 722 Dist. Ahmednagar,
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled, "**RESPONSE OF BLACK GRAM [*Vigna mungo* (L.)] CULTIVARS TO FERTILIZER LEVELS**", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY**, embodies the result of a piece of bonafide research work carried out by **MR. SARWADE VISHAL RAGHUNATH** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

Place: M.P.K.V., Rahuri
Date : / /2023

(S.S. Ilhe)
Chairman and Research Guide

Dr. A.V. Solanke
Head,
Department of Agronomy,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413 722 Dist. Ahmednagar,
Maharashtra, India.

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Place : M.P.K.V., Rahuri **(A.V. Solanke)**
Date : / /2023

Dr. B.D. Bhakare
Associate Dean,
Post Graduate Institute,
Mahatma Phule Krishi Vidyapeeth,
Rahuri – 413 722 Dist. Ahmednagar,
Maharashtra, India.

CERTIFICATE

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Place : M.P.K.V., Rahuri **(B.D. Bhakare)**
Date : / /2023

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Place : M.P.K.V., Rahuri
Date : / /2023 (V.R. Sarwade)

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LIST OF ABBREVIATIONS

%	: Per cent
&	: And
@	: At the rate of
₹	: Rupees
Annon.	: Anonymous
CD	: Critical Difference
CP	: Crude Protein
CPC	: Crude Protein Content
CPY	: Crude Protein Yield
Cm	: Centimeter (s)
cm^2	: Centimeter square
DAS	: Days After Sowing
dSm^{-1}	: Deci Seimens per meter
E.C	: Electrical Conductivity
E dn.	: Edition
et al.,	: Co-workers
etc.	: et cetera
SPD	: Split Plot Design
Fig.	: Figure
RDF	: Recommended Dose of Fertilizer
Ha	: Hectare
ha^{-1}	: per hectare
INM	: Integrated Nitrogen Management
i.e.	: that is
K	: Potassium
kg	: kilogram (s)
kg ha^{-1}	: kilogram per hectare
M	: Meter
Max.	: Maximum
Min.	: Minimum
Morn.	: Morning
MPKV	: Mahatma Phule Krishi Vidyapeeth
MW	: Meteorological Weeks
N	: Nitrogen
No.	: Number
NS	: Non-Significant
^oC	: Degree centigrade
PGI	: Post Graduate Institute
P	: Phosphorous
S. Em (±)	: Standard Error of mean
Temp.	: Temperature
viz.,	: Namely

ABSTRACT

RESPONSE OF BLACK GRAM [*Vigna mungo* (L.)] CULTIVARS TO FERTILIZER LEVELS

by

MR. SARWADE VISHAL RAGHUNATH

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRONOMY

2023

Research Guide : Dr. S.S. Ilhe

Department : Agronomy

The present investigation entitled "Response of black gram [*Vigna mungo* (L.)] cultivars to fertilizer levels" was conducted at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during *kharif,* 2021. The objective of the experiment was to study the effect of fertilizer levels on growth, yield, quality, and economics of black gram cultivars as well as response of cultivars under to fertilizer levels and to study the economics.

The experiment was laid out in a split plot design with three replications and sixteen treatment combinations consisting of black gram cultivars (4 cultivars) i.e. V_1- TPU-4, V_2- PDKV black gold, V_3- AKU-15, V_4- PU-609-43 and Fertilizer levels (4 RDF levels) i.e. F_1- Absolute control, F_2-75 % of RDF, F_3- 100% of RDF, and F_4- 125% of RDF.

In the present study, black gram cultivar PDKV black gold recorded significantly higher growth and yield attributes *viz*., plant height, number of leaves plant^{-1}, Leaf area, dry matter plant^{-1}, grain yield (1526 kg ha^{-1}) of black gram. In case of RDF levels the application of 125% of RDF recorded significantly maximum growth and yield attributes, *viz*., plant height, number of leaves plant^{-1}, number of root nodule plant^{-1} number of pod plant^{-1}, grain yield (1351 tonne ha^{-1}).

The chlorophyll and crude protein content were recorded significantly highest with black gram cultivar PDKV black gold and among the fertilizer levels the 125% of RDF was recorded significantly higher quality character such as crude protein content.

Higher uptake of nutrients *viz*., nitrogen, phosphorus and potassium were recorded with black gram cultivar (70.93, 10.86 and 45.24 kg ha^{-1}) and application of 125% of RDF recorded higher uptake of nitrogen, phosphorus and potassium (67.02, 10.12 and44.87 kg ha^{-1}).

Significantly maximum soil available nitrogen registered by AKU-15 (174.68 kg ha^{-1}), phosphorus registered by PU-609-43 (20.62 kg ha^{-1}) and potassium was registered by PDKV black gold 373.27 kg ha^{-1}). Similarly significantly higher values of available nitrogen, phosphorous and potassium were recovered by 125% RDF (175.22, 18.80 and 373.54 kg ha^{-1}) respectively.

Abstract contd… **Mr. V.R. Sarwade**

On the basis of economic studies it was observed that the black gram cultivar PDKV black gold recorded significantly higher values of gross monetary returns (₹ 99195 ha^{-1}), net monetary returns (₹ 64496 ha^{-1}) and more B : C ratio (2.86) than the rest of black gram cultivars. Similarly, application of 125% of RDF recorded significantly higher values of gross monetary returns (₹ 87799) net monetary returns (₹ 53099 ha^{-1}) and respectively higher values of B : C ratio (2.53) and it was at par with 100 % RDF.

From this experiment, it could be concluded that the black gram cultivar PDKV black gold and application of 100 % of RDF was found appropriate for achieving the higher grain yield, chlorophyll content, crude protein and as well as gross monetary returns, net monetary returns and B : C.

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1. INTRODUCTION

Pulses are commonly known as food legumes which are secondary to cereals in production and consumption in India. Pulses are important source of dietary protein, energy, minerals and vitamins for the mankind.

Pulse crop plays a vital role in Indian agriculture as fodder and feed. Due to its unique ability of biological nitrogen fixation, deep root system, mobilization of insoluble soil nutrients and bringing qualitative changes in soil physical properties make them known as a 'soil fertility restorers'. India is the major pulse growing country in the world, accounting for one-third of world acreage under pulses and one-fourth of world production. (Beg *et al.,* 2013; Maiti and Singh, 2016) Pulses are the primary source of protein for the bulk of the population, which is mostly vegetarian.

The United Nations declared 2016 as International year of pulses (IYP) to heighten public awareness of the nutritional benefits of pulses as a part of sustainable food production aimed at food security and nutrition.

Due to stagnant production, the net availability of pulses has come down from 60 g in 1951 to 41.7 g day^{-1} $capita^{-1}$ in 2016, as against Indian council of medical research (ICMR) which recommends 65 g day^{-1} $capita^{-1}$. The total area under pulses in India is around 46.7 lakh hectares with a production of 23.4 lakh tonne and productivity of 501 kg ha^{-1} in 2020-2021, (Anonymous 2022). India accounts for 33 % of world production of pulses. Pulses play an important role in Indian agriculture as they restore soil fertility by fixing atmospheric nitrogen through their nodules. Pulses are drought resistant and prevent soil erosion due to their deep root system and good ground coverage, because of these good characters, pulses are called as "Marvel of Nature". Pulses can also be referred to as mini fertilizer factory, as they fix atmospheric nitrogen through symbiosis.

Pulses are the most important component of the balanced diet in vegetarian country like India. The steady increase in Indian population together with stagnant production of pulses over the past four decades compared to cereals has naturally resulted in decreased percent availability of pulses. Therefore, much attention has been given to boost up pulse production in India. More than 80 % cultivable area of India comes under dry land agriculture and pulse crop mostly preferred in same area.

Pulses play significant role in improving economic condition of small and marginal farmers in India because of its characteristics like hardy nature, high water use efficiency, low fertilizer demand and suitable to semiarid climate and low rainfall areas.

Among pulses, black gram (*Vigna mungo* L.) is an important crop in India. It is cultivated since ancient time. It is believed that blackgram is native of India. Black gram area accounts for about 15.7 % of total pulse acreage and contribute 9.09 % of total pulse production. In *kharif* 2021-22, black gram production was 20.5 lakh tonne (1st advance estimate) in an area of 39.43 lakh ha (Anonymous 2022). According to second advance estimate during 2021-2022, black gram was grown in 3.93 lakh ha with production of 3.65 lakh tonne and productivity was 929 kg ha^{-1}.

Black gram is a small herbaceous annual erect or 30 to 100 cm tall plant. The stem is slightly ridged, covered with brown hairs and much branched from base. The leaves are large, trifoliate, green to dark green in colour. Blackgram have chromosome number 2n=24. It belongs to family leguminoceae and sub family papilionaecae. Blackgram require hot and humid growing season. It is a short duration crop suitable for multiple cropping systems and intercropping. It is generally grown as summer and rainy season crop. It can be grown successfully from sea level up to an elevation of 1800 metres.

This crop is extensively grown in Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Uttar Pradesh. The yield potential of blackgram is very low because of the fact that, the crop is mainly grown in rainfed conditions with poor management practices and also due to various physiological, biochemical as well as inherent factors associated with crop. Apart from the genetic makeup, the physiological factor *viz.*, insufficient partitioning of assimilates, poor pod setting due to the flower abscission and lack of nutrient during critical stages of crop growth play a major role in declined blackgram production was coupled with a number of diseases and pests (Mahala *et al*. 2001).

The production of pulse crop in our country including blackgram is not sufficient enough to meet the domestic demand of the population. Hence, there is an ample scope for enhancement of the productivity of blackgram by proper agronomic practices.

Blackgram (*Vigna mungo* L.) is an important pulse crop belonging to the family Leguminoceae and belongs to sub family of Papilionaceae. Blackgram (*Vigna mungo* L.) is widely cultivated throughout Asia, including India, Pakistan, Bangladesh, Sri Lanka, Thailand, Laos, Cambodia, Vietnam, Indonesia, Malaysia, South China and Formosa. Blackgram is a protein rich food containing about 24 % protein, 1.2 % fat, 0.8 % fiber, 3.5 % minerals, 59.9 % carbohydrates, 75 mg calcium, 405 mg phosphorus and 8.5 mg iron. It is also a good source of phosphoric acid and calcium. It contains a wide variety of nutrients and is popular for its fermenting action and thus, it is largely used in making fermented foods (Anonymous 2016).

Application of fertilizers is known to improve the yield attributes, seed yield and straw yield. Fertilizer has become necessary to supply essential plant nutrients to get expected crop yield, as soils are deficient in NPK. Nitrogen and phosphorus are the most crucial plant nutrient for crop production. Varietal response to fertilizer levels also different in terms of yield and quality attributes. Different variety had shown variable response to different fertilizer levels.

Nitrogen is the essential component of protein and chlorophyll, as well as nucleotides, phospholipids, alkaloids, enzymes, hormones, and vitamins, among many other chemicals important in plant metabolism. As a result, nitrogen is one of life's most fundamental components. It gives the plant a dark green colour.

Phosphorous is essential for growth, development, and maturation. It aids in the flowering and fruiting of the plant. Phosphorus is found in nucleic acid, phytine, phospholipids, and the most of enzymes in the carbohydrate and fat metabolic processes. It accelerates grain maturity and enhances grain quality, thus phosphorus application is essential.

Potassium in cell sap is involved in enzyme activation, photosynthesis, transport of sugar, protein and starch synthesis. It is known to help crop to perform better under water stress condition through the regulation of the transpiration rate at which plant stomata open and close. It is also known for its role to provide lodging resistance, pest and disease resistance to plants.

Very meagre work has been carried out on black gram varieties and fertilizer levels. Considering these aspect the present investigation entitled “Response of black gram cultivar to fertilizer levels has been planned with the following objectives:

1. To study the response of black gram cultivars to fertilizer levels
2. To study the effect of fertilizer levels on growth, yield and quality of black gram cultivars
3. To work out the economics black gram

2. REVIEW OF LITERATURE

It is always worthwhile to study the work done on the various aspects related to research problems by different research workers. To encompass the past research work, it becomes indispensable to take the review of literature that could build a sound footing of the problem. It also helps in the interpretation of the problem. The review of literature is of much utility in approaching the problems in right way and in analyzing and interpreting the data in systematic way. In this chapter an attempt is made to review the past research studies which has direct or indirect bearing on objectives of the present investigation. The available literature on "Response of blackgram (*Vigna mungo* L. Hepper) to cultivars to fertilizer levels" has been revived in this chapter.

2.1 Response of Cultivars

2.1.1 Growth Character

Yakadri *et al*. (2002) studied the effect of nitrogen (40 and 60 kg ha^{-1}) on crop growth and yield of green gram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in leaf area ratios indicating better partitioning of leaf dry matter.

Bora *et al*. (2006) conducted a field experiment to study different cultivars of green gram. The result revealed that Pusa 9531 and PDM-11 being at par produced significantly more numbers of leaves $plant^{-1}$ and number of branches $plant^{-1}$ than rest of genotypes.

Kandasamy and Kuppuswamy (2007) reported that among the six varieties of black gram (T9, ADT3, ADTS, VBN2, VBN3 and COS), cv. ADT3 recorded the highest values of all the growth and yield parameters as well as highest seed yield of 811 kg ha^{-1}.

Johnanurang *et al.* (2009) conducted a field experiment to study of different cultivars of green gram (*viz*., K-851, HUM-2, Asha and HUM-6). The result revealed that Asha variety was found most responsive for all growth parameter to the rest of varieties.

Singh and Singh (2010) studied three genotype of green gram *viz*., SMC-668, SMC-832 and SMC-843. The result indicated that the genotype SMC 843 recorded highest dry matter, nodule $plant^{-1}$ and plant height compare to rest of genotypes.

Amruta *et al*. (2015) conducted experiment on black gram cultivar LBG-625 (Rashmi) results revealed that fertilizer application of 50:100:100 NPK kg ha^{-1} + Black gram rhizobia (250 g ha^{-1}) + PSB- Bacillus megaterium (250 g ha^{-1}) with the spacing of 60 x 10 cm recorded significantly higher number of branches $plant^{-1}$ (5.60), number of leaves $plant^{-1}$ (29.87).

Jadhav *et al*. (2014) conducted field trail at AICRP on water management, MKV Parbhani. They concluded that among the different black gram cultivars BDU-1 cultivars perform higher growth parameter compaired to TAU-1 and TAU -4.

Rathod and Gawande (2014) was observed that growth and yield of green gram to fertilizer grade, FYM @10 t ha^{-1} and Rhizobium was maximum. Maximum plant height (50.66 cm), number of leaves $plant^{-1}$ (33.00) and number of branches $plant^{-1}$ (4.66) at 60 DAS were found to be significant over all other treatment.

2.1.2 Yield Contributing Character and Yield

Nag *et al*. (2000) conducted a research regional agriculture station Barisal, Bangladesh on three black gram *(Vigna mungo*) cultivars (Barimash-1, Barimash-2 and Barimash-3) to evaluate their yield and yield attributes. Among the three cultivars, Barimash-1 and Barimash-3 recorded the highest (1601.4 kg ha^{-1}) and lowest seed yield (1455.0 kg ha^{-1}), respectively. Black gram cultivar Barimash-1 had the highest pods $plant^{-1}$ and seeds pod^{-1}.

Pramanik *et al*. (2002) studied four varieties of green gram *viz.*, Local, T-44, PDM-54 and Narendra mung and revealed that Narendra mung variety of green gram recorded higher pod $plant^{-1}$, pod length and seed pod^{-1} than rest of varieties.

Rajender *et al*. (2003) investigated the effects of N (0, 10, 20 and 30 kg ha^{-1}) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85111 and T44. They observed grain yield increased with increasing N rates up to 20 kg ha^{-1}.

Manpreet *et al*. (2004) conducted a field experiment in Ludhiana, Punjab, (India) during summer 2000 to investigate the response of mungbean genotypes (SML 134, SML 357 and SML 668) to P application (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) under irrigated conditions. The harvest index significantly compared to SML 668 and SML 357. Phosphorus application showed a non-significant effect on number of branches $plant^{-1}$, number of seeds pod^{-1}, pod length and 1000 seed weight. However, the increase in P level showed significant increase in the number of pods $plant^{-1}$, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg ha^{-1}) compared to lower levels (0 and 20 kg ha^{-1}). Harvest index remained unaffected with P application. The economic optimum P level for all the 3 summer mung bean genotypes was found to be 46.1 kg P_2O_5 ha^{-1}.

Kulsum *et al.* (2007) conducted study to evaluate the performance of black gram (*Vigna mungo*) under various level of nitrogen and observed that two variety of black gram BARI mash 1 and BINA mash 1 with six nitrogen level 0 , 20, 40, 60 ,80, 100 kg N ha^{-1}

were treatment variable shows significant morphological difference including yield of grain .

Singh *et al*. (2008) studied on the response of black gram (*Vigna mungo* L. Hepper) cv. JU 2, the optimum level of phosphorus through different sources was determined with or without application of PSB (Phosphorus solubilizing bacteria). Significantly highest seed yield of 651 kg ha^{-1} was recorded due to application of 40 Kg $P_2 O_5$ ha^{-1} through DAP with PSB.

Rangari *et al.* (2012) observed performance of black gram genotype BDU-1 during summer season was found highly productive as compared to TAU-1. Application of 25 kg N, 50 kg P_2O_5, and 2 % DAP foliar spray at flowering stage was found optimum for achieving higher seed yield of summer black gram.

Amruta *et al*. (2015) conducted an experiment to assess the response of nutrient levels and yield attributes of Black gram cv. LBG-625 (Rashmi) and observed number of pods cluster-1 (22.60), number of pods $plant^{-1}$ (54.40), pod weight $plant^{-1}$ (g) (22.60), seed recovery per cent (98.45) and processed seed yield (q ha^{-1}) (15.83) as compared to rest of the treatments. Hence, it concluded the application of 50:100:100 NPK kg ha^{-1} + Black gram rhizobia (250 g ha^{-1}) + PSB- Bacillus megaterium (250 g ha^{-1}) with the spacing of 60 x 10 cm would be useful to enhance the productivity of black gram.

Jagannath *et al*. (2014) conducted a field experiment at Agronomy Farm, College of Agriculture, Dapoli, Maharashtra Reported that among the different varieties of black gram studied, TAU-1 has produced maximum and significantly higher grain (1040 kg ha^{-1}) and stover (1510 kg ha^{-1}) yield over rest of the varieties, while the minimum and maximum harvest index was obtained with variety 'T-9' and 'TAU-1', respectively.

Rahman *et al.* (2015) observed that pulses although fix nitrogen from the atmosphere, it is evident that application of nitrogenous (N) fertilizers at flowering stage becomes helpful in increasing the yield. Phosphorus (P) fertilizer and potash (K) fertilizer have a great effect on growth and yield of black gram.

2.1.3 Quality Parameter

Malik *et al*. (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25 and 50 kg ha^{-1}) and phosphorus (0, 50, 75, and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Gupta *et al*. (2006) observed that UG-218 urd bean variety produced significantly higher pod plant^{-1} 1000 seed weight, seed yield as well as straw yield and improved quality over two variety (Type -9 and pant – U19).

Mansur *et al.* (2009) a field experiment was conducted at College of Agriculture Dharwad during two consecutive *rabi* season on kabuli chickpea and they found that phosphorous level 75 kg ha^{-1} and planting density of 3.33 lakhs ha^{-1} (30 cm × 10 cm) has more protein content (23.8 %) as compare to higher and lower plant density.

Kewat *et al*. (2020) observed quality attributes, the seed rate of 25 kg ha^{-1} and 30:60:30 NPK kg ha^{-1} fertilization registered higher protein yield, although remain statistically non-significant compared to S_1 treatment. Therefore, this experiment concludes that best-balanced growth, yield and quality of black gram can be achieved with a seed rate of 15 kg ha^{-1} along with an application of NPK at the rate of 30:60:30 kg ha$^{-1.}$

Jagannath *et al*. (2014) conducted a field experiment at Agronomy Farm College of Agriculture, Dapoli, Maharashtra observed that the variety 'TAU-1' recorded significantly more total protein yield as compared to rest of the varieties. Similarly nitrogen and phosphorus removal by grain and stover were highest with variety 'TAU-1'. The application of phosphorus responded favourably up to 50 kg ha^{-1} for total protein yield and removal of nitrogen and phosphorus.

2.1.4 Nutrient Uptake

Singh and Singh (2000) a field experiment conducted at Pantnagar found that the genotype IPU 94-1 recorded significantly higher grain yield (1020 kg ha^{-1}) and total uptake of nitrogen (73.1 kg ha^{-1}) as compare to rest of genotype tested. The increase in yield was due to higher dry matter accumulation (g plant^{-1}).

Patil *et al.* (2010) conducted a field experiment was conducted at Instructional Farm, Junagadh Agricultural University, Junagadh during *Kharif* season. The experiment comprised of twelve treatment combinations of three levels of recommended dose of fertilizer and two levels each of Farmyard manure. Significantly the 100 % RDF+FYM 5 t ha^{-1} and biofertilizers inoculation with and without inoculation with *Rhizobium sp.*+ *Pseudomonous straita* enhanced protein content, nitrogen, phosphorus and potassium content and uptake by black gram as compared to rest of treatments.

Athokpam *et al*. (2009) revealed that the application of 15 kg N ha^{-1} significantly increased total uptake of nutrients by the black gram (15:60:20 kg NPK ha^{-1}) over control and recorded higher nitrogen use efficiency.

Surendar *et al.* (2013) reported that basal application of nitrogen 25 kg ha^{-1} with foliar spray of urea 2% and 0.1 ppm brassinolide significantly expressed increase in N and P content of black gram leaf potassium content is also enhanced by basal application.

Niraj and Prakash (2015) conducted research on black gram variety Pant-Urd and observed that application of 60 kg P and 45 kg S ha^{-1} produced highest grain and straw yield along with nutrient content and uptake of nitrogen, phosphorous, potassium and sulphur over the other treatment.

Bansal and Ahamad (2015) conducted field experiment during summer season of 2012 at muzaffarpur and found that 50 % RDF + 2 % urea spray at 40 DAS influenced significantly available nitrogen (197.78 kg ha^{-1}), phosphorus (17.49 kg ha^{-1}) and potassium (126.87 kg ha^{-1}) over control.

Phogat *et al*. (2020) conducted experiment to investigate the interaction effect of phosphorus and sulphur application on nutrients uptake and yield of black gram cv. Uttara. The results revealed utmost concentration and uptake of phosphorus in seed (0.376 % and 3.59 kg ha^{-1}) and sulphur in seed (0.397 % and 3.79 kg ha^{-1}) with combined application of phosphorus 60 kg and sulphur 30 kg ha^{-1}, indicating synergistic effect of phosphorus and sulphur on nutrient uptake respectively.

2.1.5 Economics

Singh *et al*. (2008) studied on the response of black gram (*Vigna mungo* L. Hepper) cv. JU 2, the optimum level of phosphorus through different sources was determined with or without application of PSB (Phosphorus solubilizing bacteria). A net return of Rs. 2624 ha^{-1} was also recorded highest in treatment (40 Kg P_2O_5 ha^{-1} through DAP with PSB). It is therefore, recommended for general adoption in medium black soils of Madhya Pradesh.

Sharma *et al*. (2010) carried out a field experiment at Gulbarga during *kharif* seasons (2003- 2005) and revealed that among the cropping systems, pigeon pea ICPL-87119 (Asha) + green gram intercropping system with RDF + 2 % urea spray at 15 and 30 days after harvest of intercrops recorded significantly higher gross returns Rs. 31439 and 30576 ha^{-1} respectively over other intercropping systems

Jagannath *et al*. (2014) conducted field experiment at Dapoli. The variety 'TAU-1' with application of 50 kg P_2O_5 ha^{-1} recorded maximum grain and stover yield with most remunerative combination of treatment having B: C ratio 1.47.

Patel *et al*. (2016) conducted field experiment at Dantiwada, Gujrat. The results revealed that green gram cultivar Meha performed better by recording 17.3 and 15.3 per cent higher seed yield and Stover yield, respectively over GM 4. Maximum net realization

along with higher BCR value were recorded with variety Meha on combined application of 75 % RDF from urea + 2 t FYM ha^{-1} + Rhizobium+ PSB.

2.2 Effect of Fertilizers

2.2.1 Growth Character

Pintoo *et al*. (2002) concluded that interaction effects of 80 kg K_2O and 40 and 80 kg P_2O_5 ha^{-1} application resulted in the highest plant height, number of branches.

Singh *et al*. (2005) conducted a field experiment at Punjab Agricultural University, Ludhiana on mung bean with different phosphorus levels. They found that phosphorus levels showed significant differences in plant height and dry matter accumulation in mung bean as 40 kg P_2O_5 ha^{-1} showed significantly higher plant height than control and 20 Kg P_2O_5 ha^{-1} dose, but it was at par with 60 Kg P_2O_5 ha^{-1}.

Meena *et al*. (2006) conducted the experiment at College of Agriculture; Bikaner, Rajasthan during *kharif* revealed that application of graded levels of phosphorus significantly increased the plant height, number of branches $plant^{-1}$ and dry matter accumulation at harvest, dry weight of root nodules $plant^{-1}$ at 45 DAS of cluster bean up to 40 Kg P_2O_5 ha^{-1} over lower doses.

Asaduzzaman (2006) found that plant height and number of leaves $plant^{-1}$ of mung bean was significantly increased by the application of nitrogen fertilizer at 30 kg ha^{-1}.

Patil and Dhonde (2009) conducted a field experiment on green gram during summer season of 2005 at MPKV, Rahuri and noted that the plant height, mean number of branches and leaves $plant^{-1}$ and the dry matter $plant^{-1}$ were obtained significantly higher by application of 50 kg K_2O ha^{-1} as compared to 37.5 kg K_2O ha^{-1}.

Rathore *et al*. (2010) conducted a field experimental during *kharif* 2007 and observed that application of 100 % RDF (20 kg N + 60 kg P_2O_5 + 20 kg K_2O + 20 kg S ha^{-1}) to black gram produced significantly higher plant height (37.96 cm), number of branch plant (8.52), number of leaves $plant^{-1}$ (20.48), dry weight $plant^{-1}$ (8.70 g) and number of root nodules plant (36.23) both over 75 % and 50 % RDF.

Results of the study conducted by Hussain *et al.* (2011) revealed that application 30 kg N + 60 Kg P_2O_5 ha^{-1} significantly increased plant height, branches, numbers and weight of root nodule of black gram over control.

Khatana *et al*. (2021) seed yield was increased by 52.20 % in treatment T_8 (100 % RDF + 100% Rhizobium) over control however; combination of rhizobium and NPK levels had proved significant influence on plant height, number of leaves and physico-chemical properties of soil under black gram.

Mir *et al*. (2012) reported that application of 60 kg P_2O_5 ha^{-1} recorded maximum plant height (cm), number of leaves $plant^{-1}$ and number of nodules plant of black gram as compared to lower levels and control.

Tungoe *et al.* (2018) observed that among the fertilizer dose, F_2 + FYM@ 5 t ha^{-1}) was found to increase the availability of NPK by the ($N_{10}P_{40}K_{20}$ crop resulting in significantly superior growth attributes *viz*., plant height, number of leaves and branches $plant^{-1}$ and leaf area index (LAI).

Shashikumar *et al*. (2013) reported a significant increase in plant height (37.11 cm), number of branches $plant^{-1}$ (8.27), leaf area index (4.18), and leaf area duration (60.45) in blackgram with RDF (12.5:25:0 NPK kg ha^{-1}) + foliar spray of 40 ppm NAA + 0.5% chelated micronutrient + 2% DAP as compared to control.

Patel *et al*. (2017) a field experiment was conducted at College Farm, Navsari Agricultural University, results revealed that phosphorus applied @ 40 kg ha^{-1} recorded significantly higher plant height at 60 DAS and at harvest and number of branches $plant^{-1}$ over control.

Sreemathi *et al*. (2019) conducted experiment at Agricultural College and Research Institute, Killikulam (TNAU) during Puratassipattam (Sep–Dec, 2017) to study the effect of crop geometry, fertilizer levels and foliar nutrition on the growth attributes and yield. The results revealed that plant spacing of 30 × 15 cm with 100 % RDF coupled with foliar spray of TNAU Pulse Wonder @ 1.12 (5%) at 50 % flowering recorded higher growth and yield attributes.

Singh (2022) reported higher growth parameters with the application of 5 t ha^{-1} FYM and with 100 % recommended dose of chemical fertilizer as compare to other treatments.

2.2.2 Yield Contributing Character and Yield

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on the yield and yield components of mungbean at the Agronomic Research Station, Farooq Abad in Pakistan during the year of 2000 and 2001. They revealed that with the application of NPK at the rate of 50-50-0 kg ha^{-1} significantly affected the 1000 grain weight.

Narayana (2003) carried out investigation at Gurazala, Guntur, concluded that the application of 60 kg P_2O_5 ha^{-1} resulted in the highest grain yield of soybean (16.7 q ha^{-1}) and it was significantly superior over the lower levels of phosphorus.

Singh *et al*. (2005) conducted a field experiment at Punjab Agricultural University, Ludhiana revealed that among the phosphorus levels, 40 kg P_2O_5 ha^{-1} showed significantly increased grain yield of mung bean than control and 20 kg P_2O_5 ha^{-1}, but at par with 60 kg P_2O_5 ha^{-1}.

Kantwa *et al*. (2005) conducted a field experiment during rainy season at IARI; New Delhi revealed that application of 40 kg P_2O_5 ha^{-1} increased the grain yield of pigeon pea by 20.6 per cent over no phosphorus.

Singh *et al*. (2007) carried out at field experiment on green gram at Ludhiana (Punjab) and reported that number of pods plant^{-1}, 100 seed weight and biological yield were found significantly higher with 12.5 kg N + 40 kg P_2O_5 ha^{-1} than lower dose.

Luikham *et al*. (2007) conducted field experiment at Imphal (Manipur) observed that the seed yield and stover yield of broad bean increased significantly with every increase in the level of phosphorus up to 60 kg P_2O_5 $ha^{-1.}$ Crop fertilized with 60 kg P_2O_5 ha^{-1} gave 68.32, 30.24 and 14 per cent more yield over control, 20 and 40 kg P_2O_5 ha^{-1}.

Athokpam *et al*. (2009) observed that the highest seed yield of blackgram with the application of 15:60:20 kg NPK ha^{-1}.

Rathore *et al*. (2010) conducted a field experimental during *kharif* 2007 and observed that application of 100 % RDF (20 kg N+ 60 kg P_2O_5 + 20 kg K_2O + 20 kg S ha^{-1}) produced significantly higher number of clusters (11.52), pods plant^{-1} (36.33), pod length (3.88 cm), seeds pod^{-1} (6.22), seed index (6.28 g), seed yield (1225 kg ha^{-1}), straw yield (8850 kg ha^{-1}) and harvest index (12.22 %) of black gram over 75 % and 50 % RDF, respectively.

Significant effect of NPK in enhancing yield of black gram has been reported by many workers (Hussain *et al.* 2011 and Athokpam *et al.* 2009). Since farmers grow black gram at low, medium and high level of input especially fertilizers and hence different doses of nutrients have been used in this study to compare the response of organic manures at given level of nutrients grown with non-pesticidal management.

Hussain *et al.* (2011) reported that application 30 Kg N + 60 Kg P ha^{-1} produced significantly higher seed yield, plant height, branches, seeds pod^{-1}, harvest index and 1000-seed weight of black gram over control.

Kumawat *et al*. (2013) observed that application of 40 kg P ha^{-1} significantly higher seed yield (10.65 q ha^{-1}), haulm yield (23.00 q ha^{-1}) and biological yield (33.66 q ha^{-1}) in black gram over 20 kg ha-^{1}.

Shashikumar *et al.* (2013) revealed that application of RDF (12.5:25:0 NPK kg ha-¹) + foliar spray of 40 ppm NAA + 0.5 % chelated micronutrient + 2 % DAP recorded significantly higher grain yield (1298 kg ha^{-1}).

Phogat *et al*. (2020) revealed that combined application of phosphorus and sulphur showed synergistic effect on seed and straw yield of black gram with increasing levels of phosphorus and sulphur. The seed and straw yield were 955.50 and 2398.30 kg ha^{-1} with combined application of phosphorus 60 kg and sulphur 30 kg ha^{-1}. The yield attributes of black gram *viz*., number of pods $plant^{-1}$ and 100 seeds weight also increased significantly with increasing levels of phosphorus and sulphur up to highest level and the optimum values were recorded with combined application of phosphorus 60 kg and sulphur 30 kg ha^{-1} umber of pods $plant^{-1}$ (38.73) of black gram over control.

Yadav *et al*. (2017) conducted an experiment on study of the use of phosphorous for maximization of summer mung bean (*Vigna radiata* L.) productivity under sub-humid condition at 12 Rajasthan, India and the results of experiment revealed that grain yield of summer green gram was significantly improved due to successive increase in the level of phosphorus up to 40 kg P_2O_5 ha^{-1}.

Patel *et al*. (2017) conducted a field experiment at College Farm, Navsari Agricultural University, result revealed that phosphorus applied @ 40 kg ha^{-1} recorded significantly higher number of pods $plant^{-1}$, number of seeds pod^{-1}, length of pod, seed and haulm yields of 1168 and 2475 kg ha^{-1} over control.

Singh (2022) reported that application of soil test based FYM @ 5 t ha^{-1} (C_2) and in 100 % recommended (20:40:20 kg N:P_2O_5:K_2O ha^{-1}) (F_1) significantly higher grain yield (pooled 2005-06, 2006-07) Stover yield (2005-06, 2006-07) and biological yield (2005-06, 2006-07) and harvest index (2005-06, 2006-07).

2.2.3 Nutrient Uptake

Singh *et al.* (2002) reported that the application of 15:60:20 kg N : P_2O_5 : K_20 ha^{-1} significantly increased total N, P and K uptake by black gram over control.

Sunder *et al*. (2003) studied the effect of phosphorus on dry matter, uptake of nutrients and quality of cluster bean at College of Agriculture, Bikaner, Rajasthan revealed that protein and gum content also increased significantly due to application of 40 kg P_2O_5 ha^{-1} in comparison to 20 kg P_2O_5 ha^{-1}.

Deepa and Poonkodi (2004) reported that application of 100 % RDF recorded the significantly maximum uptake of N, P, K, Ca, Mg and S (54.83, 5.26, 35.78, 25.57. 16.58 and 4.96 kg ha^{-1}, respectively) by black gram.

Vikrant *et al*. (2005) conducted a field trial on cow pea at Hisar and concluded that among various levels of phosphorus 60 kg P_2O_5 ha^{-1} increased the NPK content by 7.53, 8.18, 9.62 and 12.78, 6.03, 6.03 per cent in seed and stover, respectively.

Geetha and Velayutham (2009) observed that basal application of N and P fertilizers 12.5:25 kg ha^{-1} to blackgram significantly increased growth, yield and nutrient uptake.

Vidyavathi *et al.* (2020) conducted study and results revealed that highest yield and nutrient uptake by mothbean was recorded by application of 100 % RDF of green gram (12.5: 25: 0 kg N: P_2O_5: K_2O ha^{-1}) + vermincompost @ 1.0 t ha^{-1}.

2.2.4 Quality

Mishra (2003) observed that phosphorus application remarkably improved the quality of cow pea in terms of protein yield in seed with increasing levels of phosphorus from control to 30 kg P_2O_5 ha^{-1}, 30 to 60 kg P_2O_5 ha^{-1} and 60 to 90 kg P_2O_5 ha^{-1}.

Meena *et al*. (2006) conducted the experiment at College of Agriculture, Bikaner during *kharif* revealed that increasing levels of applied phosphorus up to 40 kg P_2O_5 ha^{-1} significantly increased the protein content, gum content in seed and chlorophyll content at 30, 45 and 60 DAS in cluster bean over lower doses.

P fertilizer stimulate better root growth, disease resistance and improve the water and nutrient absorption in the seedling stage. K plays a vital role in the activation of enzymes and boost up biological N fixation and protein content of pulse seeds (Bukhsh *et al.* 2011, Shrinivasrao *et al.* 2003)

Patel *et al*. (2017) a field experiment conducted at college farm, Navsari Agricultural University, showed that phosphorus applied @ 40 kg ha^{-1} recorded significantly higher protein content (19.34 %) and protein yield (226.20 kg ha^{-1}) of green gram over control, respectively.

2.2.5 Economics

Narayana (2003) from the investigation carried out at Gurazala, Guntur concluded that the application of 40 kg and 60 kg P_2O_5 ha^{-1} is essential for achieving maximum monetary benefits from soybean in black cotton soils of Gurazala where the soil status of available phosphorus is low.

Vikrant *et al*. (2005) conducted a field trial on cow pea at Hisar with varying levels of phosphorus concluded that among various levels of phosphorus 20, 40 and 60 kg P_2O_5 ha^{-1} recorded 367.37, 658.03 and 668.3 per cent higher net returns over control.

Kumawat *et al*. (2013) observed that application of 40 kg P ha^{-1} gave significantly higher net return (₹ 26.315.54 ha^{-1}) and benefit cost ratio (2.80) in black gram over 20 kg ha^{-1} (₹ 17.070.65 ha^{-1} and 1.91) and control.

Shashikumar *et al*. (2013) revealed that application of RDF (12.5:25:0 NPK kg ha^{-1}) + foliar spray of 40 ppm NAA + 0.5 % chelated micronutrient + 2 % DAP recorded significantly higher net return (₹ 35,431 ha^{-1}) and B : C ratio (3.03) of black gram over control.

Narendra *et al*. (2015) conducted a field experiment on intercropping of black gram and pigeon pea, pooled data revealed that normal intercropping system (S_2) gave maximum values of gross return (₹ 120,050), net return (₹ 99,396), B: C ratio (4.8), pigeon pea equivalent yield (21.75 q ha^{-1}), land equivalent ratio (1.70), production efficiency (7.98 kg ha^{-1} day^{-1}) and economic efficiency (364.83 ha^{-1} day^{-1}) which was at par with paired intercropping system (S_3) and significantly superior to sole planting of pigeon pea (S_1).

Khatana *et al*. (2021) recorded economics of different treatment, the maximum gross returns (₹ 72600 ha^{-1}), net returns (₹ 40974 ha^{-1}) and B : C ratio (2.29) was recorded under treatment T_8 (100 % RDF + 100 % Rhizobium) for urd bean.

Singh (2022) reported that application of soil test based 5 t FYM ha^{-1} resulted in highest gross returns (₹.16591 ha^{-1}), net returns (₹ 3251 ha^{-1}) and B : C ratio (1.25) over other nutritional treatments. Similarly, in chemical fertilizer treatments the 100 % Recommended ($N_{20}P_{40}K_{20}$) obtained the highest gross return (₹ 16510 ha^{-1}), net return (₹ 2661 ha^{-1}) and benefit cost ratio (1.27) among the other treatment respectively.

3. MATERIAL AND METHODS

A field experiment was conducted to study the "Response of Black gram (*Vigna mungo* (L.) Hepper.) cultivars to fertilizer levels" at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. The objectives of study were to assess the response of black gram cultivars to fertilizer levels and effect of fertilizer on yield, growth and quality of black gram cultivars. The details of the material and analytical techniques adopted for the investigation are presented in this chapter.

3.1 Details of Experimental Materials

3.1.1 Experimental Site

The field experiment was conducted at Post Graduate Institute Research Farm, Department of Agronomy Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during *kharif* season of 2021.

3.1.2 Soil

The soil of experimental field is grouped under the Inceptisol order and texture of soil is clay with more than 60 cm depth having the topography of experimental field is uniform and levelled. The representative initial soil samples were collected for the assessment of initial soil fertility status. These collected soil samples were thoroughly mixed and composite soil sample was prepared and analysed for physical and chemical properties of the soil.

Table 3.1. Physical and chemical properties of soil and method used

Sr. No.	Particular	Composition	Method used	References
I.	**Physical properties**			
1.	Partical size distribution		International pipette method	Piper (1966)
i.	Coarse sand (%)	5.00	-,,-	-,,-
ii.	Fine sand (%)	18.2	-,,-	-,,-
iii.	Silt (%)	21	-,,-	-,,-
iv.	Clay (%)	55.27	-,,-	-,,-
2.	Soil texture	clay	Triangular diagram	USDA Manual
3	Bulk density (g cm^{-3})	1.24	Core sampler	Dastane (1972)
4.	Field capacity	37.30	Pressure plate apparatus Black (1965)	
5.	Permanent wilting point	18.10		
6.	Available soil moisture (%)	19.20	Gravimetric (Dastane,1972)	

Table 3.1 contd…

Sr. No.	Particular	Composition	Method used	References
II.	**Chemical properties**			
1.	pH (1:2.5)	8.31	Potentiometry	Jackson (1973)
2.	EC (dSm^{-1})	0.44	Conductometry	Jackson (1973)
3.	Organic carbon (%)	0.53	Wet oxidation	Nelson and Sommer (1982)
4.	Available nitrogen (kg ha^{-1})	170.56	Alkaline permanganate	Subbiah and Asija (1965)
5.	Available phosphorus (kg ha^{-1})	21	0.5M. $NaHCO_3$ (pH 8.5)	Olsen *et al.,* (1956)
6.	Available potassium (kg ha^{-1})	380.50	N$\underline{N}$ NH_4OAc (pH 7.0)	Knudsen *et al.,* (1982)

The soil texture of experimental field was clay, low in available nitrogen (170.56 kg ha^{-1}), medium in available phosphorus (21 kg ha^{-1}) and very high in available potassium (380.50 kg ha^{-1}). The soil of experimental field was moderately alkaline in reaction (pH 8.31). Electrical conductivity of soil was 0.44 dSm^{-1} with 0.53 % organic carbon. The physical and chemical properties are given in Table 3.1.

3.1.3 Cropping History of Experimental Field

The cropping history of the experimental field for previous three years is presented in Table 3.2.

Table 3.2. Cropping history of experimental field

Sr. No.	Year	Crops growing in previous three years		
		Kharif	***Rabi***	**Summer**
1	2017-18	Maize	Chick-pea	Fallow
2	2018-19	Maize	Oat	Fodder-Sorghum
3	2019-20	Mung	Fallow	Fodder- maize
4	2020-2021	Black gram	-	-

3.1.4 Climate and Weather Conditions

3.1.4.1 General

Geographically, the Central Campus Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri is situated between the 74^0 35'E and 74^0 19'East longitude and 19^0 18'N and 19^0 57'North latitude. The altitude of the field varies from 495 to 556 m above mean sea level.

This area falls in the semi-arid tropics region with an annual rainfall ranging from 307 to 619 mm. The average rainfall of the area is 520 mm. Rainfall is erratic and

unevenly distributed in 15 to 45 rainy days. The annual rainfall, about 80 % receives from South - West monsoon from June to September and rest of the rainfall receives from North- East monsoon during October to November and practically negligible rains receive during summer.

Mean annual maximum and minimum temperature ranges from 33^0C to 49^0C and 7^0C to 24^0C, respectively. The mean relative humidity of area during morning and evening hours was 61 and 35 percent. The sunshine hours ranges from 6 to 9 hrs day^{-1}. Agro-climatically location is in drought-prone area of Maharashtra state, characterized by the low and erratic rainfall with less rainy days and long dry spell.

3.1.4.2 Climate and weather during the experimental period

The climatic conditions prevailed during experimental period expressed through data on weekly means meteorological weather parameter *viz*., maximum and minimum temperature, relative humidity, sunshine hours, wind velocity, rainfall and pan evaporation were obtained from Meteorological Observatory located at AICRP on Irrigation Water Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri and are presented in Table 3.3.

The black gram crop was sown on July 9^{th} 2021 and harvesting was undertaken on September 26^{th} 2021. The rainfall received during the crop growth period was 571 mm in 31 rainy days, in July, August and September month. The rainfall received in the month of June (123.8 mm) was useful for land preparation and rainfall received in July and august month was 165 mm and 170.6 mm respectively, which was found helpful for vegetative and reproductive growth of crop.

During the crop growing season the maximum temperature ranges between 24.3 ^{0}C during 31^{th} MW to 34.14 ^{0}C during 27^{th} MW. The minimum temperature varied from 22.23 ^{0}C during 34^{th} MW to 25.14 ^{0}C during 27^{th} MW.

The mean relative humidity ranged from 75.71 to 93.43 per cent at morning and 45.28 to 69.43 per cent at evening. The maximum relative humidity (93.43 %) was observed during 34^{th} meteorological week at morning hours and minimum relative humidity (75.71 %) was noticed during 27^{th} meteorological week. The wind speed was in the range of 0.86 to 6.93 km hr^{-1} and bright sunshine hours were ranged from 1.69 to 8.37 hours. Bright sunshine hours were lower than normal helped to the crop to utilize the

available soil moisture. Whereas the open pan evaporation ranges from 3.17 to 7.51 mm day^{-1}.

Table 3.3. Weekly meteorological data recorded on different weather parameter during experimental period

Met. Week	Date	Temperature		Humidity (%)		Wind velocity (km hr^{-1})	Rain fall (mm)	Sunshine (hrs.)	Open Pan Evaporation (mm)	Rainy days
		Max.	Min.	Morn.	Eve.					
June, 2021										
23	04-10	32.4	24.9	78	52.42	1.84	21.2	5.1	5.92	2
24	11-17	33.85	25.41	76.14	45.28	6.11	6.4	6.01	8.22	2
25	18-24	33.08	24.72	76.28	45.85	5.98	9	6.01	6.82	4
26	25-01	30.25	23.9	85.85	61.71	2.95	87.2	3.4	4.48	5
July, 2021										
27	02-08	34.14	25.14	75.71	45.28	3.34	0.00	8.37	7.51	0
28	09-15	30.31	23.76	91.29	68.14	1.80	118.60	2.27	4.46	4
29	16-22	30.06	23.86	85.29	65.57	2.26	43.60	3.03	4.17	4
30	23-29	30.09	24.66	82.29	59.00	6.93	2.80	3.60	4.80	0
August, 2021										
31	30-05	24.37	23.59	82.86	66.71	6.69	4.80	2.13	4.43	1
32	06-12	31.29	24.17	80.14	57.57	3.20	1.20	5.54	5.29	0
33	13-19	29.63	22.70	88.00	67.71	2.26	34.60	2.91	4.66	4
34	20-26	27.70	22.23	93.43	68.00	0.86	48.80	4.21	3.37	3
35	27-02	29.34	22.87	88.29	65.86	1.14	81.20	4.67	4.49	2
September, 2021										
36	03-09	29.60	23.04	91.57	67.14	2.61	117.40	4.34	3.51	4
37	10-16	29.80	23.89	84.00	63.71	4.86	7.60	4.29	4.23	1
38	17-23	28.89	23.09	87.14	68.86	1.83	51.60	3.64	3.74	3
39	24-30	28.94	22.86	92.14	69.43	1.30	58.80	1.69	3.17	5
Total		-	-	-	-	-	571	-	-	31

3.2 Experimental Details

3.2.1 Experimental Design and Treatments

The experiment was conducted in Split Plot Design with three replications. The treatment comprises 4 black gram cultivars and 4 fertilizer levels in all there were 16 treatment combinations. The details of the treatments are given below.

Treatment details

1) Main plot treatment (Cultivars):

V_1 - TPU-4

V_2 - PDKV black gold

V_3 - AKU-15

V_4 - PU-609-43

2) Sub plot treatment (Fertilizer levels)

F_1 - Control

F_2 - 75 % of RDF

F_3 - 100 % of RDF

F_4 - 125 % of RDF

Note: Seed treatment with Rhizobium 250 g^{-1} 10 kg of seed and FYM @ 5 t ha^{-1} was common to all treatments except control.

Tables 3.4. Details of treatment combinations (16)

Tr. No.	Combination	Tr. No.	Combination
T_1	V_1F_1	T_9	V_3F_1
T_2	V_1F_2	T_{10}	V_3F_2
T_3	V_1F_3	T_{11}	V_3F_3
T_4	V_1F_4	T_{12}	V_3F_4
T_5	V_2F_1	T_{13}	V_4F_1
T_6	V_2F_2	T_{14}	V_4F_2
T_7	V_2F_3	T_{15}	V_4F_3
T_8	V_2F_4	T_{16}	V_4F_4

3.2.2 Other details

1.	Name of crop	:	Black gram
2.	Cultivar	:	1) TPU -4 2) PDKV black gold 3) AKU – 15 4) PU-609-43
3.	Season	:	*Kharif* 2021
4.	Experimental design	:	Split plot
5.	No. of replications	:	03
6.	No. of treatments	:	16
7.	Seed rate	:	15- 20 kg ha^{-1}
8.	Spacing	:	30 cm × 10 cm
9.	Plot size	:	Gross = 3.00 m × 2.40 m Net = 2.60 m × 1.80 m
10.	Place of research work	:	PGI, Farm MPKV, Rahuri
11.	Commencement of research work	:	*Kharif* 2021
12.	Sowing time	:	First week of July 2021
13.	Recommended dose of fertilizer	:	20:40:00 kg N:P_2O_5:K_2O ha^{-1}

3.2.3 Cultivar

AKU-15: This variety is developed by crossing between (BM-86) x (MH). It matures in 64-72 days. This variety is suitable for *kharif* cultivation in Vidharbha region. It is moderately resistant to powdery mildew, non-lodging and non-shattering. The average grain yield is 10-12 q ha^{-1}.

TPU-4: This variety released by BARC/MAU in 1992 .this variety is recommended for MP, Maharashtra and Central part of Rajasthan. The average yield is 7.5 q ha^{-1}.Days to maturity of this variety is 75 day. Plant is erect, medium tall and seeds bold and dull black.

PDKV Black Gold: variety is released by Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola in year 2016. Maturity duration is 75 - 80 days and production is 12-16 q ha^{-1}. It is high yielding and resistant to powdery mildew and alternaria disease.

PU-609-43: The variety also known as Phule Vasu and it is developed by crossing between TAU-1 and BDU-1. This variety is released by Mahatma Phule Krishi Vidyapeeth Rahuri, Jalgaon. Bold seeded, high yielding, tolerant to major disease powdery mildew, mung bean yellow mosaic virus under field condition.

3.3 Details of field Operations

The details of operation carried out in experimental plot during the year 2021 are given in a Table 3.5.

3.3.1 Preparation of Field

The field was prepared by ploughing and followed by harrowing. Stubbles and weeds were removed from experimental plot and then plots were laid out as per plan of layout.

3.3.2 Fertilizer Application

The entire quantity of recommended dose of fertilizer and 5 tonne FYM for blackgram (20:40:00 NPK kg ha^{-1}) was applied as basal dose at the time of sowing in the form of DAP and urea.

3.3.3 Seed Material

Blackgram cultivar AKU-15 was used for sowing which was released by Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The important character of the variety are non-lodging and resistant to powdery mildew.

Black gram cultivar PDKV black gold (AKU-10-1) also used for sowing released by Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in year 2016. Maturity duration is 75 - 80 days and production is 12 – 16 q ha^{-1}. It is high yielding and resistant to powdery mildew and alternaria disease.

PU-609-43 (Phule vasu) is black gram cultivar released by MPKV Rahuri Jalgoan. This is high yielding early mature variety (average maturity 73 day), tolerance to major diseases powdery mildew, mung bean yellow mosaic virus under field condition.

Black gram cultivar TPU-4. This variety released by BARC/MAU in 1992. Plant is erect, medium tall and seeds bold and dull black. All the cultivars of black provided by oilseed specialist, Jalgaon for sowing.

3.3.4 Seed Treatment

Seeds of black gram were treated with Rhizobium culture @ 2.5 g kg^{-1} of seed just before sowing.

3.3.5 Time and Method of Sowing

The lines were marked at desired distance and shallow furrows were opened with the help of marker at 30 cm row distance for sowing of black gram. The seeds were placed manually in the furrows using the recommended seed rate @ 12-15 kg ha^{-1}. The sowing was done on 9th July 2021.

3.3.6 Gap Filling

Gap filling was done on 15th day after sowing so as to maintain the plant population. Gap filling was carried was carried on 23.7.2021.

3.7.7 Thinning

Thinning was carried out 15 days after sowing by keeping one healthy plant. Thinning was carried on 23.07.2021.

3.3.8 Weeding and Hoeing

Hoeing was done at 20th day after sowing on 28.7.2021 and hand weeding was done at 30 day after sowing to keep the crop free from weeds in all treatments.

3.3.9 Plant Protection

Timely plant protection measures were adopted whenever necessary. Attack of sucking pest in black gram was noticed in the 1st week of August. The sucking pest was controlled by spraying of imidacloprid @ 1.5 lit ha^{-1}. The spraying was undertaken on 17.08.2021.

3.3.10 Harvesting and Threshing

The black gram crop was harvested on 26th September 2021, when the pods were fully ripened and turned black. The pod was picked from each plot as per treatment. Harvested produce was kept in the Agronomy Farm Building for two days to allow in sun-drying. Harvested produce was threshed by beating with sticks with the help of manual labour and finally seeds were winnowed by using supas. Threshed seeds were sun-dried

for 2-3 days to reduce the moisture content and then the seed yield per plot was recorded in kg and expressed in quintal ha^{-1}.

Table 3.5. Details of Field Operations

Sr. No.	Nature of operation performed	Frequency	Date
A.	**Preparatory tillages**		
1.	Ploughing	1	06.07.2021
2.	Harrowing	1	07.07.2021
3.	Preparation of layout	1	07.07.2021
4.	Soil sample collection	1	07.07.2019
B.	**Seeds and sowing**		
1.	Application of basal fertilizer	1	09.07.2021
2.	Seed treatment and rhizobium biofertilizer	1	09.07.2021
3.	Sowing	1	09.07.2021
4.	Thinning	1	23.07.2021
5.	Gap filling	1	23.07.2021
6.	Hand weeding	1	08.08.2021
7.	Irrigation	1	12.08.2021
8.	Spraying of imidacloprid	1	17.08.2021
C.	**Harvesting**		
1.	Harvesting of crop		26.09.2021
2.	Threshing of crop		29.09.2021

3.4 Biometric Observations

The biometric observations were recorded from labelled five plants, selected randomly to represent the population in each net plot.

3.4.1 Crop Growth Study

3.4.1.1 Germination count m^{-2}

Number of plants was counted and recorded at 15th days after sowing in the net plot to calculate mean plant stand ha^{-1}.

3.4.1.2 Final plant population

Number of plants was counted and recorded at the time of harvesting in the net plot to calculate mean plant stand $ha^{-1.}$

3.4.1.3 Plant height

Plant height was measured in order to estimate the effect and extent of plant growth due to various treatments. Height of the five randomly selected plants in each plot was measured at 15th days interval up to maturity. Height was measured from the soil surface to

the main stem (apical). The average height of five plants was taken as plant height and expressed in centimetres.

3.4.1.4 Leaf area plant^{-1}

The leaves from the plant taken for dry matter are separated from 5 plants were passed through biovis portable leaf area meter for estimation of leaf area. The leaf area plant^{-1} recorded at 30, 45, 60 DAS and at harvest and expressed as dm^{-2} plant^{-1}.

3.4.1.5 Chlorophyll content (mg g^{-1})

Plant samples for chlorophyll content studies were collected at flowering Total chlorophyll were estimated in a fully expanded young leaf with the help of portable clorophyll meter. It expressed in mg g^{-1} fresh weight.

3.4.1.6 Root nodules plant^{-1}

Number of root nodules plant^{-1} were recorded at 30, 45 and 60 DAS from uprooted plants in experimental plot. The plant uprooted for dry matter accumulation are used to count number of root nodule.

3.4.2 Crop Yield Components and Yield

3.4.2.1 Number of pod plant^{-1}

The number of pods plant^{-1} were recorded from randomly selected five plants of each plot just before the harvesting and the average was taken as the number of pods per plant.

3.4.2.2 Pod length (cm)

The lengths of the 10 pods were randomly selected from the total number of pods which were separated from the sampled plants. These were measured and the average was worked out to single pod.

3.4.2.3 Number of seed pod^{-1}

The pods were picked up from randomly selected five plants of each plot. The seed from 10 representative pods were separated, counted and the mean number of seeds pod^{-1} was calculated by dividing the number of seeds by the number of pods.

3.4.2.4 Test weight (g)

The seed sample from the produce of each plot was taken and counted 1000 seeds and then its weight was recorded and expressed in g.

3.4.2.5 Seed yield plot^{-1} (kg)

The black gram plants were harvested from each plot and then threshed separately. The seed yield of each plot were sun dried, cleaned and weight was recorded and expressed in kg.

Table 3.6. Details of observation recorded during experimental trial

Sr. No.	Particulars	Frequency	Period	Size of Sample
A)	**Crop growth and development**			
1)	Plant population Initial Final	 1 1	 15 DAS At harvest	Net plot
2)	Plant height (cm)	4	30, 45, 60 DAS and at harvest	5 Plants
3)	No. of leaves plant^{-1}	4	30, 45, 60 DAS and at harvest	5 Plants
4)	Leaf area	4	30, 45, 60 DAS and at harvest	5 Plants
5)	No. of root nodules	1	At flowering	5 Plants
6)	Chlorophyll content	1	At flowering	5 Plants
B)	**Yield parameters**			
1)	No. of pods plant^{-1}	1	At harvest	5 Plants
2)	No. seeds pod^{-1}			
3)	Test weight (1000) seed			
4)	Seed yield ha^{-1}			Net plot
5)	Straw yield ha^{-1}			Net plot
C)	**Quality parameters**			
1)	Crude protein content (%)	1	At harvest	Composite
D)	**Uptake studies**			
1)	Nitrogen uptake (%)	1	At harvest	Net plot
2)	Phosphorous uptake (%)			
3)	Potassium uptake (%)			
E)	**Soil studies**			
	Soil properties			
1)	Sand , silt and clay (%)	1	At harvest	-
2)	Field capacity (%)	2	Initial and at harvest	-
3)	Permanent wilting point (%)			
4)	Bulk density (g cm^{3})			
	Soil chemical properties			
1)	pH	2	Initial and at harvest	-
2)	EC (dsm^{-1})			
3)	Organic carbon (%)			
4)	Soil available N (kg ha^{-1})			
5)	Soil available P (kg ha^{-1})			
6)	Soil available K (kg ha^{-1})			
F)	**Economic Study**			
1)	Cost of cultivation	1	After harvest	Net plot
2)	Gross monetory return			
3)	Net monetory return			
4)	B : C ratio			

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

The black gram plants were harvested from net plot and then threshed after the sun drying. The seed yield of net plot was recorded and then converted in to kg ha by multiplying with hectare factor.

$$\text{Seed yield (kg ha}^{-1}\text{)} = \frac{\text{Seed yield plot}^{-1} \times 10000}{\text{Net plot size (m}^{-2}\text{)}}$$

3.4.2.7 Straw yield (kg ha^{-1})

The plant from net plot were cut close to ground, tied into bundles, dried in the sun and their weight was recorded as per treatments. From per plot yield per hectare was worked out.

3.4.3 Quality Parameters

3.4.3.1 Protein content (%)

Nitrogen content in the seeds of Black gram was estimated by Kjeldhal's method (Jackson, 1967). The protein percent in the seed was calculated by multiplying the nitrogen content by a factor of 6.25.

3.4.3.2 Crude Protein Yield (CPY)

The crude protein yield was calculated by the following formula given below:

$$\text{CPY (tonne ha}^{-1}\text{)} = \frac{\text{DMY (tonne ha}^{-1}\text{)} \times \text{Crude protein content (\%)}}{100}$$

3.5 Chemical Properties of the Soil of the Experimental Site

Pre experimental composite soil samples were collected at random in the experimental field before sowing and chemical analysis was done. Similarly, post-harvest soil samples were collected treatment wise, air dried under shade, ground and sieved through 2 mm sieve and used for analysis of macro elements

3.5.1 Chemical Analysis of Soil and Plant Samples

3.5.1.1 Soil nutrient analysis

Soil samples were collected before sowing of the crop randomly from the proposed plot. The soil samples were analysed for available nitrogen, phosphorus and potassium.

Available soil nitrogen was estimated by alkaline potassium permanganate method as outlined by Subbaiah and Asija (1956), whereas the phosphorus estimation was done by Brays's extractant method as outlined by Olsen *et. al.* (1954) using spectrophotometer. Available potassium was extracted with neutral normal ammonium acetate and the content was estimated by flame photometer (Knudsen *et al*., 1982).

3.5.1.2 Chemical analysis of plant samples

Plant samples collected for dry matter estimation at harvesting stage from the respective treatments were oven dried and ground into fine powder in a mill and used for estimating Nitrogen, Phosphorus and Potassium. The percent concentration of the nutrients was multiplied with the respective dry matter content and NPK uptake values were worked out.

Total nitrogen content in composite plant samples (stem, leaves and pods) of black gram at harvest was estimated by modified Micro-Kjeldhal method (Jackson, 1967) and expressed in percent and converted to kg ha^{-1} based on dry matter obtained. For analysis of phosphorus and potassium, plant samples were predigested with tri acid mixture (HNO_3: $HClO_4$: H_2SO_4 at 10:4:1) which was used for complete digestion of plant samples.

Phosphorus content in plant samples was determined by vanado molybdophosphoric yellow colour method by using spectrophotometer at 470 nm (Jackson, 1967) and expressed in percent and converted into to kg ha^{-1} based on dry matter.

Potassium content in plant sample was determined by Flame Photometric method and expressed in percentage and converted into kg ha^{-1} based on dry matter.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%) x Dry matter yield (kg ha}^{-1}\text{)}}{100}$$

3.6 Economics

The economics of various treatments was worked out taking into account the existing market rate of various production factors and produce during the course of investigation.

3.6.1 Cost of Cultivation (₹ ha^{-1})

Cost of cultivation is an important factor for economic analysis. It can be calculated by considering prevailing market price of inputs, wages and actually cost involved on various aspects during the investigation.

3.6.2 Gross Monetary Returns (₹ ha^{-1})

Gross monetary returns is the total earnings from crop produce (grain + straw) in terms of (ha^{-1}). The gross monetary return was calculated by considering the prevailing price of the produce at time of harvesting.

3.6.3 Net Monetary Returns (₹ ha^{-1})

The net monetary returns (₹ ha^{-1}) was calculated after deducting all the expenditure (₹ ha^{-1}) from gross return. It was obtained by subtracting cost of cultivation from gross return. This represents the actual income of farmer.The net monetary returns (₹ ha^{-1}) for different treatments were calculated with the following formula.

Net monetary returns (₹ ha^{-1}) = Gross returns (₹ ha^{-1}) – Cost of cultivation (₹ ha^{-1})

3.6.4 Benefit - Cost ratio

The Benefit cost ratio was worked out as follows

$$\text{B : C ratio} = \frac{\text{Gross returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}}$$

3.7 Statistical Analysis

The data collected during the course of present investigation were statistically analysed by adopting standard method known as analysis of variance (Panse and Sukhatme, 1967). Where ever results were significant, critical difference (CD) were worked out at 5 % level of probability for comparison of treatment mean. The treatment effects were presented by making tables of means with appropriate standard error (S.Em (±)) and CD values.

4. RESULTS AND DISCUSSION

The field experiment entitled "Response of black gram *(Vigna radiata* L.) cultivars to fertilizer levels" was conducted during *kharif*, 2021 at the Post Graduate Institute Research Farm, Department of Agronomy MPKV Rahuri. The details of results obtained from the present investigation are presented and discussed in this chapter.

4.1 Crop Growth Studies

4.1.1 Plant Population

The data on the mean initial and final plant population influenced by different treatments are presented in table 4.1.

The result revealed that the initial plant population and final plant population at harvest was not influenced by different treatments. Similarly, the final plant population at harvest was also fairly uniform indicating that the variations obtained in the different treatments under study were real effect of treatments. The mean initial and final population was 316917 ha^{-1} and 302917 ha^{-1} respectively.

Table 4.1 Initial and final plant population of black gram as influenced by different treatment

Treatment	Initial plant population	Percentage (%)	Final plant population	Percentage (%)
Main plot: Cultivars – C				
C_1- TPU-4	**316119**	**94.83**	**302119**	**90.63**
C_2- PDKV Black gold	**317617**	**95.28**	**303617**	**91.81**
C_3-AKU-15	**316739**	**95.01**	**302729**	**90.8**
C_4-PU-609-43	**317204**	**95.16**	**303204**	**90.96**
S. Em. (±)	**807.5**	**0.25**	**807.50**	**0.24**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
Sub plot: Fertilizer levels - F				
F_1-Control	**315972**	**94.79**	**301972**	**90.59**
F_2-75 % RDF	**316270**	**94.88**	**302270**	**90.68**
F_3-100 % RDF	**317345**	**95.20**	**303345**	**91.00**
F_4-125 % RDF	**318081**	**95.42**	**304081**	**91.22**
S. Em. (±)	**658.28**	**0.20**	**658.2**	**0.19**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**1316.9**	**0.4**	**1316.5**	**0.39**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means				
S. Em. (±)	**1397**	**0.42**	**1397.2**	**0.41**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
General mean	**316917**	**95.07**	**302917**	**90.87**

Response of black gram cultivars

The initial plant count and final plant count ha^{-1} of black gram did not differ significantly due to different black gram cultivars. However, black gram cultivars PDKV black gold recorded higher initial and final plant count (317617 and 303617) followed by PU-609-43, AKU-15, TPU-4.

Effect of fertilizer levels

The initial and final plant count ha^{-1} of black gram cultivars was not influenced significantly due to fertilizer levels. However, application of 125 % of RDF ha^{-1} recorded higher initial and final plant count (318081 and 304081) than other fertilizer levels and it was nearly followed by application of 100 % of RDF ha^{-1}.

Interaction

The interaction effects between black gram cultivars and fertilizer levels with respect to initial and final plant count of black gram cultivars were non-significant.

4.1.2 Plant Height

The data on mean plant height recorded during various growth stages are presented in Table 4.2 and graphically depicted in Fig. 4.1. Plant height was increased during every growth stages of black gram up to maturity. The mean plant height was increased progressively with an advancement of crop age and reached maximum at harvest. The rate of increase in height was rapid up to 60 days. The mean plant height $plant^{-1}$ recorded at 30, 45, 60, DAS and at harvest was 19.02, 41.47, 59.89, and 60.08 cm respectively.

Response of black gram cultivars

The plant height of black gram cultivars was influenced significantly at all crop growth stages. Black gram cultivar PDKV black gold (C_2) produced significantly maximum plant height (20.53, 43.30, 62.30, 62.49) than rest of cultivars *viz.,* PU-609-43, AKU-15 and TPU-4 at 30, 45,60 days and at harvest and it was at par with PU-609-43. TPU-4 (C_1) had lowest plant height as compared to the other three cultivars at all the growth stages. Higher plant height accounted due to more activities of meristematic tissues of plant, increasing number and size of cells, which is responsible for increased plant height. This might be due to genetical character of the cultivar. Similar results was recorded by Jadhav *et al.* (2014).

Effect of fertilizer levels

Plant height of black gram cultivars were influenced significantly due to different fertilizer levels during all growth stages of crop. The application of different RDF level to black gram cultivars significantly increased the plant height. Significantly maximum plant

height (21.41, 42.91, 60.70 and 61.02) at 30, 45, 60 and at harvest respectively were recorded by 125 % (F_4) of RDF ha^{-1} than the other levels of fertilizer, however, it was at par with the application of 100 % (F_3) of RDF ha^{-1}. Since N is a major component of protoplasm help in photosynthesis and enhance metabolic rate, cell division and cell elongation which allow the plant growth faster and phosphorous enhances the root elongation, leaf expansion and help in cell elongation might have resulted in increased plant height due to the application of fertilizer up to certain limit. Increased application of fertilizer ultimately causes more uptake of nutrients in plant, which enhance cell division and thereby increased the growth attributes. Similar results have also been reported by Rathore *et.al*. (2010).

Interaction

The interaction effects of black gram cultivars and fertilizer levels in respect of plant height were seems to be non-significant at all stages of black gram.

Table 4.2 Periodical plant height of black gram as influenced by different treatment

Treatment	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	At harvest
Main plot: Cultivars – C				
C_1- TPU-4	**17.80**	**39.23**	**57.27**	**57.25**
C_2- PDKV Black gold	**20.53**	**43.30**	**62.30**	**62.49**
C_3-AKU-15	**17.99**	**40.72**	**58.17**	**58.31**
C_4-PU-609-43	**19.78**	**42.61**	**61.83**	**62.27**
S. Em. (±)	**0.56**	**0.63**	**0.68**	**0.20**
C.D. at 5 %	**1.94**	**2.18**	**1.24**	**0.70**
Sub plot: Fertilizer levels - F				
F_1- Control	**16.30**	**39.75**	**59.40**	**59.30**
F2- 75 % RDF	**17.95**	**40.93**	**59.41**	**59.56**
F_3- 100 % RDF	**20.44**	**42.28**	**60.01**	**60.36**
F_4- 125 % RDF	**21.41**	**42.91**	**60.70**	**61.02**
S. Em. (±)	**0.38**	**0.56**	**0.229**	**0.22**
C.D. at 5%	**1.11**	**1.66**	**0.71**	**0.68**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**0.76**	**1.13**	**0.42**	**0.41**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means				
S. Em (±)	**0.868**	**1.17**	**0.37**	**0.41**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
General mean	**19.02**	**41.47**	**59.89**	**60.08**

4.1.3 Number of Leaves Plant^{-1}

Leaves serve as the chief food-producing organ in most of the plants. The leaves considered as the most important life giving organ of the plant body. The carbohydrate which is produced in the leaves due to the process of photosynthesis sustains animal life directly and indirectly.

The data with respect of mean number of functional leaves plant^{-1} as influenced by different black gram cultivars and fertilizer levels are presented in Table 4.3 and graphically depicted in Fig. 4.2. From the data, it was quite clear that the mean number of functional leaves plant^{-1} of black gram cultivars was found to be increased with the advancement in crop stages from 30 days. The mean number of functional leaves of black gram cultivars plant^{-1} was 12.84, 23.42, 40.39 and 36.72 at 30, 45, 60 DAS and at harvest respectively.

Response of black gram cultivars

The number of functional leaves plant^{-1} in black gram cultivars was influenced significantly at all crop growth stages. Black gram cultivar PDKV black gold (C_2) produced significantly maximum number of leaves plant^{-1} than the rest of cultivars PU-609-43, AKU-15 and TPU-4 at 30, 45, 60 DAS and at harvest and it was at par with PU-609-43 at 30, 45, 60 DAS and at harvest also with AKU-15 at 30 DAS. TPU-4 had lowest functional leaves plant^{-1} as compared to the other three cultivars at all the growth stages. Similar results was recorded by Jadhav *et al.* (2014).

Effect of fertilizer levels

The number of functional leaves plant^{-1} of black gram cultivars were influenced significantly due to different fertilizer levels during all growth stages of crop.The application of different RDF level to black gold (C_2) cultivars significantly increased the number of leaves plant^{-1}. Significantly maximum number of leaves plant^{-1} (14.60, 24.66, 43.06 and 40.77) at 30, 45, 60 and at harvest, respectively were recorded by 125 % (F_4) of RDF ha^{-1} than the other levels of fertilizer, however, it was at par with the application of 100 % (F_3) of RDF ha^{-1}. This might be due to increased nitrogen levels had increased the functional leaves plant^{-1} to increase meristematic activities associated with protein synthesis which help to promotes cell division and cell elongation that in turn to accelerates vegetative growth of black gram. Increase in number of functional leaves plant^{-1} in black gram with the application of fertilizer was also reported by Singh *et al*., (2005) and Singh *et al*., (2010).

Interaction

The interaction effect between black gram cultivar and fertilizer levels on the number of leaves plant^{-1} was found to be non-significant.

Table 4.3 Periodical number of leaves of black gram as influenced by different treatment

Treatment	Number of leaves plant^{-1}			
	30 DAS	45 DAS	60 DAS	At harvest
Main plot: Cultivars – C				
C_1- TPU-4	**11.16**	**21.03**	**39.07**	**34.14**
C_2- PDKV Black gold	**13.68**	**25.54**	**41.69**	**38.95**
C_3-AKU-15	**13.11**	**22.06**	**39.25**	**35.15**
C_4-PU-609-43	**13.39**	**25.05**	**40.57**	**37.95**
S. Em. (±)	**0.28**	**0.35**	**0.47**	**0.98**
C.D. at 5 %	**0.95**	**1.21**	**1.63**	**3.39**
Sub plot: Fertilizer levels - F				
F_1-Control	**11.14**	**22.49**	**37.71**	**32.68**
F_2-75 % RDF	**11.58**	**22.95**	**38.76**	**34.85**
F_3-100 % RDF	**14.03**	**23.58**	**42.05**	**38.65**
F_4-125 % RDF	**14.60**	**24.66**	**43.06**	**40.77**
S. Em. (±)	**0.33**	**0.39**	**0.52**	**0.73**
C.D. at 5%	**0.97**	**1.14**	**1.53**	**2.14**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**0.67**	**0.78**	**1.05**	**1.46**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means				
S. Em. (±)	**0.64**	**0.76**	**1.02**	**1.60**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
General mean	**12.84**	**23.42**	**40.39**	**36.72**

4.1.4 Leaf Area

Data in respect of mean leaf area of black gram cultivars as influenced by different fertilizer levels are presented in Table 4.4 and graphically depicted in Fig. 4.3. The mean leaf area at 30, 45, 60 DAS and at harvest was 25.84, 34.74, 34.94 and 34.48 dm^2 respectively.

Response of black gram cultivars

Leaf area vary significantly according to the cultivar, among the four black gram cultivars PDKV- black gold (C_2) recorded maximum leaf area at 30, 45, 60 and at harvest than the rest of cultivars PU-609-43, AKU-15 and TPU-4 and it was at par with PU-609-43 at 30, 45, 60 DAS and at harvest also with AKU-15 at 30 DAS. TPU-4 (C_1) had lowest

leaf area as compared to the other three cultivars at all the growth stages. Similar results was recorded by Jadhav *et al.* (2014) and Ahmad *et al*. (2003).

Effect of fertilizer levels

Among fertilizer levels, the three fertilizer levels *viz*., 75 % RDF, 100 % RDF and 125 % RDF recorded significantly higher leaf area over control. However, fertilizer level (F_4) 125 % RDF recorded significantly higher leaf area 26.77, 35.75, 35.85 and 35.61 dm^2 at 30, 45, 60 and at harvest however it was at par with 100 % RDF (F_3) level at all growth stages. Whereas significantly lower leaf area was recorded by F_1-control treatment at all the growth stages of black gram. Availability of more nutrients might have helped for cell elongation and multiplication, which produced a greater number of leaves and the resultant increased leaf area (Kulsum *et al*. 2007).

Interaction

The interaction effect between black gram cultivars and fertilizer levels on leaf area $plant^{-1}$ was found to be non-significant.

Table 4.4. Periodical leaf area of black gram as influenced by different treatment

Treatment	Leaf area $plant^{-1}$ (dm^2)			
	30 DAS	45 DAS	60 DAS	At harvest
Main plot: Cultivars – C				
C_1- TPU-4	**23.84**	**32.92**	**33.12**	**32.54**
C_2- PDKV Black gold	**26.79**	**36.04**	**36.13**	**35.92**
C_3-AKU-15	**26.07**	**34.14**	**34.40**	**34.13**
C_4-PU-609-43	**26.64**	**35.88**	**36.10**	**35.32**
S. Em. (±)	**0.45**	**0.33**	**0.319**	**0.358**
C.D. at 5 %	**1.57**	**1.14**	**1.10**	**1.24**
Sub plot: Fertilizer levels - F				
F_1-Control	**24.90**	**33.56**	**33.81**	**32.82**
F_2-75 % RDF	**25.37**	**34.32**	**34.27**	**34.15**
F_3-100 % RDF	**26.31**	**35.34**	**35.62**	**35.24**
F_4-125 % RDF	**26.77**	**35.75**	**35.85**	**35.61**
S. Em. (±)	**0.328**	**0.39**	**0.50**	**0.39**
C.D. at 5%	**0.95**	**1.15**	**1.48**	**1.15**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**0.657**	**0.73**	**1.01**	**0.79**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means				
S. Em (±)	**0.728**	**0.760**	**0.935**	**0.77**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**
General mean	**25.84**	**34.74**	**34.94**	**34.48**

4.1.5 Number of Root Nodule

Data related to mean number of root nodule of black gram cultivars as influenced by different fertilizer levels are presented in Table 4.5 and graphically depicted in Fig. 4.4. The mean number of root nodule at 30, 45 and 60 DAS was 12.54, 22.12 and 14.62 respectively.

Response of black gram cultivars

Number of root nodule vary significantly according to the cultivar, among the four black gram cultivars PDKV- black gold (C_2) observed significantly maximum root nodule (13.81,23.01,and 15.63) than the rest of cultivars at 30, 45 and 60 days and it was at par with PU-609-43. TPU-4 had lowest root nodule as compared to the other three cultivars (PDKV black gold, PU-609-43 and AKU-15) at all the growth stages.

Table 4.5. Periodical number of root nodule of black gram as influenced by different treatment

Treatment	Number of root nodules		
	30 DAS	45 DAS	60 DAS
Main plot: Cultivars – C			
C_1- TPU-4	**10.88**	**20.65**	**12.90**
C_2- PDKV Black gold	**13.81**	**23.01**	**15.63**
C_3-AKU-15	**12.45**	**21.95**	**14.65**
C_4-PU-609-43	**12.82**	**22.88**	**15.30**
S. Em. (±)	**0.38**	**0.21**	**0.16**
C.D. at 5 %	**1.33**	**0.75**	**0.55**
Sub plot: Fertilizer levels - F			
F_1- Control	**11.27**	**20.91**	**13.58**
F_2- 75 % RDF	**11.87**	**21.39**	**14.10**
F_3- 100 % RDF	**13.06**	**22.62**	**15.17**
F_4- 125 % RDF	**13.98**	**23.56**	**15.63**
S. Em. (±)	**0.35**	**0.35**	**0.19**
C.D. at 5%	**1.03**	**1.03**	**0.57**
Interaction (C × F)			
Between two subplot means at the same level of main plot means			
S. Em. (±)	**0.70**	**0.71**	**0.39**
C.D. at 5%	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means			
S. Em. (±)	**0.72**	**0.65**	**0.38**
C.D. at 5%	**NS**	**NS**	**NS**
General mean	**12.54**	**22.12**	**14.62**

Effect of fertilizer levels

Fertilizer level significantly influenced root nodule of black gram crop. Fertilizer level of 125 % RDF (F_4) produced significantly higher number of root nodule (13.98,

23.56 and 15.63) at 30, 45 and 60 DAS, however it was at par with 100 % RDF (F_3) at all growth stages. Similarly control (F_1) treatment recorded significantly lower number of root nodule at all crop growth stages of black gram. Increased fertilizer level influenced better root development and plant vigour which has enhanced the nitrogen fixing power of the plant by increasing the activity of nodulating bacteria and resulting in more number of root nodules plant^{-1}.These results are in conformity with Hussain *et al*. (2011).

Interaction

The interaction effect between black gram cultivar and fertilizer levels on number of root nodule was found to be non-significant.

4.1.6 Mean Dry Matter Plant^{-1} (g)

The data on mean dry matter accumulation plant^{-1} during various growth stages are presented in Table 4.6 and graphically depicted in Fig. 4.5. The mean dry matter accumulation plant^{-1} recorded at 30, 45, 60 DAS and at harvest was 1.05, 10.67, 15.23 and 20.41 (g), respectively.

Response of black gram cultivars

Dry matter plant^{-1} vary significantly according to the cultivars, among the four black gram cultivars PDKV- black gold (C_2) observed maximum dry matter plant^{-1} than the rest of cultivars PU-609-43, AKU-15 and TPU-4 at 30, 45,60 days and at harvest and it was at par with PU-609-43 (C_4). TPU-4 (C_1) had significantly lowest dry matter plant^{-1} as compared to the other three cultivars at all the growth stages. This might be due to higher biomass potential of the cultivar. Similar results was recorded by Jadhav *et al.,* (2014).

Effect of fertilizer levels

Mean dry matter accumulation plant^{-1} was influenced significantly due to different fertilizer levels during various crop growth stages. Significantly maximum dry matter accumulation plant^{-1} was recorded by 125 % RDF (F_4) treatment (1.37, 11.56, 15.88,and 20.46 (g) at 30, 45, 60 DAS and at harvest, which was significantly superior over the rest of treatment during all growth stages, however it was at par with treatment 100 % RDF (F_3) among different fertilizer levels. Treatment control (F_1) recorded the significantly lowest dry matter accumulation plant^{-1} at all the days of observation. Similar result was also reported by Yakadri *et al*., 2002 and Patel *et al.* 2017.

Interaction

The interaction effect between cultivar and fertilizer levels on dry matter plant^{-1} was found to be non-significant.

Table 4.6. Periodical dry matter plant^{-1} of black gram as influenced by different treatment

Treatment	Dry matter plant^{-1} (g)			
	30 DAS	45 DAS	60 DAS	At harvest
Main plot: Cultivars – C				
C_1- TPU-4	**1.00**	**9.78**	**14.88**	**18.82**
C_2- PDKV Black gold	**1.08**	**11.48**	**15.61**	**20.75**
C_3-AKU-15	**1.06**	**10.15**	**14.90**	**19.03**
C_4-PU-609-43	**1.07**	**11.26**	**15.52**	**20.09**
S. Em. (±)	**0.11**	**0.21**	**0.18**	**0.21**
C.D. @ 5 %	**NS**	**0.75**	**0.62**	**0.73**
Sub plot: Fertilizer levels - F				
F_1- Control	**0.72**	**9.63**	**14.43**	**18.83**
F_2- 75 % RDF	**1.02**	**10.28**	**14.91**	**19.43**
F_3- 100 % RDF	**1.11**	**11.21**	**15.45**	**19.96**
F_4- 125 % RDF	**1.37**	**11.56**	**15.88**	**20.46**
S. Em. (±)	**0.09**	**0.16**	**0.62**	**0.30**
C.D. at 5 %	**0.29**	**0.47**	**0.45**	**0.88**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**0.03**	**0.32**	**0.31**	**0.60**
C.D. at 5 %	**NS**	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means				
S. Em. (±)	**0.30**	**0.35**	**0.33**	**0.56**
C.D. at 5 %	**NS**	**NS**	**NS**	**NS**
General mean	**1.05**	**10.67**	**15.23**	**20.41**

4.1.7 Chlorophyll Content

The data on mean total chlorophyll content as influenced by different fertilizer levels recorded at flowering stage are presented in Table 4.7 and graphically depicted in Fig. 4.6. The mean chlorophyll content at flowering was 44.27 mg g^{-1}.

Response of black gram cultivars

The chlorophyll content was estimated at flowering stage of black gram crop. Among the cultivars, (C_2) PDKV black gold (46.37 mg g^{-1}) recorded significantly higher chlorophyll content as compare to other cultivars, and it was at par with (C_4) PU-609-43 black gram cultivars. Cultivar TPU-4 recorded lower (41.71 mg g^{-1}) chlorophyll content.

Effect of fertilizer levels

There were significant differences observed among all the fertilizer levels. It could be seen from the data presented in Table 4.7 that the chlorophyll content of black gram found significantly higher in (F_4) 125 % RDF (46.84 mg g^{-1}) and it was at par with (F_3) 100 % RDF (45.61 mg g^{-1}) However, lower chlorophyll content at flowering of black gram

was recorded in F_1 (absolute control) treatment. Similar findings were also reported by Sritharan *et al*. (2015) in black gram.

Interaction

The interaction effect between black gram cultivars and fertilizer levels on chlorophyll content at flowering was found to be non-significant.

Table 4.7 Chlorophyll content at flowering, protein content and protein yield of black gram as influenced by different treatment

Treatment	Chlorophyll content at flowering (mg g^{-1})	Protein content (%)	Protein yield (kg ha^{-1})
Main plot: Cultivars – C			
C_1- TPU-4	**41.71**	**20.50**	**195.27**
C_2- PDKV Black gold	**46.37**	**24.00**	**367.62**
C_3-AKU-15	**43.02**	**21.77**	**239.83**
C_4-PU-609-43	**45.98**	**23.03**	**342.77**
S. Em. (±)	**0.40**	**0.47**	**10.45**
C.D. AT 5 %	**1.39**	**1.64**	**36.18**
Sub plot: Fertilizer levels - F			
F_1- Control	**41.69**	**20.75**	**241.21**
F_2- 75 % RDF	**42.94**	**21.81**	**274.89**
F_3- 00 % RDF	**45.61**	**22.87**	**304.80**
F_4- 125 % RDF	**46.84**	**23.86**	**324.59**
S. Em. (±)	**0.60**	**0.34**	**7.93**
C.D. at 5%	**1.71**	**0.10**	**23.14**
Interaction (C × F)			
Between two subplot means at the same level of main plot means			
S. Em. (±)	**1.20**	**0.68**	**15.86**
C.D. at 5%	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means			
S. Em. (±)	**1.12**	**0.76**	**17.26**
C.D. at 5%	**NS**	**NS**	**NS**
General mean	**44.27**	**22.32**	**286.37**

4.1.8 Protein Content and Protein Yield

The data on mean protein content in grain (%) of black gram was found significantly different by the effect of cultivar and fertilizer levels are presented in Table 4.7 and graphically depicted in Fig. 4.7 The mean percent protein content in black gram grain was 22.32.

Response of black gram cultivars

Protein content in black gram grain (%) and protein yield (kg ha^{-1}) was found significantly higher in cultivar (C_2) PDKV black gold 24 % and 367.62 kg ha^{-1}

respectively than rest of the cultivars, However it was at par with (C_4) PU-609-43 in respect of protein yield and protein content. The lowest protein content (20.50 %) and protein yield (195.27 kg ha^{-1}) was observed in (C_1) TPU-4 cultivar. This result is in conformity with Kurle *et al.* (2022).

Effect of fertilizer cultivars

The results revealed that the mean protein content in black gram grain (%) and protein yield was also vary significantly by different fertilizer levels. The 125 % RDF (F_4) recorded maximum protein content and protein yield (23.86 % and 324.59 kg ha^{-1}) respectively, However it was at par with protein yield (F_3) 100 % RDF (304.80 kg ha^{-1}). Similarly significantly lower protein content (%) and protein yield 20.75 % and 241.21 kg ha^{-1} was recorded by (F_1) control treatment.

Interaction

The interaction effect between black gram cultivar and fertilizer levels on protein content and protein yield was found to be non-significant.

4.2 Yield Study

In this experiment, not only the growth parameters but also different yield attributes have been witnessed to be affected by different black gram cultivar and fertilizer levels.

The data furnished in Table 4.8 and graphically depicted in Fig. 4.8 revealed that performance of genotype PDKV black gold (C_2) in respect of yield attributing characters *viz*. number of pods $plant^{-1}$, number of seeds pod^{-1}, pod length, seed yield $plant^{-1}$ and test weight was significantly superior as compared to all other cultivars of black gram. The probable reason for this may be the genetic makeup of the cultivar that has helped in improving the photosynthetic activity due to increased source capacity and efficient translocation of photosynthates to the sink. Similarly, Yadahalli *et al*. (2006) also observed yield differences in black gram cultivars having different genetic makeup.

As regards to fertilizer levels, the yield attributing characters *viz*., pod length, numbers of pods $plant^{-1}$, and seed yield $plant^{-1}$ and test weight were significantly influenced by different treatments of fertilizers. The application of 125 % RDF (F_4) had augmented effect on the yield attributes *viz*., numbers of pods $plant^{-1}$ and seed yield $plant^{-1}$ and found significantly superior over control but at par with 100 % RDF (F_3) treatment. These sorts of favourable effect of fertilizers on yield attributes were noticed by Rathore *et al*. (2010).

4.2.1 Pod Length (cm)

The data related to pod length are presented in Table 4.8 and graphically depicted in Fig. 4.8. The mean pod length was 5.72 cm.

Response of black gram cultivars

The pod length were significantly higher in black gram cultivar PDKV black gold (C_2), having significantly higher pod length (6.17 cm) than the rest of cultivars *viz.,* PU-609-43, AKU-15 and TPU-4 (C_1) and it was at par with PU-609-43 (C_4). TPU-4 had lowest pod length (5.27 cm) as compared to the other three cultivars.

Effect of fertilizer levels

The data observed on mean pod length differed significantly due to different fertilizer levels. Among the fertilizer levels, treatment 125 % RDF (F_4) recorded the highest pod length (6.57 cm) which was significantly superior over the treatment control, however it was found at par with treatment 100 % RDF (F_3). Lowest pod length (4.99 cm) were observed in (F_1) treatment control.

Interaction

The interaction effect between black cultivar and fertilizer levels on pod length yield was found to be non-significant

4.2.2 Number of Pod Plant^{-1}

The data related to number of pod plant^{-1} are presented in Table 4.8 and graphically depicted in Fig. 4.8. The mean of number of grains pod^{-1} was 28.73 plant^{-1}.

Response of black gram cultivars

The mean number of pods plant^{-1} were significantly higher in black gram cultivar PDKV black gold (C_2), produced significantly maximum number of pods plant^{-1} (30.60) than the rest of cultivars PU-609-43, AKU-15 and TPU-4 and it was at par with PU-609-43 (C_4).Whereas the TPU-4 (C_1) had lowest number of pod plant^{-1} (25.93) as compared to the other three cultivars.

Effect of fertilizer levels

Application of 125 % RDF kg ha^{-1} (F_4) fertilizer level produced significantly (33.00) higher number of pods plant^{-1}. However it was at par with 100 % RDF kg ha^{-1} remained statistically equal and produced significantly higher number of pods plant^{-1} over control. Whereas significantly lower number of pods plants^{-1} was recorded by control (F_1) level. The improvement in the number of pods plant^{-1} might have resulted from the favourable influence of nutrients on the growth attributes efficient and more significant partitioning of metabolites and adequate translocation of photosynthates and nutrients to

developing reproductive structures at higher fertilizer level. Similar result was observed by Rangari *et al*., 2012.

Interaction

The interaction effect between black gram cultivar and fertilizer levels on the number of pod plant^{-1} was found to be non-significant.

4.2.3 Number of Seed Pod^{-1}

The data on mean number of seed pod^{-1} are presented in Table 4.8 and graphically depicted in Fig. 4.8. The mean of number of grains pod^{-1} was 6.91.

Response of black gram cultivars

The number of seed pod^{-1} were significantly higher in black gram cultivar PDKV black gold (C_2) than the rest of black gram cultivars PU-609-43, AKU-15 and TPU-4 and it was at par with PU-609-43 (C_4). TPU-4 (C_1) had lowest seed pod^{-1} (5.98) as compared to the other three cultivars.

Effect of fertilizer levels

The data on mean number of seed pod^{-1} differed significantly due to different RDF levels. Among the RDF levels, treatment 125 % RDF (C_4) recorded the highest number of seed pod^{-1} (7.55), which was significantly superior over rest of treatment, however it was found comparable with treatment 100 % RDF (F_3). Lowest number of seed pod^{-1} (6.12) were observed in treatment control (F_1). Thus, higher uptake of nutrients might have favoured significant increase in number of seed pod^{-1} of black gram. Similar result was also reported by Manpreet *et al*., (2004) and Patel *et al.,* (2017).

Interaction

The interaction effect between black gram cultivars and fertilizer levels on the number of seed pod^{-1} was found to be non-significant.

4.2.4 Weight of Seed Plant^{-1}

The data on seed weight plant^{-1} are presented in Table 4.8. and graphically depicted in Fig. 4.8. The mean seed weight plant^{-1} was 7.23 g.

Response of black gram cultivars

The seed weight plant^{-1} were significantly influenced the different black gram cultivars. The black gram cultivar PDKV black gold (C_2), produced significantly maximum seed weight plant^{-1} (8.04 g) than the rest of the black gram cultivars PU-609-43, AKU-15 and TPU-4 and it was at par with PU-609-43 (C_4). TPU-4 (C_1) had lowest seed weight plant^{-1} (6.23 g) as compared to the other three cultivars.

Effect of fertilizer levels

The data recorded on weight of seed plant^{-1} was differed significantly due to different fertilizer levels. Among the fertilizer levels, treatment 125 % RDF (F_4) recorded the highest seed weight plant^{-1} (7.55 g), which was significantly superior over the rest of treatment, however it was found comparable with treatment 100 % RDF (F_3). Lowest seed weight plant^{-1} (6.85 g) were observed in treatment control (F_1). Thus, higher uptake of nutrients might have favoured significant increase in seed weight plant^{-1} of black gram.

Interaction

The interaction effect between black gram cultivar and fertilizer levels on weight of seed plant^{-1} was found to be non-significant.

Table 4.8. Yield attributes of black gram as influenced by different treatment

Treatment	Pod length (cm)	No. of pod plant^{-1}	No. of seed pod^{-1}	Seed weight plant^{-1} (g)	Test weight (g)
Main plot: Cultivars – C					
C_1- TPU-4	**5.27**	**25.93**	**5.98**	**6.23**	**39.81**
C_2- PDKV Black gold	**6.17**	**30.60**	**8.08**	**8.04**	**42.54**
C_3-AKU-15	**5.43**	**28.80**	**5.99**	**6.71**	**41.55**
C_4-PU-609-43	**6.01**	**29.59**	**7.61**	**7.92**	**42.02**
S. Em. (±)	**0.16**	**0.54**	**0.27**	**0.11**	**0.49**
C.D. at 5 %	**0.56**	**1.87**	**0.93**	**0.33**	**1.70**
Sub plot: Fertilizer levels - F					
F_1- Control	**4.99**	**23.30**	**6.12**	**6.85**	**39.57**
F_2- 75 % RDF	**5.21**	**26.42**	**6.75**	**7.16**	**41.10**
F_3- 100 % RDF	**6.11**	**32.10**	**7.25**	**7.36**	**42.31**
F_4- 125 % RDF	**6.57**	**33.00**	**7.55**	**7.55**	**42.94**
S. Em. (±)	**0.19**	**0.36**	**0.15**	**0.09**	**0.22**
C.D. at 5%	**0.56**	**1.05**	**0.43**	**0.26**	**0.64**
Interaction (C × F)					
Between two subplot means at the same level of main plot means					
S. Em. (±)	**0.38**	**0.71**	**0.30**	**0.17**	**0.44**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means					
S. Em. (±)	**0.37**	**0.82**	**0.37**	**0.18**	**0.62**
C.D. at 5%	**NS**	**NS**	**NS**	**NS**	**NS**
General mean	**5.72**	**28.73**	**6.91**	**7.23**	**41.58**

4.2.5 Test Weight

The data on mean test weight of seeds (g) (1000 grains) are presented in Table 4.8 and graphically depicted in Fig. 4.8. The mean test weight of grains was 41.58 g.

Response of black gram cultivars

The test weight of black gram was influenced significantly due to black gram cultivars. The test weight was significantly higher in black gram cultivar PDKV black gold

(C_2) (42.54 g) significantly maximum test weight than the rest of cultivars PU-609-43, AKU-15 and TPU-4 and it was at par with PU-609-43 (C_4). The black gram cultivar TPU-4 (C_1) had lowest test weight (39.81g) as compared to the other three cultivars.

Effect of fertilizer levels

The data recorded on mean test weight of black gram (g) differed significantly due to different fertilizer levels. Among the fertilizer levels, treatment 125 % RDF (F_4) recorded the highest mean test weight of seeds (g) (42.94), which was significantly superior over the rest of treatment, however it was found comparable with treatment 100 % RDF (F_3). Lowest mean test weight of seed (g) (39.57) were observed in treatment control (F_1). Similar results reported by Mahboob and Asghar (2002), Manpreet *et al*., (2004).

Interaction

The interaction effect between black gram cultivar and fertilizer levels on the mean test weight of seeds (g) (1000 grains) was found to be non-significant.

4.2.6 Seed Yield (kg ha^{-1})

The data on mean seed yield influenced significantly due to black gram cultivars and different fertilizer levels are presented in Table 4.9 and graphically depicted in Fig. 4.9. The mean seed yield was 1269 kg ha^{-1}.

Response of black gram cultivars

The data furnished in Table 4.9 revealed that black gram cultivar PDKV black gold (C_2) recorded significantly higher seed yield (1526 kg ha^{-1}) than other cultivars, However it was at par with black gram cultivar (C_4) PU-609-43. Similarly significantly minimum grain yield was produced by black gram cultivar (C_1) TPU-4 (958.00 kg ha^{-1}) than the rest of black gram cultivars. This increase in seed yield might be due to the higher production efficiency that has been reflected through improvement in different yield attributing characters. These findings are in conformity with the earlier findings reported by Patel *et al*. (1992). Similar, trend was observed in respect of straw yield, biological yield and harvest index.

Higher seed yield could be attributed to favourable changes in physical and chemical characteristics of the soil which might have enabled better pod formation. Moreover, the positive influence of these treatments through immediate supply of fertilizer at the early stage of the crop, which might have improved adequate biomass production and improvement in yield parameters resulting in higher seed yield. Similar results reported by Patel *et al*. (2017).

Effect of fertilizer levels

Seed yield of black gram significantly influenced by different fertilizer levels. The application of 125 % RDF (F_4) recorded the highest seed yield (1351.00 kg ha^{-1}), whereas significantly minimum seed yield was recorded by (F_1) control treatment (1150 kg ha^{-1}) and it was at par with (F_3) 100 % RDF (1317 kg ha^{-1}). The probable reason for this might be the combined effect of nitrogen and phosphorus application which has enhanced the photosynthetic activity and thus helped in food accumulation in seed at maturity and ultimately resulted in better seed formation and its development. Such increase in seed yield was reported by Bhairappanavar *et al*. (2005).

Table 4.9 Seed, straw, biological yield and harvest index of black gram as influenced by the different treatment

Treatment	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Main plot: Cultivars – C				
C_1- TPU-4	**958**	**1642**	**2600**	**36.85**
C_2- PDKV Black gold	**1526 (59.2%)**	**2497**	**4023**	**37.93**
C_3-AKU-15	**1102 (15 %)**	**1880**	**2982**	**36.95**
C_4-PU-609-43	**1485 (52 %)**	**2440**	**3899**	**37.83**
S. Em. (±)	**19.91**	**40**	**39.74**	**-**
C.D. at 5 %	**68.89**	**139**	**137.5**	**-**
Sub plot: Fertilizer levels - F				
F_1-Control	**1150**	**1960**	**3110**	**36.97**
F_2-75 % RDF	**1253 (8.9 %)**	**2096**	**3341**	**37.26**
F_3-100 % RDF	**1317 (14.5 %)**	**2154**	**3495**	**37.68**
F_4-125 % RDF	**1351 (17.5 %)**	**2228**	**3579**	**37.74**
S. Em. (±)	**14.81**	**27.83**	**33.16**	**-**
C.D. at 5%	**43.24**	**81.2**	**96.79**	**-**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**29.63**	**55.66**	**66.32**	**-**
C.D. at 5%	**86.48**	**NS**	**NS**	**-**
Between two main plot means at the same level of subplot plot means				
S. Em. (±)	**32.47**	**62.78**	**69.85**	**-**
C.D. at 5%	**101.41**	**NS**	**NS**	**-**
General mean	**1269**	**2103**	**3378**	**37.40**

***Figure in the parenthesis indicates the percent increase**

Table 4.9 a. Seed yield of black gram as influenced by different interaction combination between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars				
	C_1- TPU-4	C_2- PDKV black gold	C_3- AKU-15	C_4- PU-609-43	Mean
F_1- Control	922	1360	944	1374	**1150**
F_2- 75 % of RDF	927	1480	1106	1501	**1253**
F_3- 100 % of RDF	976	1622	1162	1509	**1317**
F_4- 125 % of RDF	1006	1643	1196	1557	**1351**
Mean	**958**	**1526**	**1102**	**1485**	**1269**
Between two subplot means at the same level of main plot means					
S. Em. (±)	**29.63**				
C.D. at 5 %	**86.48**				
Between two main means at the same level of sub plot means					
S. Em. (±)	**32.47**				
C.D. at 5 %	**104.41**				

Interaction

The interaction effects between black gram cultivars and fertilizer levels in respect of seed yield kg ha^{-1} were found to be significant. The interaction effect between black gram cultivar PDKV black gold with fertilizer level 125 % of RDF produced significantly higher seed yield (1643 kg ha^{-1}) than other treatment combinations and it was at par with black gram cultivar PDKV black gold with 100 % RDF (1622 kg ha^{-1}) and PU-609-43 with 125 % of RDF (1557 kg ha^{-1}). Similarly, significantly lowest seed yield of black gram was produced by the cultivar TPU-4 in combination of absolute control (922 kg ha^{-1}). Higher seed yield due to more number of pod and seeds pod^{-1}.

4.2.7 Straw Yield

The data on mean straw yield are presented in Table 4.9 and graphically depicted in Fig. 4.9. The mean straw yield was 2103 kg ha^{-1}.

Response of black gram cultivars

The data furnished in Table 4.9 revealed that black gram cultivars (C_2) PDKV black gold (2497 kg ha^{-1}) recorded significantly higher straw yield than other cultivars but it was at par with PU-609-43 cultivar (2440 kg ha^{-1}). However significantly lower yield of straw was produced by the black gram cultivar (C_1) TPU-4 (1642 kg ha^{-1}).

Effect of fertilizer cultivars

Straw yield of black gram were significantly influenced by different fertilizer levels. The treatment (F_4) application of 125 % RDF (2228 kg ha^{-1}) recorded the highest

straw yield which was significantly superior over control (1960 kg ha^{-1}) and 75 % RDF (2096 kg ha^{-1}) and 100 % RDF (2154 kg ha^{-1}) but was at par with (F_3) treatment 100 % RDF.

Interaction

The interaction effect between black gram cultivar and fertilizer levels on the straw yield was found to be non-significant.

4.2.8 Biological Yield

The data on mean biological yield are presented in Table 4.9 and graphically depicted in Fig. 4.9. The mean biological yield was 3378 kg ha^{-1}.

Response of black gram cultivars

The data furnished in Table 4.9 revealed that black gram cultivars (C_2) PDKV black gold (4023 kg ha^{-1}) recorded significantly higher biological yield than other cultivars. The higher biological yield of PDKV black gram might be due to accumulation of more dry matter and higher biomass potential. However it was at par with black gram cultivar (C_4) PU-609-43. Similarly significantly lower biological yield of black gram was registered by cultivars (C_1) TPU-4 (2571 kg ha^{-1}).

Effect of fertilizer levels

Biological yield of black gram cultivars were significantly influenced by different fertilizer levels. The application of 125 % RDF (F_4) recorded the highest biological yield (3579 kg ha^{-1}) which was significantly superior over control and 75 % RDF and 100 % RDF but was at par with 100 % RDF (F_3). Whereas significantly minimum biological yield of black gram were produced by the fertilizer level (F_1) control treatment (3110 kg ha^{-1}).

Interaction

The interaction effect between black gram cultivar and fertilizer levels on the biological yield was found to be non-significant at all treatment combination interaction.

4.2.9 Harvest Index

The data on mean harvest index influenced significantly due to different black gram cultivars and fertilizer levels are presented in Table 4.9. The mean harvest index was 37.41.

Response of black gram cultivars

The data furnished in Table 4.9 revealed that black gram cultivars PDKV black gold recorded numerically higher harvest index (37.93), followed by black gram cultivars (C_4) PU-609-43, (C_3) AKU-15 and (C_1) Minimum harvest index observed in TPU-4 cultivar (36.92).

Effect of fertilizer levels

Harvest index of black gram cultivars were significantly influenced by different fertilizer levels. The (F_4) treatment application of 125 % RDF (37.74) recorded the highest harvest which was numerically higher over control, 75 % RDF and 100 % RDF, Whereas numerically minimum values of harvest index (%) was recorded by (F_1) control treatment (36.97 %). The higher growth and yield contributing character results in increase of economic as well as biological yield which helpful for obtaining higher value of harvest index. The similar result was observed by Kumar and Elamathi (2007).

4.3 Nutrient Uptake

4.3.1 Nutrient Uptake by Seed

Data pertaining to the nutrient uptake by seed of black gram are presented in Table 4.10. The mean uptake of nitrogen, phosphorous and potassium by seed was 49.65, 6.11 and 15.78 kg ha^{-1} respectively.

Response of black gram cultivars

The uptake of N, P and K was significantly influenced by different cultivars. Significantly higher uptake of N, P and K were recorded with cultivar (C_2) PDKV black gold 57.31, 7.60, 16.49 kg ha^{-1} respectively than rest of the cultivars, and it was at par with (C_4) PU-609-43, Whereas lowest uptake observed in TPU-4 *viz*., 40.37, 4.25, 14.45 N, P and K kg ha^{-1} respectively. The higher nutrient uptake by seed is attributed due to the high dose fertilizer which increase availability and also due to genetic character of cultivars. This finding is in conformity with Rathod and Gawande (2014)

Effect of fertilizer levels

The application of fertilizers increases the nutrient concentration in soil solution. Therefore, higher application of fertilizer increases the nutrient uptake. The uptake of N, P and K were significantly influenced by different fertilizer levels. The application of 125 % RDF (F_4) treatment recorded the highest nutrient uptake 52.73, 7.09, 16.66 kg ha^{-1} respectively which was significantly superior over control and 75 % RDF and it was at par with 100 % RDF (51.94, 6.90, 16.41 N, P and K kg ha^{-1} respectively.

Interaction

The interaction effects between black gram cultivars and fertilizer levels in respect of nutrient uptake by seed of cultivars were found to be significant. The interaction effect between black gram cultivar PDKV black gold (C_2) and fertilizer level 125 % of RDF(F_4) produced significantly higher N, P and K uptake 59.35, 8.45, and 17.77 kg ha^{-1} respectively than other treatment combinations and it was at par with PU-609-43 and 125 % of RDF (57.73, 8.20 and 16.84 kg ha^{-1}) respectively.

Table 4.10. Nitrogen, phosphorous and potassium uptake of black gram as influenced by different treatment

Treatment	N Uptake (kg ha^{-1})			P Uptake (kg ha^{-1})			K Uptake (kg ha^{-1})		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
Main plot: Cultivars – C									
C_1- TPU-4	**40.37**	**9.64**	**50.01**	**4.25**	**1.73**	**6.05**	**14.45**	**23.06**	**37.51**
C_2- PDKV Black gold	**57.31**	**13.63**	**70.93**	**7.60**	**3.18**	**10.86**	**16.49**	**28.74**	**45.24**
C_3-AKU-15	**45.32**	**13.40**	**58.72**	**5.25**	**1.94**	**7.19**	**15.94**	**26.65**	**42.59**
C_4-PU-609-43	**55.60**	**13.02**	**68.61**	**7.36**	**2.90**	**10.37**	**16.23**	**28.23**	**44.46**
S. Em. (±)	**0.58**	**0.33**	**0.81**	**0.07**	**0.13**	**0.18**	**0.14**	**0.30**	**0.28**
C.D. at 5 %	**2.03**	**1.14**	**2.81**	**0.26**	**0.44**	**0.63**	**0.47**	**1.03**	**1.01**
Sub plot: Fertilizer levels - F									
F_1-Control	**45.19**	**9.93**	**55.12**	**4.78**	**1.86**	**6.72**	**14.66**	**25.33**	**39.99**
F_2-75 % RDF	**48.75**	**11.76**	**60.51**	**5.68**	**2.26**	**7.95**	**15.37**	**25.98**	**41.35**
F_3-100 % RDF	**51.94**	**13.69**	**65.62**	**6.90**	**2.60**	**9.79**	**16.41**	**27.17**	**43.58**
F_4-125 % RDF	**52.73**	**14.30**	**67.02**	**7.09**	**3.02**	**10.12**	**16.66**	**28.21**	**44.87**
S. Em. (±)	**0.28**	**0.24**	**0.92**	**0.08**	**0.16**	**0.13**	**0.09**	**0.45**	**0.48**
C.D. at 5%	**0.82**	**0.70**	**2.68**	**0.23**	**0.46**	**0.39**	**0.29**	**1.31**	**1.41**
Interaction (C × F)									
Between two subplot means at the same level of main plot means									
S. Em. (±)	**0.56**	**0.24**	**1.84**	**0.16**	**0.31**	**0.27**	**0.20**	**0.89**	**0.97**
C.D. at 5%	**1.66**	**NS**	**NS**	**0.46**	**NS**	**NS**	**0.581**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means									
S. Em. (±)	**0.76**	**0.53**	**1.79**	**0.15**	**0.32**	**0.29**	**0.22**	**0.82**	**0.88**
C.D. at 5%	**2.48**	**NS**	**NS**	**0.48**	**NS**	**NS**	**0.69**	**NS**	**NS**
General mean	**49.65**	**12.42**	**62.07**	**6.11**	**2.44**	**8.64**	**15.78**	**26.67**	**42.45**

Table 4.10 a. N uptake of black gram as influenced by different interaction combination between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars				
	C_1- TPU-4	C_2- PDKV black gold	C_3- AKU-15	C_4- PU-609-43	Mean
F_1- Control	36.68	55.54	36.05	52.47	**45.19**
F_2- 75 % of RDF	39.54	56.33	44.31	54.82	**48.75**
F_3- 100 % of RDF	42.60	58.00	49.78	57.37	**51.94**
F_4- 125 % of RDF	42.67	59.35	51.15	57.73	**52.73**
Mean	**40.37**	**57.31**	**45.32**	**55.60**	**49.65**
Between two subplot means at the same level of main plot means					
S. Em. (±)	**0.56**				
C.D. at 5 %	**1.66**				
Between two main means at the same level of sub plot means					
S. Em. (±)	**0.76**				
C.D. at 5 %	**2.48**				

Table 4.10 b. P uptake of black gram as influenced by different interaction combination between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars

	C_1- TPU-4	C_2- PDKV black gold	C_3- AKU-15	C_4- PU-609-43	Mean
F_1- Control	3.11	6.37	3.67	5.97	**4.78**
F_2- 75 % of RDF	3.67	7.40	4.50	7.17	**5.68**
F_3- 100 % of RDF	5.10	8.17	6.23	8.10	**6.90**
F_4- 125 % of RDF	5.13	8.45	6.59	8.20	**7.09**
Mean	**4.25**	**7.60**	**5.25**	**7.36**	**6.11**
Between two subplot means at the same level of main plot means					
S. Em. (±)	**0.16**				
C.D. at 5 %	**0.46**				
Between two main means at the same level of sub plot means					
S. Em. (±)	**0.15**				
C.D. at 5 %	**0.48**				

Table 4.10 c. K uptake of black gram as influenced by different interaction combination between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars				
	C_1- TPU-4	C_2- PDKV black gold	C_3- AKU-15	C_4- PU-609-43	Mean
F_1- Control	13.50	14.91	15.27	14.97	**14.66**
F_2- 75 % of RDF	13.93	15.68	15.66	16.20	**15.37**
F_3- 100 % of RDF	15.07	17.62	16.17	16.80	**16.41**
F_4- 125 % of RDF	15.30	17.77	16.64	16.84	**16.66**
Mean	**14.45**	**16.49**	**15.94**	**16.23**	**15.78**
Between two subplot means at the same level of main plot means					
S. Em. (±)	**0.19**				
C.D. at 5 %	**0.58**				
Between two main means at the same level of sub plot means					
S. Em. (±)	**0.22**				
C.D. at 5 %	**0.69**				

4.3.2 Nutrient Uptake by Straw

Data pertaining to the nutrient uptake by straw of black gram as influenced by black gram cultivars and different fertilizer levels are presented in Table 4.10. The mean uptake of nitrogen, phosphorous and potassium by straw was 12.42, 2.44 and 26.67 kg ha^{-1} respectively.

Response of black gram cultivars

The nutrient uptake by straw of black gram cultivar was significantly influenced due to different cultivars. Maximum uptake of N, P and K was recorded by cultivar PDKV black gram (13.63, 3.18 and 28.74 kg ha^{-1} N, P and K) respectively and it was at par with of PU-609-43 (C_4). Similarly, significantly lower uptake was recorded by TPU-4 (9.64, 1.73 and 23.06 kg ha^{-1}) N, P and K respectively.

Effect of fertilizers levels

Higher application of nitrogen fertilizer increases the nutrient uptake. The application of 125 % RDF (F_4) showed significantly higher total nitrogen, phosphorous and potassium uptake by straw 14.30, 3.02 and 28.21 kg ha^{-1} respectively followed by (F_3) 100 % of RDF ha^{-1} (13.69, 2.60 and 27.17 kg ha^{-1}) respectively. The significantly lowest uptake of nutrients were recorded by absolute control (F_1) treatment (9.93, 1.86 and 25.33 kg ha^{-1}) respectively.

Interaction

The interaction effect between black gram cultivar and fertilizer levels on nutrient uptake by straw was found to be non-significant.

4.3.3 Total Uptake of Nutrient

Data pertaining to the total nutrient uptake of black gram are presented in Table 4.10 and graphically depicted in Fig. 4.10. The mean total uptake of nitrogen, phosphorous and potassium was 62.07, 8.64 and 42.45 kg ha^{-1} respectively.

Response of black gram cultivars

The total uptake of N, P and K was significantly influenced by different cultivars. Significantly higher uptake of N, P and K were recorded with cultivar (C_2) PDKV Black gold. 70.93, 10.86 and 45.24 kg ha^{-1} respectively than rest of the cultivars and it was at par with black gram cultivars (C_4). Similarly significantly minimum uptake of N, P, and K was registered by black gram cultivars (C_1) TPU-4.

Effect of fertilizer levels

Total uptake of N, P and K were significantly influenced by different fertilizer levels. The application of 125 % RDF (F_4) recorded the highest nutrient uptake 67.02, 10.12 and 44.87 kg ha^{-1} respectively which was significantly superior over control and 75 % RDF and it was at par with 100 % RDF, Whereas minimum value of nutrient uptake was registered by the treatment control (F_1) 55.12, 6.72 and 39.99 kg ha^{-1} of N, P and K. This might be due to increased availability of nutrients by higher doses of fertilizer. Higher nitrate nitrogen content with increasing nitrogen application was also due to more uptake of nitrogen in the form of nitrate by plant also due to synergetic effect of phosphorous on other mineral nutrient including nitrogen. This finding is in conformity with Rajendar *et al*. (2003).

Interaction

The interaction effect between black gram cultivars and fertilizer levels on total nutrient uptake was found to be non-significant.

Table 4.11 Soil chemical properties as influenced by different treatment after harvest of black gram

Treatment	pH	EC (dSm^{-1})	Organic Carbon (%)
Main plot: Cultivars – C			
C_1- TPU-4	**8.22**	**0.46**	**0.58**
C_2- PDKV Black gold	**8.35**	**0.48**	**0.56**
C_3-AKU-15	**8.29**	**0.47**	**0.54**
C_4-PU-609-43	**8.31**	**0.48**	**0.57**
S.E m(±)	**0.02**	**0.003**	**0.002**
C.D. at 5 %	**0.07**	**0.011**	**0.005**
Sub plot: Fertilizer levels - F			
F_1 -Absolute control	**8.07**	**0.46**	**0.53**
F_2 -75 % RDF	**8.26**	**0.47**	**0.55**
F_3 -100 % RDF	**8.40**	**0.48**	**0.56**
F_4 -125 % RDF	**8.44**	**0.49**	**0.56**
S.E m(±)	**0.023**	**0.003**	**0.002**
C.D. at 5 %	**0.06**	**0.01**	**0.007**
Interaction (C × F)			
Between two subplot means at the same level of main plot means			
S.E m(±)	**0.05**	**0.007**	**0.004**
C.D. at 5 %	**NS**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means			
S.E m(±)	**0.04**	**0.01**	**0.004**
C.D. at 5 %	**NS**	**NS**	**NS**
General mean	**8.29**	**0.47**	**0.56**
Initial status	**8.31**	**0.44**	**0.53**

4.4 Soil Chemical Properties

The soil chemical properties were assessed in terms of soil pH, EC and organic carbon content after harvest of black gram as influenced by different cultivars and fertilizer levels are presented in Table 4.11. The mean initial value of soil pH, electrical conductivity and organic carbon content before start of experiment were 8.31, 0.44 dSm^{-1} and 0.53%, respectively. While the mean value of soil pH, electrical conductivity and organic carbon after harvest were 8.29, 0.47 dSm^{-1} and 0.56% respectively.

Response of black gram cultivars

Among the different black gram cultivars PDKV black gold showed higher pH, EC (8.35, 0.48 dsm^{-1}) and TPU-4 has showed highest OC (0.58 %) respectively than other black gram cultivars. Whereas, TPU-4 showed lowest pH, EC 8.22, 0.46 dsm^{-1} respectively and cultivar AKU- 15 showed lowest OC (0.54 %)

Effect of fertilizer levels

Among the different fertilizer levels under experimentation, application of 125 % RDF (F_4) showed higher pH, EC and OC (8.44, 0.49 dsm^{-1}, 0.56%), respectively and it was at par with application of 100 % RDF in respect pH, EC, and OC (8.40, 0.48 dsm^{-1}, 0.56 %), respectively. The absolute control treatment (F_1) registered significantly lower values of pH, EC, and OC (8.07, 0.46 dsm^{-1}, 0.53 %), respectively.

Interaction

The interaction effect of black gram cultivar and fertilizer levels was found non-significant in respect of soil properties like pH, electrical conductivity and organic carbon content of soil under study.

4.5 Soil Available Nutrients

The residual soil fertility after harvest of black gram with respect available nitrogen, phosphorus and potassium as influenced by different treatments are presented in Table 4.12 and graphically depicted in Fig. 4.11. The mean soil available nitrogen, phosphorus and potassium were 167.04, 17.82 and 367.68 kg ha^{-1} respectively.

Response of black gram cultivars

The residual soil fertility in respect of nitrogen at the end of experimentation of black gram was significantly higher in cultivar AKU-15 (174.68 kg ha^{-1}) and it was at par with PU-609-43 (166.28 kg ha^{-1}) and PDKV black gold (165.98 kg ha^{-1}) in case of phosphorous cultivar PU-609-43 (20.62 kg ha^{-1}) observed significantly maximum available phosphorous and (C_2) PDKV black gold found at par (20.60 kg ha^{-1}) Significantly maximum soil available potassium was registered by PDKV black gold (373.27 kg ha^{-1}) followed by PU-609-43 and AKU-15. Black gram cultivar TPU-4 recorded significantly lowest residual soil fertility of nitrogen, phosphorus and potassium (161.19, 14.91 kg ha^{-1} and 355.94 kg ha^{-1}) respectively than other black gram cultivars.

Effect of fertilizer levels

The residual nitrogen, phosphorus and potassium in the soil were differed significantly due to different treatments of RDF levels. Among the different RDF levels, an application of 125 % of RDF (F_4) showed significantly higher residual nitrogen (175.22 kg ha^{-1}), phosphorous (18.80 kg ha^{-1}) and potassium (373.54 kg ha^{-1}) and it was at par with 100 % RDF (F_3) in case of nitrogen, phosphorous and potassium. Whereas, in control treatment (F_1) recorded significantly lower residual nitrogen (158.68 kg ha^{-1}), phosphorous (16.70 kg ha^{-1}) and potassium (360.20 kg ha^{-1}) respectively.

Table 4.12 Soil available nutrient after harvest of black gram

	Soil available nutrient (kg ha^{-1})		
Treatment	**N**	**P**	**K**
Main plot: Cultivars – C			
C_1- TPU-4	**161.19**	**14.91**	**355.94**
C_2- PDKV Black gold	**165.98**	**20.60**	**373.27**
C_3-AKU-15	**174.68**	**15.14**	**369.44**
C_4-PU-609-43	**166.28**	**20.62**	**372.09**
S. Em. (±)	**2.53**	**0.33**	**1.07**
C.D. at 5 %	**8.76**	**1.14**	**3.73**
Sub plot: Fertilizer levels - F			
F_1-Control	**158.68**	**16.70**	**360.26**
F_2-75 % RDF	**164.76**	**17.39**	**364.91**
F_3-100 % RDF	**169.48**	**18.38**	**372.03**
F_4-125 % RDF	**175.22**	**18.80**	**373.54**
S. Em. (±)	**2.09**	**0.21**	**1.08**
C.D. at 5%	**6.01**	**0.62**	**3.17**
Interaction (C × F)			
Between two subplot means at the same level of main plot means			
S. Em. (±)	**4.18**	**0.42**	**2.18**
C.D. at 5%	**12.21**	**NS**	**NS**
Between two main plot means at the same level of subplot plot means			
S. Em. (±)	**4.42**	**0.49**	**2.17**
C.D. at 5%	**13.69**	**NS**	**NS**
General mean	**167.04**	**17.82**	**367.68**
Initial status	**170.56**	**21**	**380.5**

Interaction

The interaction effect of black gram cultivar and fertilizer levels treatment was found non-significant in respect of soil available phosphorous and potassium and in case of nitrogen it was found significant. Interaction combination between cultivar AKU-15 and 125 % RDF (F_4) showed highest available nitrogen (194.67 kg ha^{-1}) and lowest available nitrogen observed in interaction combination involving cultivar TPU-4 and absolute control fertilizer level (157.8 kg ha^{-1}).

Table 4.12 a. Available nitrogen after harvest of black gram as influenced by different interaction combination between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars				
	C_1- TPU-4	C_2- PDKV black gold	C_3- AKU-15	C_4- PU-609-43	Mean
F_1- Control	157.87	160.64	152.63	162.68	**158.68**
F_2- 75 % of RDF	158.57	165.99	172.27	164.20	**164.76**
F_3- 100 % of RDF	164.63	166.47	179.17	167.67	**169.48**
F_4- 125 % of RDF	165.00	170.84	194.67	170.37	**175.22**
Mean	**161.19**	**165.98**	**174.68**	**166.28**	**167.04**
Between two subplot means at the same level of main plot means					
S. Em (±)	**4.18**				
C.D. at 5 %	**12.21**				
Between two main means at the same level of sub plot means					
S. Em (±)	**4.42**				
C.D. at 5 %	**13.69**				

4.6 Economics Study

The economics of black gram cultivars and fertilizer levels in terms of cost of cultivation, gross monetary returns, net monetary returns and B : C ratio are presented in Table 4.13 and graphically depicted in Fig. 4.12.

4.6.1 Cost of Cultivation

The cost of cultivation of black gram cultivars and different fertilizer levels are presented in Table 4.13 and graphically depicted in Fig. 4.12. The prevailing market price and input cost are given in appendix-I. The mean cost of cultivation was ₹ 34699 ha^{-1}.

Response of black gram cultivars

The cost of cultivation was registered by each cultivar was ₹ 34699 ha^{-1}.

Effect of fertilizer levels

Numerically higher cost of cultivation was registered by (F_4) 125 % of RDF (₹ 37830 ha^{-1}) followed by (F_3) 100 % of RDF (₹ 37254 ha^{-1}), (F_2) 75 % of RDF (₹ 36679 ha^{-1}) and minimum cost of cultivation was registered by (F_1) absolute control treatment (₹ 27034 ha^{-1}).

Interaction

The interaction effect between black gram cultivars and different fertilizer levels on cost of cultivation was found non-significant.

4.6.2 Gross Monetary Returns

The gross monetary returns of black gram cultivars and different fertilizer levels are presented in Table 4.13 and graphically depicted in Fig. 4.12. The mean gross monetary return was ₹ 82412 ha^{-1}.

Response of black gram cultivars

The gross monetary return of black gram was significantly influenced by black gram cultivars. The significantly higher gross monetary returns were registered by (C_2) PDKV black gold (₹99195 ha^{-1}) and it was at par with (C_4) PU-609-43 (₹96541 ha^{-1}). Whereas significantly minimum gross monetary returns was recorded by (C_1) cultivar TPU-4 (₹62269 ha^{-1}). The higher seed yield of PDKV black gold cultivars gives maximum gross monetary return compare to other cultivars. This result is in conformity with Kurle *et al.* (2022).

Effect of fertilizer levels.

The gross monetary returns significantly influenced due to different fertilizer levels. The significantly maximum gross monetary returns was produced by the treatment (F_4) application of 125 % of RDF (₹ 87799 ha^{-1}) over the rest of fertilizer levels and it was at par with 100 % (₹ 85610). Similarly, significantly minimum gross monetary returns recorded by absolute control (F_1) treatment (₹ 74761 ha^{-1}). Application of higher dose fertilizer produces maximum seed and biomass yield as results the gross return obtained is higher for 125 % RDF. Similar result observed by Mehdi and Kant (2010).

Interaction

The interaction effect between black gram cultivars and different fertilizer levels on gross monetary return was found significant. The significantly maximum gross monetary returns was recorded by ($C_2 \times F_4$) PDKV black gold with 125 % of RDF (₹ 106816 ha^{-1}) and it was at par with ($C_2 \times F_3$) PDKV black gold with 100 % RDF(₹ 105365 ha^{-1}). Similarly significantly minimum values of gross monetary returns were recorded by all black gram cultivar with absolute control fertilizer treatment.

Table 4.13. Economics of black gram as influenced by different treatment

Treatment	Gross monetory return (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net monetory return (₹ ha^{-1})	B: C Ratio
Main plot: Cultivars – C				
C_1- TPU-4	**62269**	**34699**	**27570**	**1.79**
C_2- PDKV Black gold	**99195**	**34699**	**64496**	**2.86**
C_3-AKU-15	**71641**	**34699**	**36941**	**2.06**
C_4-PU-609-43	**96541**	**34699**	**61842**	**2.78**
S. Em. (±)	**1294**	**-**	**1294**	**-**
C.D. at 5 %	**4477**	**-**	**4477**	**--**
Sub plot: Fertilizer levels - F				
F_1-Control	**74761**	**27034**	**40062**	**2.15**
F_2-75 % RDF	**81477**	**36679**	**46778**	**2.35**
F_3-100 % RDF	**85610**	**37254**	**50911**	**2.47**
F_4-125 % RDF	**87799**	**37830**	**53099**	**2.53**
S. Em. (±)	**962**	**-**	**962**	**-**
C.D. at 5%	**2811**	**-**	**2811**	**-**
Interaction (C × F)				
Between two subplot means at the same level of main plot means				
S. Em. (±)	**1926**	**-**	**1926**	**-**
C.D. at 5%	**5621**	**-**	**5621**	**-**
Between two main plot means at the same level of subplot plot means				
S. Em. (±)	**2111**	**-**	**2111**	**-**
C.D. at 5%	**6591**	**-**	**6591**	**-**
General mean	**82412**	**34699**	**47713**	**2.38**

Table 4.13 a. Gross monetary returns (₹ ha^{-1}) of black gram as influenced by different interaction combinations between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars				
	C_1- TPU-4	**C_2- PDKV black gold**	**C_3- AKU-15**	**C_4- PU-609-43**	**Mean**
F_1- Control	59951	88400	61382	82440	**74761**
F_2- 75 % of RDF	60252	96200	71890	90060	**81477**
F_3- 100 % of RDF	63440	105365	75530	98107	**85610**
F_4- 125 % of RDF	65433	106816	77762	101183	**87799**
Mean	**62269**	**99195**	**71641**	**96541**	**82412**
Between two subplot means at the same level of main plot means					
S.Em. (±)	**1926**				
C.D. at 5 %	**5621**				
Between two main means at the same level of sub plot means					
S.Em. (±)	**2111**				
C.D. at 5 %	**6591**				

Table 4.13b. Net monetary returns (₹ ha^{-1}) of black gram as influenced by different interaction combinations between black gram cultivars and fertilizer levels

Fertilizer levels	Cultivars				
	C_1- TPU-4	**C_2- PDKV black gold**	**C_3- AKU-15**	**C_4- PU-609-43**	**Mean**
F_1- Control	25253	53701	26683	54611	**40062**
F_2- 75 % of RDF	25552	61501	37191	62866	**46778**
F_3- 100 % of RDF	28741	70666	40831	63408	**50911**
F_4- 125 % of RDF	30734	72117	43063	66484	**53000**
Mean	**27570**	**64496**	**36942**	**61842**	**47713**
Between two subplot means at the same level of main plot means					
S. Em. (±)	**1926**				
C.D. at 5 %	**5621**				
Between two main means at the same level of sub plot means					
S. Em. (±)	**2111**				
C.D. at 5 %	**6591**				

4.6.3 Net Monetary Returns

The net monetary returns of black gram cultivars and different RDF levels are presented in Table 4.13 and graphically depicted in Fig. 4.12. The mean net monetary return was ₹ 47713 ha^{-1}.

Response of black gram cultivars

The net monetary returns of black gram cultivars was significantly influenced. The significantly higher net monetary returns was produced by PDKV black gold (₹ 64496 ha^{-1}) and it was at par with PU-609-43 (₹ 61842 ha^{-1}). Similarly, significantly minimum net monetary return was registered by black gram TPU-4 (₹ 27570 ha^{-1}).

Effect of fertilizer levels

The net monetary returns of different fertilizer levels were influenced significantly. The significantly highest net monetary return was associated with (F_4) treatment 125 % of RDF (₹ 53099 ha^{-1}) and is at par with treatment (F_3) 100 % of RDF (₹ 50119 ha^{-1}. Whereas significantly minimum net monetary return was produced by absolute control treatment (₹ 40062 ha^{-1}). Similar results found by Kumawat *et al*. (2013).

Interaction

The interaction effect between black gram cultivars and fertilizer levels was found significant. Higher net monetary return was registered by treatment combination ($C_2 \times F_4$) PDKV black bold with 125 % of RDF and it was at par with ($C_2 \times F_3$) PDKV black gold

with 100 % RDF Similarly, all black gram cultivar with absolute control of nitrogen produced minimum net monetary returns.

4.6.4 B:C Ratio

The B:C ratio of black gram cultivars and fertilizer levels are presented in Table 4.13. The mean B:C ratio was 2.38.

Response of black gram cultivars

The B:C ratio of black gram cultivars is influenced numerically. The higher B:C ratio was registered by (C_2) PDKV black gold (2.86) followed by (C_4) PU-609-43 (2.78), (C_3) AKU-15 (2.06). Similarly numerically minimum B:C ratio was registered with (C_1) TPU-4 (1.79).

Effect of fertilizer levels

The B:C ratio of different levels of fertilizer was influenced numerically. The higher B:C ratio was registered by (F_4) 125 % of RDF (2.53) followed by (F_3) 100 % of RDF (2.47) and (F_2) 75 % of RDF (2.35). Whereas minimum B:C ratio was registered by (F_1) absolute control treatment (2.15).

5. SUMMARY AND CONCLUSION

The present investigation entitled “Response of black gram [*Vigna mungo* (L.)] cultivars to fertilizer levels” was conducted at Post Graduate Institute Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during *kharif,* 2021. The objective of the experiment was to study the effect of fertilizer levels on growth, yield, quality, and economics of black gram cultivars.

The experiment was laid out in a split plot design with three replications and sixteen treatment combinations consisting of 4 black gram cultivars i.e. V_1- TPU-4, V_2- PDKV Black gold, V_3- AKU-15, V_4- PU-609-43 and 4 fertilizer levels i.e. F_1- Absolute control, F_2-75 % of RDF, F_3- 100 % of RDF, and F_4- 125 % of RDF.

The soil of experimental field was clay in texture, low in available nitrogen (170.56 kg ha^{-1}), medium in available phosphorous (21 kg ha^{-1}) and high in potassium (380.50 kg ha^{-1}). The soil was moderately alkaline in reaction (pH 8.31), electrical conductivity (EC) of soil was normal (0.44) dSm^{-1} with medium (0.53 %) in organic carbon.

The crop was sown on 9th of July, 2021 by line sowing method with recommended dose of fertilizer levels (RDF). The crop was fertilized as per treatments by using urea, diammonium phosphate and fertilizer was given by placement method. In general, the *kharif* season was good for crop growth and development.

The seeds were sown at spacing 30 cm × 10 cm. one irrigation were given as per requirement during dry spell. One hand weeding was done on 20 day after sowing and keep the plots weed free. Plant protection measures were carried out as per requirement. The recommended fertilizer dose 20:40:00 (N, P_2O_5, K_2O kg ha^{-1}) was applied to the crop as a basal dose. The 5 tonne ha^{-1} of FYM was applied before sowing except control plot.

The observations on growth, yield and yield contributing characters were recorded periodically after plant emergence *viz.*, plant height (cm), number of branches $plant^{-1}$, number of leaves $plant^{-1}$, leaf area $plant^{-1}$ (dm^2), number of root nodule, dry matter $plant^{-1}$ (g) and after harvest observation such as number of pod, pod length (cm), number of seed pod^{-1}, test weight (g), seed yield kg ha^{-1}, straw yield kg ha^{-1} were recorded. The N, P and K content and protein content was worked out to assess the quality of grains. The residual fertility of the soil after harvest was also determined in terms of available N, P and K.

The effect of fertilizer on growth and yield and quality of black gram were determined. Based on inputs and outputs economics of different treatments were worked out.

The finding emerged from the present investigation are summarized as below with appropriate subheadings.

5.1 Response of Blackgram Cultivars

5.1.1 Plant Count

The initial and final plant population of black gram cultivars were not influenced significantly due to black gram cultivars. Numerically higher initial and final plant population was recorded by PDKV black gold cultivar.

5.1.2 Plant Height

The plant height of black gram cultivars was influenced significantly after 30, 45, 60 DAS and at harvest. The PDKV black gold recorded significantly higher plant height at 30, 45 60 DAS and at harvest (20.53, 43.30, 62.30 and 62.49 cm) respectively than other cultivars, However it was at par with PU-609-43 cultivar.

5.1.3 Number of Leaves Plant^{-1}

The number of leaves plant^{-1} of black gram cultivars were influenced significantly at 30, 45, 60 DAS and at harvest. The PDKV black gold cultivar registered significantly higher number of leaves plant^{-1} at 30, 45, 60 DAS and at harvest of crop (13.68, 25.54, 41.69 and 38.95) respectively than other black gram cultivars, However it was at par with PU-609-43 cultivar.

5.1.4 Leaf Area (dm^2)

The leaf area (dm^2) of black gram cultivars were influenced significantly at 30, 45, 60 DAS and at harvest. The PDKV black gold cultivar registered significantly more leaf area at 30, 45, 60 days and at harvest of crop (26.79, 36.04, 36.13 and 35.92) respectively than other black gram cultivars, However it was at par with PU-609-43 cultivar.

5.1.5 Number of Root Nodules

The number of root nodule of black gram cultivars were influenced significantly at 30, 45 and 60 DAS. The PDKV black gold cultivar registered significantly more number of root nodule at 30, 45, 60 and DAS of crop (13.81, 23.01 and 15.63) respectively than other black gram cultivars, However it was at par with PU-609-43 cultivar.

5.1.6 Dry Matter Plant^{-1}

The dry matter plant^{-1} of black gram cultivars were influenced significantly at 30, 45, 60 DAS and at harvest. The PDKV black gold cultivar registered significantly higher

dry matter at 45, 60 DAS and at harvest of crop (1.08, 11.48, 15.61, and 20.75) respectively, than other black gram cultivars, However it was at par with PU-609-43 cultivar.

5.1.7 Quality

The crude protein content (%) and protein yield (kg ha^{-1}) (24.00 and 367.60) respectively, were significantly higher in black gram cultivar PDKV black gold and it was at par with PU-609-43 cultivar.

5.1.8 Yield Attributes

The yield contributing character such as number of pod $plant^{-1}$ (30.60), pod length (6.17 cm), seed pod^{-1} (8.08), seed weight $plant^{-1}$ (8.04 g), test weight (42.02 g) found significantly higher in PDKV black gold and it was at par with PU-609-43 cultivar. Whereas significantly lower yield attribute recorded with TPU-4 cultivar.

5.1.9 Yield

The seed yield 1526 kg ha^{-1} and straw yield 2497 kg ha^{-1}, Biological yield 4023 kg ha^{-1}, Harvest index 37.93 % were recorded in PDKV black gold cultivar and it was at par with PU-609-43 cultivar, whereas TPU-4 recorded significantly lower seed and straw yield.

5.1.10 Uptake

The total uptake of nitrogen (70.93 kg ha^{-1}), phosphorous (10.86 kg ha^{-1}) and potassium (45.24 kg ha^{-1}) recorded by black gram cultivar was significantly higher in PDKV black gold and it was at par with PU-609-43 cultivar, whereas TPU-4 recorded significantly lower nutrient uptake.

5.1.11 Available Nutrients

The soil available nitrogen after harvest of black gram was significantly higher in cultivar AKU-15 (174.68 kg ha^{-1}), the soil available phosphorous was significantly higher in cultivar PU-609-43 (20.62 kg ha^{-1}) and significantly higher soil available potassium was recorded by cultivar PDKV black gold (373.27 kg ha^{-1}).

5.1.12 Economic Studies

The significantly higher gross monetary returns (₹ 99195 ha^{-1}) and net monetary returns (₹ 64496 ha^{-1}) was recorded by the cultivar PDKV black gold, however it was at par with PU-609-43 and TPU-4 recorded significantly lower gross and net monetary return. Whereas numerically higher values of B: C ratio was also registered by PDKV black gold cultivar than rest of black gram cultivars.

5.2 Effect of Fertilizer Levels

5.2.1 Plant Count

The initial and final plant population of black gram cultivars was not influenced significantly due to different fertilizer levels. Numerically higher initial and final plant population was recorded with 125 % of RDF.

5.2.2 Plant Height

The plant height of black gram cultivars was influenced significantly at 30, 45, 60 DAS and at harvest. Application of 125 % of RDF recorded significantly higher plant height at 30, 45, 60 DAS and at harvest (21.41, 42.91, 60.70 and 61.02 cm) respectively, than other fertilizer levels, however it was at par with 100 % RDF.

5.2.3 Number of Leaves Plant^{-1}

The number of leaves plant^{-1} of black gram cultivars were influenced significantly at 30, 45, 60 DAS and at harvest. Application of 125 % of RDF registered significantly more number of leaves plant^{-1} at 30, 45, 60 DAS and at harvest of crop were (14.60, 24.66, 43.06 and 40.77) respectively, than other fertilizer levels, however it was at par with 100 % RDF.

5.1.4 Leaf Area (dm^2)

The leaf area (dm^2) of black gram cultivars were influenced significantly at 30, 45, 60 days and at harvest. Application of 125 % of RDF registered significantly higher leaf area at 30, 45, 60 DAS and at harvest of crop were (26.77, 35.34, 35.85 and 35.61) respectively, than other fertilizer levels, however it was at par with 100 % RDF.

5.1.5 Number of Root Nodules

The number of root nodule of black gram cultivars were influenced significantly at 30, 45, 60 days and at harvest. Application of 125 % of RDF registered significantly more number root nodule at 30, 45, days and at harvest of crop were (13.98, 23.56, and 15.63.) respectively, than other fertilizer levels, however it was at par with 100 % RDF.

5.1.6 Dry Matter Plant^{-1}

The dry matter plant^{-1} of black gram cultivars were influenced significantly at 30, 45, 60 DAS and at harvest. Application of 125 % of RDF registered significantly higher dry matter at 30, 45, 60 DAS and at harvest of crop were (1.37, 11.56, 15.88 and 20.46) respectively, than other fertilizer levels, however it was at par with 100 % RDF.

5.2.7 Quality

The crude protein content (23.86 %) and protein yield (324.59 kg ha^{-1}) were significantly higher recorded with application of 125 % of RDF than other fertilizer levels, however it was at par with 100 % RDF.

5.2.8 Yield Attributes

The yield contributing character such as number of pod $plant^{-1}$ (33.00), pod length (6.57 cm), seed pod^{-1} (7.55), test weight (42.94 g) found significantly higher in 125 % RDF and it was at par with 100 % RDF, and minimum yield contributing characters recorded in control.

5.2.9 Yield

The seed yield 1351 kg ha^{-1} and straw yield 2228 kg ha^{-1}, Biological yield 3579 kg ha^{-1}, harvest index 37.74 % were recorded significantly higher in 125 % RDF and it was at par with 100 % RDF, whereas control recorded significantly lower seed and straw yield.

5.2.10 Uptake

The total uptake of nitrogen (67.02 kg ha^{-1}), phosphorous (10.12 kg ha^{-1}) and potassium (44.87 kg ha^{-1}) by black gram cultivars was significantly higher with application of 125% of RDF and it was at par with 100 % RDF.

5.2.11 Available Nutrients

The soil available nutrients after harvest of black gram i.e. nitrogen (175.22 kg ha^{-1}), phosphorous (18.80 kg ha^{-1}) and potassium (373.54 kg ha^{-1}) of black gram was found significantly higher with application of 125 % of RDF.

5.2.12 Economic Studies

The economics of black gram production was significantly influenced due to fertilizer levels. The significantly highest gross monetary returns (₹ 87799 ha^{-1}) and net monetary returns (₹ 53099 ha^{-1}) were recorded by 125 % of RDF and it was at par with 100 % RDF. The higher values of cost of cultivation (₹ 37830 ha^{-1}) and highest B : C ratio (2.53) was obtained with application of 125% of RDF followed by 100 % RDF.

Conclusion

On the basis of one season experimental findings, it is concluded that cultivation of black gram cultivar PDKV black gold or PU-609-43 with the application of 100 % of RDF found appropriate for achieving higher seed yield and protein content as well as gross monetary returns, net monetary returns and B: C ratio of black gram grown during *kharif* season.

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7. APPENDIX

Prevailing market prices of input and output

Sr. No.	Particular	Unit	Rate^{-1} (₹)
1.	Tractor ploughing	₹ ha^{-1}	5000
2.	Harrowing	₹ ha^{-1}	2500
3.	Sowing charges	₹ day^{-1}	328
4.	Seed	₹ kg^{-1}	80
5.	Gap filling	₹ day^{-1}	328
6.	Weeding	₹ day^{-1}	328
7.	Fertilizer application labour charges	₹ day^{-1}	328
8.	Chemical fertilizer		
	1) Urea cost	₹ kg^{-1}	5.6
	2) DAP cost	₹ kg^{-1}	24
	3) Rhizobium	₹ kg^{-1}	20
9.	FYM	₹ ton^{-1}	2500
10.	Irrigation labour charges	₹ day^{-1}	328
11.	Imidacloprid spraying	₹ ha^{-1}	650
12.	Harvesting labour charges	₹ day^{-1}	328
13.	Selling rate	₹ Kg^{-1}	65
14.	Land revenue	₹ Year^{-1}	750

8. VITAE

MR. SARWADE VISHAL RAGHUNATH

MASTER OF SCIENCE (AGRICULTURE)

in

AGRONOMY

2023

Title of thesis		**:**	Response of black gram [*Vigna mungo* (l.)] cultivars to fertilizer levels
Major field		**:**	Agronomy
Biographical information			
Personal	**Date of Birth**	**:**	23 January 1998
	Place of birth	**:**	Tuljapur, Dist-Osmanabad
	Father's Name	**:**	Sarwade Raghunath Namdev
	Mother's Name	**:**	Sarwade Nandubai Raghunath
Educational	**Bachelor degree obtained**	**:**	B. Sc. (Agriculture) at College of Agriculture, Parbhani.
	Class	**:**	First class
	Name of university	**:**	Vasantrao Naik Marathawada Krishi Vidyapeeth, Parbhani (Maharashtra)
	Address	**:**	At. Post. Yeoti, Tal.-Tuljapur Dist-Osmanabad Pincode : 413603
	Email– id	**:**	vishalsarwade99@gmail.com
	Contact No.	**:**	9970594828