

**Response of Black Gram (*Vigna mungo* L.) to Graded
Doses of Phosphorus and Sulphur under Rainfed
Conditions**

THESIS



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**Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.)
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by

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Indore (M.P.)

2017

CERTIFICATE-I

This is to certify that the thesis entitled “Response of black gram (Vigna mungo L.) to graded doses of phosphorus and sulphur under Rainfed Conditions”, submitted in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN AGRICULTURE (Agronomy) of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bona-fide research work carried out by Mr. Jitendra Singh Jaiswal under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigation has been acknowledged by scholar.

Place: Indore

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Place

Date

Jitendra Singh Jaiswal

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ABBREVIATIONS

S. N.	Legends	Discription
1.	%	percent
2.	&	And
3.	@	At the rate of
4.	^o C	Degree celcius
5.	ANOVA	Analysis of variance
6.	BF	Biofertilizer
7.	CD	Critical Difference
8.	CGR	Crop Growth Rate
9.	cm	Centi meter
10.	DAS	Days after sowing
11.	Df	Degree of freedom
12.	dS m ⁻¹	Deci Siemens per meter
13.	Ec	Electrical conductivity
14.	EMS	Error means sum of square
15.	<i>et al.</i>	Allied (and other)
16.	FYM	Farm yard manure
17.	g	Gram
18.	Ha	Hectare
19.	HI	Harvest index
20.	<i>i.e.</i>	That is (in reference to)
21.	kg	Kilogram
22.	l	Liter
23.	LAI	Leaf area index
24.	LER	Land equivalent ratio
25.	m	Meter

26.	mt or t	Metric tonnes
27.	Max.	Maximum
28.	mg/kg	Miligram per kilogram
29.	Min.	Minimum
30.	mm	Millimeter
31.	MSS	Mean sum of square
32.	NS	Non significant
33.	OC	Organic carbon
34.	P	Phosphorus
35.	PSB	Phosphorus solubilising bacteria
36.	q	Quintal
37.	RDF	Recommended doses of fertilizers
38.	RGR	Relative Growth Rate
39.	RH	Relative humidity
40.	Rs	Rupees
41.	S	Sulphur
42.	S.S.	Sum of square
43.	S.V.	Source of variance
44.	SE (m) \pm	Standard error for mean
45.	SEY	Soybean equivalent yield
46.	SMW	Standard metrological week
47.	Sq. m	Square meter
48.	STBF	Soil test based fertilizer
49.	Viz	Wide list

INTRODUCTION

CHAPTER - I

INTRODUCTION

Black gram (*Vigna mungo* L.) is one of the important kharif pulse crop. It belongs to leguminosae and sub family papilionaceae, and is being grown as one of the principle crop since ages in Madhya Pradesh as well as in the country. India is the largest producer as well as consumer of black gram. It produce about 15 to 19 lakh tones black gram annually from about 35 lakh ha.of area, with an average productivity of 500kg/ha (Ministry of Agriculture, GOI 2014-15). It controls soil erosion and competes with weeds effectively due to its deep root system and foliage cover. It fixes atmospheric nitrogen into the soil and improved the soil fertility. It is rich in carbohydrate, protein, fat and phosphoric acid.

There exists a vast gap between potential productivity and actual productivity of black gram being realized at present. Apart from other agronomical management practices, imbalanced plant nutrition is the major constraint to higher productivity of the crop. Black gram being a leguminous crop, requires adequate amount of phosphorus and sulphur as well as apart from other nutrients these are directly involved in growth and development of plant.

Phosphorus is essential constituent of every living cell. It is concerned with structural compounds, nucleic acids for reproductive purpose, and the conservation and transfer of energy in the metabolic reactions taking place. Phosphorus ranks next to nitrogen in importance, and its availability to growing crops is of prime importance. It is an essential constituent of many vital compounds like lecithin and most enzymes. It promotes the development of roots, seed formation, and gives strength to straw, hastens maturity of crops, and increases ratio of grain to straw. Leguminouscrops grown under P deficient conditions may suffer from Ndeficiency as well, since the nodule bacteria function normally only when plants are supplied with adequate phosphorus. The P nutrition is therefore considered critical particularly for legumes.

Sulphur is another essential nutrient which is usually required by leguminous crops in amounts comparable to P. S is a part of amino acids cysteine and

methionine, hence essential for protein production. Another sulphur containing amino acid cystine is derived by oxidation of cysteine. Sulphur is involved in formation of chlorophyll, activation of enzymes, and is a part of co-enzyme. Sulphur deficiency symptoms, in many ways resemble those of nitrogen, pale yellow or light green leaves. Sulphur is known to help in chlorophyll formation, stimulating growth, seed formation and N fixation by enhancing nodule formation. Unlike N, S-deficiency symptoms appear first on the younger leaves, and will persist even after N application. Plants deficient in S are small and spindly with short and slender stalks, growth is retarded, maturity in cereals is delayed, nodulation in legumes may be poor and N fixation reduced. Crops with a relatively high requirement of S and sensitive to S deficiency are legumes, oilseed, crucifers, forages etc in that order. Thus, involvement of sulphur in plant metabolism and yield responses makes sulphur as the fourth major element after nitrogen, phosphorus and potassium.

Agricultural feasibility and economic viability of black gram (*Vigna mungo* L.) as sole as well as intercrop in different crop sequence have been established due to its unique property of maintaining and restoring soil fertility through biological nitrogen fixation as well as conserving and improving physical properties of soil by virtue of its deep root system and leaf fall.

In view of the above cited facts the present investigation entitled "Response of Black Gram (*Vigna mungo* L.) to Graded Doses of Phosphorus and Sulphur under Rainfed Conditions" was carried out with the following broad objectives.

1. To study the effect of phosphorus and sulphur on growth, development and yield of black gram.
2. To evaluate the interactive effect of P and S for higher productivity of black gram.
3. To work out the economic viability of different treatments.

REVIEW OF
LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

Although there are some reports on the effect of different levels of phosphorus and sulphur on the production and profitability of some leguminous crops in India and abroad but very meager information is available on black gram grown especially under rain fed black clay soils. Effort are, therefore made to present in this chapter, a brief summary of results of the studies carried out at various places, more or less related to the present investigation. Since, the literature on the effect of different levels of phosphorus and sulphur on black gram crop grown on rain fed Vertisols is very meager, related research findings on other pulses have also been incorporated in the review. Attempts have been made to compile the research work done on these aspects in present chapter under different heads.

2.1 Effect of different levels of Phosphorus on growth and yield of black gram and other pulses.

Shah et al.(1994) reported, that,Phosphorus fertilization @ 30, 60 and 90 kg P_2O_5 / ha. recorded an increases of 22.1 %, 31.9 % and 37.9% and 5.7 %, 17.5% and 19.4% in seed yield over no phosphorus application respectively, Pooling of seed yield over 2 years recorded an increase of 10.3, 22.0 and 24.2% over the control with 30, 60 and 90 kg P_2O_5 /ha. This may perhaps be due to reason that phosphorus helped in proliferation of root system and thus resulted in increasing the nutrient by absorption by increasing the absorbing surface. Thus the higher absorption of nutrient by the crop favorably influenced the yield attributes and finally the yield.

Prabhakan et al. (1999) observed in a study that the seed and straw yields increasing on seed inoculation with PSB were mainly owing to increased yield attributes.

Dubey and Agarwal (1999) found in a study,the improvement in nodulation with inoculation using phosphorus solublising organisms may have resulted in higher nitrogen fixation and hence higher nitrogen availability to plants, whereas solubalisation of fixed phosphorus by PSB probably resulted in increased content and uptake of phosphorus by plants.

Reddy and Swamy (2000) reported that, the yield attributes, viz. pods/plant,

seeds/pod and 1,000 seed weight, increased significantly with phosphorus application up to 60kg P₂O₅ /ha. However, seed/pod during 2001 and 1,000 seed weight during 2 years (pooled) and 2001 showed significant response up to 90 kg P₂O₅/ha. This may be due to availability of water soluble phosphorus from applied single super phosphate causing vigorous growth, initiating more number of flower buds in the plant thereby increasing pods/plant and seed yield.

Yadav and Tripathi(2003) conducted an experiment on the effect of *Rhizobium* +N+P+S on yield of black gram independently and in combination. They found that the application of N, P and S with *Rhizobium* gave the significant increases in yield of black gram over the other treatments.

Singh and Singh (2004) concluded the study of the treatments of three levels of sulphur (0, 30 and 60 kg/ha) and four levels of phosphorus (0, 30, 60 and 90 kg/ha) applied through gypsum and triple super phosphate, respectively and reported that the grain, straw and total dry matter yield increased with the application of sulphur and phosphorus individually.

Yadahalli and Palled (2004) revealed in a study that the yield, yield components, nutrient uptake as well as economics were significantly influenced by black gram genotypes and dates of sowing. The phosphorus levels had no significant influence. Black gram genotype, TAU-1 produced significantly higher seed yield (845.41 kg/ha) over Manikya and K-3. Crop sown on 16th June recorded significantly higher seed yield (1068.87 kg/ha) over other dates of sowing. The maximum net income and B:C ratio were recorded by TAU-1 sown on 16th June with 50 kg P₂O₅ per ha.

Gupta et al. (2006) studied the effect of bio-fertilizer inoculation and phosphorus fertilization on yield and quality of the cultivars of Urdbean (*Vigna mungo* (L). Hepper) UG 218' urdbean produced significantly higher pods /plant, 1,000 seed weight, seed yield as well as straw yield over other 2 varieties. However, the protein content was higher in the seeds of type 9. Phosphorus application also resulted in significant increases in seed protean content and N and P uptake in seed and straw.

Sheikh et al. (2012) initiated an investigation to work out the effect of *Rizobium* culture and phosphate solubilising bacteria (PSB) with nitrogen and phosphorus applications on the performance of Black gram (*Vigna mungo* L.

Hopper) Cv-T9. The results revealed that all the attributes under study were highly influenced by the *Rizobium* and Phosphate Solublizing Bacteria (PSB) along with nitrogen and phosphorus applied @10kg ha⁻¹ and 25 kg ha⁻¹, respectively; implying the application of dual doses of bio fertilizers helpful in combination with inorganic nutrient application in overall enhancement of yield of Black Gram.

Rangarai et al. (2012) conducted an experiment in split plot design with two genotypes in main plot and four levels of fertilizer + 2 % DAP foliar spray at flowering stage in sub plot with eight treatment combination and three replications. Performance of black gram genotype BDU – 1 during summer season was found highly productive as compared to TAU-1.

Beg et al. (2013) reported that, the Foliar application of phosphorus on mung bean and urd bean at the time of flowering at half and full basal fertilizer doses in different concentrations was applied and it was found that the treatment where 2.5 kg. Phosphorus/ ha was applied as foliar spray showed best results. It enhanced almost all the vegetative and yield characteristics of mung bean and urd bean. The best result was observed at T treatment at half basal fertilization dose. In this way a little amount of phosphorus used as foliar spray at the time of flowering when the plant required maximum nutrients can enhanced the productivity and save a large amount of fertilizers.

2.2 Effect of different levels of sulphur on growth and yield of black gram and other pulses:

Umesh et al.(1997) observed positive effect of sulphur with zinc on plant height, branches, number of functional leaves/plant in green gram.

Singh and Agarwal(1998) conducted a trial to see the effect of different sources of fertilizer on yield of black gram cv. Pant U-19. The sulphur containing fertilizer (30 kg S/ha) produced significantly higher pod length, seeds/pod and test weight.

Shankaralingappa et al. (1999) reported the result of the application of factorial combination of three levels of phosphorus (0, 50 and 75 kg P₂O₅ /ha) and sulphur (0, 20, and 40 kg S/ha) and two sources of sulphur (gypsum and elemental sulphur.) on sandy clay loam soil deficient in available S and high in available P under rainfed conditions. Seed yield of cowpea differed

significantly due to interaction between P and S. combined application of 50 kg P₂O₅/ha and 20 kg S/ha yielded, 1757 kg/ha as compared with 50 kg P₂O₅ /ha and 0 kg S/ha (1491 kg/ha) and 0 kg P₂O₅/ha and 40 kg S/ha (1470 kg/ha) while comparing to (1082 kg/ha) under control treatment.

Ammal et al. (2000) conducted an experiment to investigate the effect of rock phosphate-sulphur (RP-S) granular at 0, 15, 30, 45, 60 and 75 kg /P₂O₅ /ha on the yield of onion cv. Co. 4 and black gram (*Vigna mungo*) cv. Co. 5, planted in sequence and concluded that RP-S at 60 kg/ha resulted in the highest yields of both (onion and black gram) crops and the availability of N, P and S in the soil was increased.

Srinivasan et al. (2000) pointed out that sulphur fertilization had a significant effect on root nodulation in black gram. They further reported that there was a linear response of 40 kg S/ha in lateritic soils to root nodules when given through gypsum.

Srinivasan and Shankaran (2001) recorded the highest plant height of black gram cv. Vamban-1, with gypsum application (49.1 and 53.8 cm during 1995 and 1996 respectively). Among the sulphur sources, gypsum gave highest number of pods/ plant in black gram cv. Vamban-1 and 30 and 40 kg sulphur gave highest number of pods/ plants.

Sengupta (2001) studied the effect of sulphur containing fertilizer on productivity of rainfed black gram and found that application of 30 kg S/ha through single super phosphate gave significantly higher number of branches, leaves effective root nodules and dry matter accumulation per plant as compare to control.

Teotia et al. (2001) found that application of sulphur up to 40 mg/kg soil along with 60 kg/ha phosphorus in green gram show linear response to number of nodules

Nitachand et al. (2002) reported, that, application of potassium and sulphur at the rate of 40 kg S/ha increased the yield and harvest index in green gram.

Poonkodi and Deepa (2003) conducted a field trial on the effect of different sources of sulphur on yield of black gram. They found that gypsum produced significantly higher pods length, seed/pod, and other yield attributes were also increased with the sulphur application @ 40 kg S/ha.

Siag and Yadav (2003) studied in a field trial, the response of mung bean cv. MUM 2 to sulphur (applied as gypsum) with different application rates and reported that the number of pods/plant increased with increasing S rates. Basal dose of 40 kg S/ha recorded the highest number of pods per plant, which was at par with 40 kg S /ha (half applied as basal + half as side dressing) and 20 kg S/ha as basal.

Yadav and Tripathi(2003) conducted an experiment on the effect of *Rhizobium* +N + P+ S on yield of black gram independently and in combination. They found that the application of N, P and S with *Rhizobium* gave the significant increases in yield of black gram over the other treatments.

Chettri and Mondal (2004) reported the results of a study on growth and productivity of black gram at different levels of potassium and sulphur. They found that maximum dry matter accumulation, yield attributes and seed yield of black gram were obtained with application of 30 kg K₂O /ha, 30 kg S /ha with an irrigation at early pod filling stage.

Singh and Singh (2004) studied the interaction effects of sulphur and phosphorus in a field experiment on soil, deficient in S and medium in P with black gram as the test crop. The treatment were taken in factorial combination of three levels of sulphur (0, 30 and 60 kg/ha) and four levels of phosphorus (0, 30, 60 and 90 kg/ha) applied through gypsum and triple super-phosphate respectively. A uniform dose of nitrogen was applied with the treatment. The grain, straw and total dry matter yield increased with the application of sulphur and phosphorus individually.

Singh (2004) conducted a trial on effect of sulphur and phosphorus on yield of black gram and reported the application of sulphur up to 30 kg/ha enhanced the average grain yield of black gram by 22.2% over control.

Subramaniam et al. (2005) conducted a field experiment during the kharif season of 2002 and 2003 in Tamil Nadu, to study the nutritional and yield responses of black gram cv. TMV-1 to soil or seed treatment with Zn, B, Mo and S in various combination and reported positive responses of the nutrient application under consideration.

Kumawat et al. (2005) examined the effect of application of different levels of sulphur and iron on dry matter accumulation, crop growth rate (CGR), specific leaf weight (SLW) and LAI. The application of 40 or 60 kg sulphur/ha

significantly increased dry matter accumulation & LAI, CGR and SLW at various growth stages as compared to plant growth without sulphur and with 20 kg/ha.

Thesia et al. (2012) conducted an experiment during the kharif season of the year 2003 to study the effect of potassium and sulphur on growth and yield of black gram (*Vigna mungo* L. Hepper) under rainfed condition. Combined application of 20 kg K₂O ha⁻¹ along with 30 kg S ha⁻¹ recorded significant increase in respect of yield attributes and yield.

Limbakai and Netravati (2015) laid out an experiment in split plot design with three replications. The interaction effect between sulphur and foliar sprays revealed that, application of 20kg S/ha + RDF in combination with foliar sprays of 2% DAP + 40 ppm NAA at 45 and 55 days after sowing recorded significantly higher seed yield (1415 kg/ha).

2.3. Effect of phosphorus and sulphur interaction on growth and yield of black gram and other pulses.

Abraham and Lal (2004) conducted a field experiment during *kharif* seasons of 1998 and 1999 at Allahabad Agricultural Institute – Deemed University, Allahabad to study the effect of fertilizer levels, organic manures and biofertilizer along with organic spray on the yield of blackgram under blackgram – wheat – greengram system. Plant dry weight values showed no significant difference between one hundred per cent and 33% RDF levels. Similarly, some yield parameters showed same trends. Organic manure application showed increased yield over the control. Biofertilizer and organic spray helped in significant increase of the dry matter production and test weight. The interaction of these components registered better performance, thus inferring the importance of integrated nutrient supply system.

Karche et al. (2012) conducted an experiment for the summer season of 2009 at the College Agronomy Farm, B.A. College of Agriculture, Anand Gujarat in order to find out the effect of phosphorus and sulphur on cluster bean, three levels of phosphorus and sulphur (0, 20 and 40 kg P₂O₅ and S ha⁻¹) were applied. The yield of cluster bean (seed and Stover) and nutrient uptake were influenced by the rate of phosphorus and sulphur. Application of

40 kg P₂O₅ and S ha⁻¹ gave significantly higher yield and nutrient uptake (N, P, K and S) by cluster bean.

Sathyamoorthi et al. (2012) studied and found that, response of green gram to fertilizer application varies from place to place and variety to variety. Hence, to have an understanding on the works done on so far the literature pertaining to response of green gram to fertilizer application through soil and foliage is reviewed in this article.

Mir et al. (2013) conducted a field experiment at Allahabad Agricultural Institute- Deemed University, Allahabad to study the effect of levels of phosphorus, sulphur and Phosphorus Solubilizing Bacteria (PSB) on growth, yield and nutrient content of blackgram for consecutive two years 2004 and 2005. The crop growth parameters viz., plant height, number of nodules and number of leaves per plant, yield and nutrient content increased significantly with the application of high levels of phosphorus, sulphur with or without bio-fertilizer inoculation. Application of 60 kg P₂O₅ ha⁻¹ recorded maximum plant height (49.9 cm), number of leaves plant⁻¹ (50.8), number of nodules plant⁻¹ (27.8), haulm yield (28.9 q ha⁻¹), grain yield (8 q ha⁻¹) and phosphorus, sulphur and protein content of grain (0.356 %, 0.253% and 22.64%, respectively) as compared to lower levels. Application of Sulphur @ 40 kg ha⁻¹ recorded maximum plant height (47.31 cm), number of leaves plant⁻¹ (49.80), number of nodules plant⁻¹ (25.58), haulm yield (28.80 q ha⁻¹), grain yield (7.92 q ha⁻¹) and phosphorus, sulphur and protein content (0.295 , 0.281 and 21.79%, respectively). Inoculation of black gram seeds with phosphorus solubilising bacteria recorded slightly higher grain yield (7.49 q ha⁻¹) as compared to no inoculation (7.39 q ha⁻¹).

Kokani et al. (2014) conducted a field experiment during summer 2013 at college farm, Navsari Agricultural University, Navsari to study the response of summer black gram (*Vigna mungo* L.) to FYM, phosphorus and sulphur. The plant height at harvest (36.73 cm), number of branches (5.02), seed yield (1149 kg/ha) and Stover yield (2652 kg/ha) of blackgram were produced significantly higher under the incorporation of 5 t FYM /ha over control, which was 10.16 and 19.08 per cent higher over control, respectively. Significantly the higher plant height at harvest (37.38 cm), number of branches (5.18),

number of pods per plant (20.68), number of seeds per pod (6.26), length of pod (4.74 cm), grain yield (1171kg/ha) and Stover yield (2667 kg/ha) were obtained with the application of 40 kg P₂O₅/ha over control. Application of sulphur @ 20kg/ha was also recorded significantly highest plant height at harvest (37.07 cm), number of branches(5.17), number of pods per plant (20.93), number of seeds per pod (6.30), grain (1153 kg/ha) and Stover yield (2548 kg/ha) over control, respectively.

Kadam et al. (2014) conducted a field experiment to study the effect of phosphorus, vermicompost and PSB inoculation on growth, yield and quality of black gram during Kharif 2011 on the farm of Agronomy department, at college of Agriculture, Latur. The research showed that the application of 75 kg P₂O₅/ha-1 recorded highest seed yield (1194 kg ha-1) and yield attributes as well as high economic returns but it was found at par with 50 kg P₂O₅/ha-1. The higher B: C ratio (1.58) was recorded at 50 kg P₂O₅/ha-1. Therefore, it is recommended to apply 50 kg phosphorus ha-1 to black gram crop. The superior development and yield parameters were recorded by the combine application of vermicompost and PSB inoculation. It was also found superior in respect of gross monetary return but higher net monetary return (18377 kg ha-1) and B: C ratio (1.74) was obtained by the application of PSB inoculation. Hence it is recommended to apply PSB inoculation to black gram.

Niraj and Prakash(2014) reported, that, sixteen treatments were replicated thrice in Randomized Block Design. Black gram variety pant urd – 35 was taken as test crop. The data revealed that 45 kg/ha P and 30 kg/ha S significantly increased growth parameters such as plant height, number of branches and dry matter accumulation. The same treatment combination proved most effective in improving the yield and yield attributing characters viz. number of pods, number of grains per pod, grains wt. per plant test weight, grain and straw yield.

Chaudhary et al. (2016) conducted a field trial during the *kharif* season of 2010 and 2011, to study the “Effect of Integrated Nutrient Management on yield and quality of black gram (*Vigna mungo* L.) in an Inceptisol of Varanasi”.

Data revealed that integrated use of organic manure, inorganic and bio fertilizer had significant effect on yield and yield attributes of blackgram over control during both the years of experiment.

2.4. Effect of different factors on economics of black gram

Srinivasan and Ramaswamy (1997) conducted a trial on black gram with 0,20,40, and 60 kg P₂O₅ /ha and 0, 20, or 40 kg S/ha. They recorded greatest net margin ratio with the 60 kg P + 40 kg S and cost benefit ratio with 40 kg P + 40 kg S.

Trivedi et al. (1997) observed that the application of 30 kg N + 60 kg P₂O₅ + 60 kg S/ha in kharif season in black gram gave maximum net return (Rs 3893/ha) and benefit cost ratio (BCR) of 2.01.

Srinivasan and Sankaran (2001) studied the effect of S sources (elemental S, gypsum and pyrites) and rates of application (0, 10, 20 and 40 kg S/ha) on black gram cv. Vamban-1 during 1995 and 1996 and reported that gypsum gave greatest benefit cost ratio (2.49 and 3.46). Whereas, 0, 10, 20, and 40 kg S/ha gave benefit cost ratio of 2.21, 2.55, 2.57 and 2.60 respectively.

Chetri and Mondal (2004). Studied in a field trial nutrient uptake and economics of black gram at different level of potassium and sulphur and obtained maximum nutrient uptake and net production value (based on net return and total cost of cultivation) were obtained when the crop was treated with 30 kg K₂O/ha and 30 kg S/ha.

MATERIAL AND METHODS

CHEPTER – III

MATERIAL AND METHODS

This chapter presents a brief description of methods employed and material used during the course of investigation entitled “**Response of Black Gram (*Vigna mungo* L.) to Graded Doses of Phosphorus and Sulphur under Rainfed Conditions.**” The study was carried out during kharif season 2016 at the research field of AICRP on pulses, College of Agriculture, Indore (M. P.).

3.1 Experimental site

The present experiment was laid out in the field of the research scheme of AICRP on pulses, College of Agriculture, Indore during kharif season, 2016. The topography of the experimental site was almost uniform with an adequate surface drainage. The internal drainage of the experimental site was good.

3.2 Location and Climate

Indore is situated in Malwa plateau region in the Western part of the state of Madhya Pradesh at an altitude of 555.5 meters above mean sea level. It is located at latitude 22.43⁰ N and longitudinal of 75.66⁰ E. It has subtropical climate having a temperature range of 21⁰ C to 45⁰ C and 6⁰ C to 31⁰ C in summer and winter season, respectively. The rainfall in the region is mostly inadequate and erratic. Late commencement, early withdrawal of monsoon and occurrence of two to three dry spells during the rainy seasons are the common features. The mean annual rainfall is 964 mm. The meteorological data during pre sowing period, crop growth period, and post harvest period from the fourth week of May to second week of October 2016 are given in Table 3.1

3.3 Soil

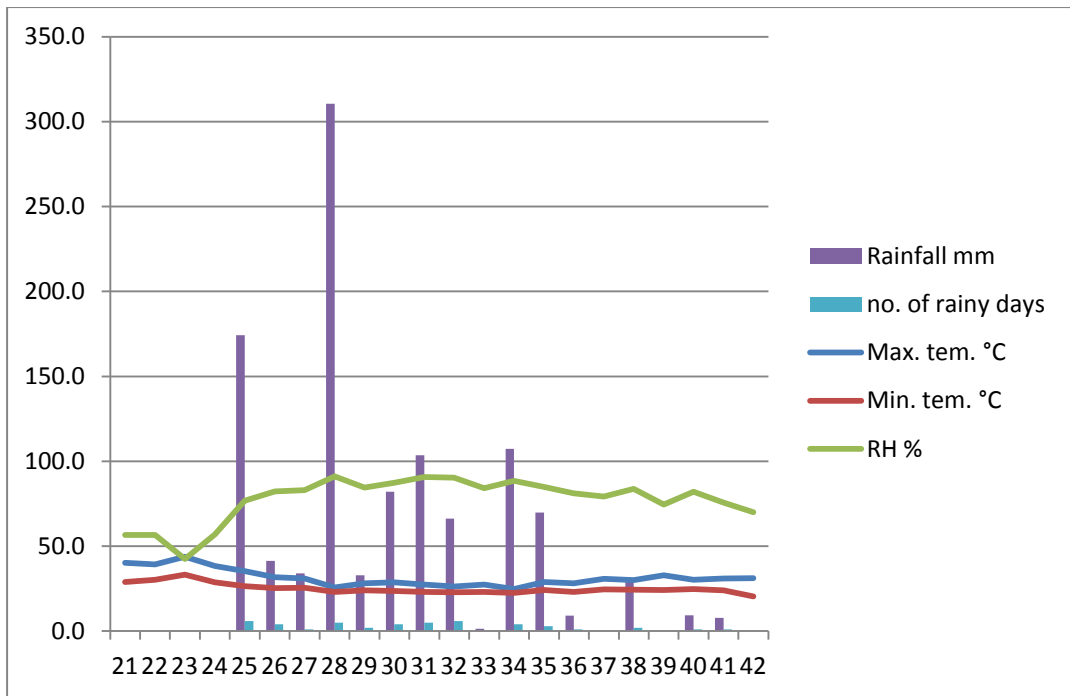
The soil of the experimental field has been grouped under medium black clay soil (Vertisols) belonging to Kamlikhedi series, which is a member of fine smectitichyperthermic family of Vertic, Ustochrepts. In order to determine the textural class and fertility status of the experimental area, the soil samples were collected randomly from each plot with the help of soil auger before sowing from the experimental field. Initially samples were mixed

to prepare a composite soil sample of each replication to study physico - chemical properties of the experimental field. The data pertaining to various physico-chemical properties have been presented in Table 3.2

Table: 3.1 Meteorological information (Standard Metrological week) during entire crop season of the year 2016-17 at Indore, (M.P.)

Date	SMW	Tem. Max.	Tem Min.	RH (%)	Rainfall (mm)	No.of rainy days
May 21 – 27	21	40.3	29.0	56.7	0.0	0
May 28 – June 3	22	39.2	30.3	56.6	0.0	0
June 4– 10	23	43.8	33.3	42.6	0.0	0
June 11– 17	24	38.3	28.8	57.1	0.0	0
June 18– 24	25	35.3	26.4	76.9	174.3	6
June 25– July 01	26	31.7	25.3	82.2	41.4	4
July 02– 08	27	31.0	25.6	83.0	34.1	1
July 09 – 15	28	25.6	23.1	91.1	310.5	5
July 16 – 22	29	28.2	24.0	84.5	32.9	2
July 23 – 29	30	28.6	23.7	87.4	82.0	4
July 30 – Aug.05	31	27.4	23.1	90.7	103.5	5
Aug. 06 – 12	32	26.4	22.9	90.4	66.2	6
Aug. 13 – 19	33	27.4	23.1	84.1	1.4	0
Aug. 20 – 26	34	24.9	22.6	88.5	107.4	4
Aug.27 –Sept 02	35	28.9	24.3	84.9	69.9	3
Sept. 03 – 09	36	28.1	23.0	81.1	9.2	1
Sept 10 – 16.	37	30.7	24.5	79.2	0.0	0
Sept. 17 – 23	38	30.0	24.4	83.7	30.0	2
Sept 24 – 30	39	32.9	24.3	74.6	0.0	0
Oct. 01 – 07	40	30.3	24.9	82.1	9.3	1
Oct. 08 – 14	41	31.0	24.0	75.7	7.8	1
Oct. 14 – 21	42	31.1	20.4	70.1	0.0	0

Source – AICRP on Dry land Agriculture, College of Agriculture, Indore



(SMW 21 – 42) at Indore

Fig.1 Weather Parameters during Crop Growth Period

Table 3.2 mechanical and chemical composition of soil

S.No.	Composition	Content	Category	Method used
A. Mechanical composition				
1.	Sand (%)	10.8	-	BouyoucosHydrometer method (Piper, 1950)
2.	Silt (%)	38.2	-	
3.	Clay (%)	51.0	-	
4.	Textural class		Clayey	
B. Chemical composition				
S.No.	Analysis	Values	Category	Method adopted
1.	Soil pH	7.5	Slightly alkaline	Glass electrode method (pH meter) (Jackson, 1967)
2.	Electrical conductivity (ds/m)	0.33	normal	Conductivity meter at 25 ^o C (Jackson, 1967)
3.	Organic carbon (%)	0.50	Low	Wakley and black rapid titration method , 1934
4.	Available Nitrogen (kg N/ ha)	211.1	Low	Alkaline permanganate method (Subbiah and Asija 1956)
5.	Available phosphorus (kg p ₂ O ₅ /ha)	10.4	Medium	Olsen's method (Jackson, 1967)
6.	Available potash (kg K ₂ O/ha)	460	Medium	Flame photometer (Jackson, 1967)
7.	Available sulphur (kg/ S/ha)	8.76	Low	UV visible Spectro photometer (Turbidity method)

3.5 Experimental details

The present experiment consisting of the 16 treatment combination was carried out in a Factorial Randomized Block Design. The detailed plan of layout of experiment has been depicted in fig. 3.1 Details of experiment are given below

(a) Treatment details

Factor (1)

Phosphorus levels (4) :

P0	:	0 kg/ha.
P1	:	20kg/ha.
P2	:	40kg/ha.
P3	:	60kg/ha.

Factor (2)

Sulphur levels (4)

S0	:	0kg/ha.
S1	:	10kg/ha.
S2	:	20kg/ha.
S3	:	30kg/ha.

NOTE- A Uniform dose of 20kg/ha. N and 20kg/ha K was be given to all Treatment as per practice.

Treatment combination:

Treatments	Description
P0S0	0 kg P ha ⁻¹ and 0kg S ha ⁻¹
P0S1	0 kg P ha ⁻¹ and 10kg S ha ⁻¹
P0S2	0 kg P ha ⁻¹ and 20kg S ha ⁻¹
P0S3	0 kg P ha ⁻¹ and 30kg S ha ⁻¹
P1S0	20 kg P ha ⁻¹ and 0kg S ha ⁻¹
P1S1	20 kg P ha ⁻¹ and 10kg S ha ⁻¹
P1S2	20 kg P ha ⁻¹ and 20kg S ha ⁻¹
P1S3	20 kg P ha ⁻¹ and 30kg S ha ⁻¹
P2S0	40 kg P ha ⁻¹ and 0kg S ha ⁻¹
P2S1	40 kg P ha ⁻¹ and 10kg S ha ⁻¹
P2S2	40 kg P ha ⁻¹ and 20kg S ha ⁻¹
P2S3	40 kg P ha ⁻¹ and 30kg S ha ⁻¹
P3S0	60 kg P ha ⁻¹ and 0kg S ha ⁻¹
P3S1	60 kg P ha ⁻¹ and 10kg S ha ⁻¹

P3S2	60 kg P ha ⁻¹ and 20kg S ha ⁻¹
P3S3	60 kg P ha ⁻¹ and 30kg S ha ⁻¹

Crop : black gram (JU- 86)
 Design : Factorial Randomized Block Design
 Replications : 03
 Treatment : 16
 Gross plot size : 4.00 m x 3.20 m = 12.8 m²
 Net plot size : 3.20 m x 2.60 m = 8.32 m²
 Distance between plots : 50 cm
 Distance between replications : 1.00 m

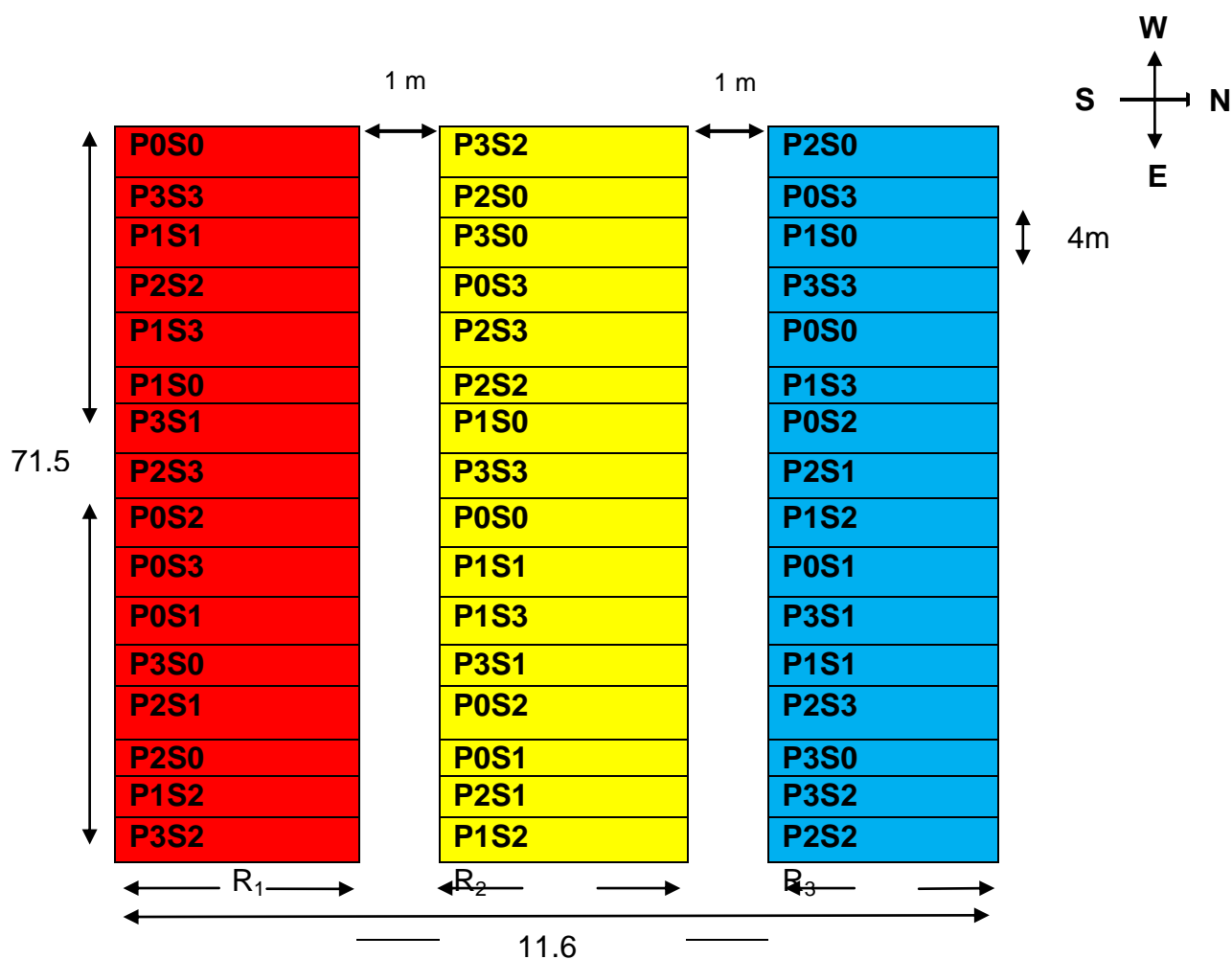


Fig.2. Plan of the layout of experimental plot

Plot size: (i) Gross plot size = 4 x 3.20 m², (ii) Net plot size = 3.20 x 2.60 m²

P0 = 0 kg P/ ha, P1 = 20 kg P/ha, P2 = 40 kg P/ha, P3 = 60 kg P/ha, S0= 0kg S/ha S1 = 10 kg S/ha S2 = 20 kg S/ha S3 = 30 kg S/ha.

Seed rate : 25kg/ha.

Crop geometry : 40 cm x 8cm

Date of sowing : 30/06/2016 (end of June)

Date of harvesting : 13/10/2016 (Second week of October)

3.6 Field Operations

Various operation undertaken prior to planting of the crop and after planting have been summarized in Table 3.3. These operations included field preparation, fertilizer application, sowing, inter culture, plant protection measure, sampling, and harvesting etc.

Table 3.3 date of different field operation

SN	Operations	Date	Remark
1.	Field preparation:		
	(a) Cultivation	21/06/16	
	(b) Bakhering	25/06/16	
	(c) Leveling	26/06/16	
2.	Field layout	28/06/16	Manually
3.	Soil sampling	29/06/16	by soil auger
4.	Fertilizer application and sowing	30/06/16	
5.	Weeding and maintenance of plant population	10/07/16	Manually
6.	Spray of Trizophos for plant protection	02/08/16	Manually
7.	Harvesting	13/10/16	Manually
8.	Threshing	18/10/16	Manually

3.7 Varietal characteristics

JU-86-

It is a cross between K-8219 x RU-2 Indore. It is a semi spreading, medium in

height, dark green color of leaves, pod medium brownish back medium size, 100 seed weight 3 -3.5 g, seed cylindrical shining black with slight tinge, flowering about 30-35 days, it has 20-22 % protein and yield potential 1800 – 2000 kg/ha.

3.8 details of agronomical practices

3.8.1 Field preparation

The field was ploughed once in summer with tractor drawn plough followed by two cross harrowing. Finally blade harrowing (Bakhering) was carried out before sowing followed by planking to level the field properly for desirable seedbed for sowing.

3.8.2 Seed and seed rate

For ensuring good germination, healthy and good quality seeds were used. Seed at the rate of 25 kg/ha was sown for optimum plant population.

3.8.3 Seed treatment

The seed of black gram variety (JU-86) treated with fungicide Thirum @ 3 g/kg seed and *Rhizobium* culture @ 5 g/kg

3.8.4 Depth of sowing

depth of 3-4 cm was kept approximately for sowing.

3.8.5 Method of fertilizer application and sowing

In experimental plot furrows were opened with the help of small *kudali* at a distance of 40 cm. The calculated quantity of fertilizer to supply prescribed levels of nutrients as per treatments was applied plot wise. The weighed quantities of fertilizer as per treatment (20 kg N 20 kg K₂O /ha and prescribed levels of P for each plot/treatment) were applied through Diammonium phosphate (DAP) and additional quantity of N by urea and Muriate of potash (MOP) and sulphur (Cossavet), respectively. Entire required quantity of nitrogen, phosphorus, potash and sulphur were applied at the time of sowing, as basal application.

All the fertilizer were applied as basal dose in furrows and mixed with soil before placing the seed in furrows. The required quantity of seeds were placed in furrows by hand and covered with soil immediately.

3.8.6 Weeding

hand weeding was done to keep the crop weed free.

3.8.7 Plant protection operations

To protect the crop from insects and pests, one spray Trizophos 35 EC @ 1.5 liter with 650 liter of water was sprayed on the crop.

3.8.8. Harvesting

The crop was harvested on 13 Oct 2016. Before harvesting of the crop, five randomly tagged plants from each plot of the crop were taken out for recording post harvest scheduled observations. After harvesting the produce of each plot was tied in bundles properly labeled and it was allowed to dry in the field for about 4 – 5 days. The produce of individual plot was threshed separately and winnowed. Yield of the crop in kilograms obtained from each net plot was recorded.

3.9 observations recorded

The observations for different growth parameter were recorded prior to harvest of the crop. These observations were made on randomly selected and then tagged plants from each plot and the treatments. Later on post harvest observations for different yield attributes and yield were recorded as detailed below.

Table 3.4 (i) **Growth parameters taken on date wise**

S.N.	Observation to be recorded	Date
1.	Plant population (i) first observation (ii) second observation	30 July 8 Oct.
2.	Plant height & No. of leaves (i) first observation (ii) second observation (iii) third observation (iv) fourth observation	30 July 15 August 30 August 8 Oct.
3.	No. of root nodules/plant, leaf area(cm ²), Chlorophyll content (SPAD), Light intensity by lux meter, Dry matter/plant, CGR, RGR (i) first observation (ii) second observation (iii) third observation	30 July 15 Aug. 30 Aug.

4.	No. of pods/plant, No. of seeds/pod	08 Oct.
5.	Seed yield, biological yield, straw yield, Harvest index, seed index	20 oct.

- (1.) Plant population / meter² : at 30 DAS & at harvest
- (2.) Plant height (cm) : at 30, 45, 60 DAS & at harvest
- (3.) Number of leaves : at 30, 45, 60 DAS & at harvest
- (4.) Number of root nodules / plant : at 30, 45, 60 DAS
- (5.) Leaf area (cm²) : at 30, 45, 60 DAS
- (6.) Chlorophyll content (SPAD) : at 30, 45, 60 DAS
- (7.) Light intensity by lux meter : at 30,45, 60 DAS
- (8.) Dry matter/plant : at 30, 45, 60 DAS
- (9.) CGR : at 30, 45, 60 DAS
- (10.) RGR : at 30, 45, 60 DAS

(ii) Yield attributing characters

- (1.) Number of pods / plant
- (2.) Number of seeds / pod
- (3.) Seed index
- (4.) Biological yield (kg/ plot)
- (5.) Seed yield (kg/plot)
- (6.) Straw yield (kg/ plot)

(iii) Data computed

- (1.) Plant population/m²at 30 DAS and maturity
- (2.) Seed and straw yield (kg/ha)
- (3.) Harvest index (%)

(iv) Chemical analysis

- (1.) Soil analysis for N P K and S before sowing and after harvesting of crop.
- (2.) Soil analysis for organic carbon, Ec, pH before sowing and after harvesting of crop.
- (3.) N P K & S uptake by plant at harvesting stage.

(v) Economic analysis of the treatments

- (1.) Cost of cultivation (Rs/ha)
- (2.) Gross monetary returns (Rs /ha)
- (3.) Net monetary returns (Rs/ ha)
- (4.) Benefit cost ratio (B: C ratio)

3.10 Methodology adopted for recording different observations

A brief resume of the techniques used for recording different observations have been given in this section.

3.10.1. Pre-harvest observations

Various observations recorded prior to harvest of the crop under different treatments have been given in the following paragraphs.

3.10.1.1 Plant population

The plant population/m² was taken initially and finally at 15 DAS and before harvesting. Plant population was counted per meter row length at three random rows within each net plot and the mean thus obtained was used to estimate plant population.

3.10.1.2. Plant height

Five plants per plot were selected randomly and tagged for taking observation on height of the plant 30, 45 and 60 DAS and at harvest. The height was measured from the ground surface to the tip of plant.

3.10.1.3. Number of leaves/plant

The number of green leaves were counted on five already tagged plants at 30, 45, 60 DAS and at harvest of the crop in all the plots.

3.10.1.4. Number of nodules/plant

Five plants were randomly selected from each plot, for counting of root nodules. A block of soil containing the plants was dug out at the distance of 15 cm either side of row to a depth of 22.5 cm. The soil adhering on the root system was removed by gentle washing with water and the average number of nodules per plant was recorded at 30, 45 and 60 days after sowing (DAS).

3.10.1.5. Leaf area (cm² / plant)

Leaf area was measured at 30, 45 and 60 DAS and at harvesting stage by leaf area meter software.

3.10.1.6 Chlorophyll content (SPAD 500)

It was measured with the help of an instrument, named “SPAD 500 meter”. The unit of chlorophyll content readings were taken on five tagged plant at 30, 45, 60 DAS in standing crop. Three leaves (from top, middle and bottom) per plant were selected. Each leaf was clamped in the chlorophyll meter for a fraction of second than chlorophyll meter gave the value in SPAD on digital display of screen. The value of chlorophyll content (SPAD) shows relative distribution of chlorophyll in leaves.

3.10.1.7. Light intensity by lux meter

It was measured with the help of an instrument, named “Lux meter”. The unit of light intensity readings were taken on five tagged plant at 30, 45, 60 DAS in standing crop. Three leaves (from top, middle and bottom) per plant were selected. Press the range select button until desired range. Remove the photo detector cap and face it to light source. Read the test value from the LCD display. Data-hold mode: “DH” key to select hold mode. During hold mode, the value is locked on the LCD and the reading taken.

3.10.1.8 Estimated growth parameter

Using the data on total dry matter from each specific treatment, Crop Growth Rate (CGR) and Relative Growth Rate (RGR) growth parameters were derived by following the below mentioned calculation (Hunt, 1978):

Crop Growth Rate (CGR)

Crop growth rate was calculated using the following formula:

$$\text{CGR} = \frac{1}{\text{GA}} \times \frac{\text{W}_2 - \text{W}_1}{\text{T}_2 - \text{T}_1} \text{ g m}^{-2}\text{day}^{-1}$$

Where,

GA = Ground area (m²)

W₁ = Total dry weight at previous sampling date (T₁)

W₂ = Total dry weight at current sampling date (T₂)

T₁ = Date of previous sampling

T₂ = Date of current sampling

Relative Growth Rate (RGR)

Relative growth rate was calculated using the following formula:

$$\text{RGR} = \frac{\text{LnW2} - \text{LnW1}}{\text{T2-T1}} \quad (\text{g g}^{-1}\text{day}^{-1})$$

Where,

W1 = Total dry weight at previous sampling date (time T1)

W2 = Total dry weight at current sampling date (time T2)

T1 = Date of previous sampling

T2 = Date of current sampling

Ln = Natural logarithm

3.10.2 Post-harvest observations

3.10.2.1 Number of pods / plant

The number of pods per plant was counted on 5 tagged plants collected from each plot at maturity and the average was worked out.

3.10.2.2 Number of seeds / pod

Random samples of 20 pods were drawn from each plot to work out the average number of grains/pod.

3.10.2.3 Seed index (100 seed weight)

Representative seeds samples were drawn from finally cleaned produce from each plot. The seeds were counted and thereafter the weight was recorded.

3.10.2.4 Biological yield

Biological yield is the sum of grain and straw yield of the specified treatment / plot.

3.10.2.5 Seed yield

After picking, threshing and winnowing, the grain yield of each plot was weighed and recorded in kilograms. The plot yield was later on converted into kg/ha.

3.10.2.6 Straw yield

After picking the crop, bundle of each plot was weighed and recorded as per treatment in kilograms and thereafter, the straw yield was calculated by subtracting the grain yield from the bundle weight. The results were expressed in kg/ha.

3.10.2.7 Harvest index (%)

Harvest index is the ratio of economic yield (kg/ha) to biological yield (kg/ha) and multiplied by 100 to obtain its value in percentage. The harvest index is calculated by using the following equation.

$$\text{Harvest index\%} = [\text{Economic yield (kg/ha)} / \text{Biological yield (kg/ha)} \times 100]$$

3.11 Analytical procedure

3.11.1 collection and preparation of soil sample

Soil samples were collected randomly from plough layer depth with the help of soil sampling tube before sowing and after harvesting of crops each plot and finally composite soil samples were made. The samples were mixed thoroughly and dried and air, crushed, sieved through 2 mm sieve. The soil

samples so prepared were subjected to chemical analysis for evaluating soil fertility status following standard procedures. Different methods adopted for chemical analysis of soil samples have been briefly described as below.

3.11.1.1 Mechanical analysis

Mechanical composition of the soil samples was determined by adopting Bouyoucos hydrometer method as described by Piper (1950) and reported as percentage.

3.11.1.2 Soil pH

Soil pH was determined by using Beckman glass electrode pH meter in 1:2 soil: water suspensions at 25⁰C. (Piper, 1967).

3.11.1.3 Electrical conductivity

Electrical conductivity was also determined by electrical conductivity meter in 1:2 soil water suspensions at 25⁰C and it is expressed as dS /m (deciseimans per meter).

3.11.1.4 Organic carbon

Organic carbon was determined by Walkley and Black (1934) wet digestion method. Organic carbon content in soil is expressed in percent of soil.

3.11.1.5 Available nitrogen (kg/ ha)

Determination of available nitrogen was done by alkaline permanganate method suggested by Subbiah and Asija (1956).

3.11.1.6 Available phosphorus (kg/ha)

The estimation of available P was done by using Olsen's extract (0.5 N sodium bicarbonates solution of pH 8.5) as referenced by Olsen's et al.(1954). It was determined as stannous chloride reduced to blue color. The extraction procedure adopted was as described by Black (1965) and developing the colure in the extract (Motiramani and Wanklhede, 1965) using "UV visible Spectro Photometer".

3.11.1.7 Exchangeable potassium (kg/ha)

The available amount of potassium was determined by using normal neutral ammonium acetate by flame photometer (Black, 1956)

3.11.1.8 Available Sulphur

Available sulphur in soil samples was determined by turbidimetric method after extracting the soil with 0.15% CaCl₂ Solution (Tandon, 1995).

3.11.1.9 N,P, K & S uptake by plant at harvesting stage

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient concentration (\%)} \times \text{yield (kg/ha)}}{100}$$

3.12 Computation of economics of treatment

Several economics indices are available to evaluate the profitability of cropping system. No single index is capable of giving good comparison of different cropping system and so a number of indices are used together to assess the economic viability of the system. Since the price of farm produce changes from year to year and season to season and also place to place, the profitability of the system also changes accordingly. The procedures used for working out economics of different treatments under consideration was as suggested by Yang and Dhondhyal (1971)

3.12.1 Cost of Cultivation (Rs/ha)

Cost of cultivation is the total expenditure incurred for raising crop in a treatment. The cost included for this purpose consists of own or hired human labour. Owned or hired bullock labor, value of seed, manures, fertilizers, pesticides, herbicides and irrigation charges. A poor farmers may choose a practices with lesser cost of cultivation though it gives lesser profit, because of limited resources.

3.12.2 Gross Monetary Returns (Rs/ha)

Gross returns are the total monetary value of economic produce and byproduct obtained from the crop raised in the different treatments is calculated based on the local market prices.

3.12.3 Net Monetary Returns (Rs/ha)

It is computed by subtracting cost of cultivation from gross returns. It is good indicator of suitability of a cropping system since this represents the actual income of the farmer. Monetary returns for different treatments were

calculated with the help of prevailing market rates of produce and different inputs used in the experiments (Table 4.16).

Net Monetary Returns(Rs/ha) = Gross return (Rs/ha) – Cost of cultivation (Rs/ha).

3.12.4 Benefit cost ratio

It is the ratio of gross returns to cost of cultivation. It is expressed as returns per rupee invested. This index provides an estimate of the benefit a farmer derives for the expenditure he incurs in adopting a particular cropping system. Any value above 2.0 is considered safe as the farmer gets Rs. 2 for every rupee invested.

$$\text{Benefit cost ratio} = \text{Gross return (Rs/ha)}/\text{Cost of cultivation (Rs/ha)}$$

3.13 Statistical analysis

The statistical design of experiment was Factorial randomized design with three replications. The data was analyzed by following the method of analysis of variance as described by Panse and Sukhatme (1967). The table of skeleton of analysis showing degrees of freedom for variance have been presented in Table 3.5.

The null hypothesis was tested (t' test) which revealed the significance of the treatments effect. The critical difference for treatment means was calculated by using the equation. Standard errors means were calculate from error mean square as follows:

Table.- 3.5 Skeleton of complete analysis of variance.

Source	Df	SS	MSS	F- calculated	F 5 % tabulated	F 1 % tabulated
Replication	2	RSS	RMS	RMS/EMS	-	-
Treatments:		TrSS	TrMS	TrMS/EMS	-	-
Phosphorus	3					
Sulphur	3					
Interaction	9					

(P x S)						
Errors	30	ESS	EMS	-	-	-
Totals	47	TSS		-		

Where,

r = Number of replications

t = Number of treatments

D.F. = Degrees of freedom

RSS = Replication sum of square

TrSS = Treatment sum of square

ESS = Error sum of square

TSS = Total sum of square

RMS = Replication mean sum of square

TrMS = Treatment mean sum of square

EMS = Error mean sum of square

A significant value of F test indicates that the test entries differ significantly among themselves, which requires computing.

$$SE_{\bar{m}} \pm = \sqrt{\frac{EMS}{r}}$$

$$SE_d = \sqrt{\frac{2 EMS}{r}}$$

CD at 5% prob. Level = $SE_d \times t$ at 5% table value

Where,

$SE_{\bar{m}} \pm$ = Standard error of means

S E diff. = Standard error of difference

C.D. = Critical difference

t 5% = t, table value 5% probability level at error degree of freedom.

RESULT

CHAPTER – IV

RESULT

The present chapter deals with experimental finding obtained during the course of investigation. The results obtained from the presented study have been interpreted and presented under the following headings:

A. Pre harvest studies

4.1 Effect of different levels of phosphorus and sulphur on mean plant population/m²

Table- 4.1 Effect of different levels of phosphorus and sulphur on plant population/m² of black gram at 30 DAS and at harvest stages.

Factors	Treatments	Mean plant population at different times (No. of plants/m ²)	
		30 DAS	At harvest
(a) Phosphorus	P ₀ -(0 kg P/ha)	36.42	34.50
	P ₁ -(20 kgP/ha)	36.08	34.17
	P ₂ -(40kg P/ha)	35.50	32.75
	P ₃ -(60kg P/ha)	35.50	33.83
(b) Sulphur	S ₀ -(0 kg S/ha)	36.00	33.16
	S ₁ -(10 kg S/ha)	35.91	34.41
	S ₂ -(20 kg S/ha)	35.83	34.08
	S ₃ -(30 kg S/ha)	35.75	33.58
	S. Em (±)	0.52	2.68
	C.D. 5%	NS	NS
(c) Interaction: (P x S)	S. Em (±)	1.05	5.37
	C.D. 5%	NS	NS

NS – Non significant

Data presented in Table 4.1 indicated the mean plant population/m² of black gram at 30 DAS and at harvest of the crop. Initially at the time of sowing little

higher seed rate was maintained and plant population was made uniform in all the plots by thinning of the plants to maintain higher levels of accuracy in assessing the impact of different treatments under consideration. It is obvious from the data that the differences in plant population due to factors as well as due to their interaction were statistically non significant so these was no treatment effect because plant population was maintained by thinning.

4.2. Effect of different levels of phosphorus and sulphur on mean plant height (cm)

Table-4.2 Effect of different levels of phosphorus and sulphur on plant Height (in cm) of black gram at 30 DAS,45 DAS,60 DAS and at harvest stages.

Factors	Treatments	Mean plant height (in cm) at different times			
		30DAS	45 DAS	60 DAS	Atharvest
(a) Phosphorus	P ₀ -(0 kg P/ha)	21.03	31.00	37.44	42.29
	P ₁ -(20 kg P/ha)	21.14	31.36	37.66	42.76
	P ₂ -(40kg P/ha)	21.31	31.70	37.76	43.88
	P ₃ -(60kg P/ha)	21.54	31.84	37..94	44.06
(b) Sulphur	S ₀ -(0 kg S/ha)	21.01	31.26	37.45	43.10
	S ₁ -(10 kg S/ha)	21.05	31.34	37.50	43.29
	S ₂ -(20 kg S/ha)	21.35	31.58	37.87	43.37
	S ₃ -(30 kg S/ha)	21.60	31.72	37.96	43.41
	S. Em. (±)	0.41	0.53	0.60	0.25
	C.D. 5%	1.21	1.54	1.74	0.73
(c) Interaction: (P x S)	S. Em. (±)	0.83	1.07	1.20	0.50
	C.D. 5%	NS	NS	NS	NS

NS – Non significant

Data presented in Table 4.2. indicated the mean plant height (in cm) of black gram at 30,45, 60 and at harvest stages increased significantly with increasing doses of phosphorus and sulphur, however, the impact of interaction of phosphorus and sulphur (P X S) did not show any significant effect on mean plant height (in cm) at any of the stage. While, the treated plot

showed more plant height in comparison to the control plot at all the stages.

4.3. Effect of different levels of phosphorus and sulphur on mean no. of leaves

Table- 4.3 Effect of different levels of phosphorus and sulphur on mean no. of leaves of black gram at 30 DAS, 45 DAS, 60 DAS and at harvest stages.

Factors	Treatments	Mean no. of leaves at different times			
		30 DAS	45 DAS	60 DAS	At Harvest
(a) Phosphorus	P ₀ -(0 kg P/ha)	5.49	7.29	9.76	3.14
	P ₁ -(20 kg P/ha)	5.83	7.76	9.89	3.43
	P ₂ -(40kg P/ha)	6.23	8.35	10.18	3.59
	P ₃ -(60kg P/ha)	7.02	8.63	10.36	3.67
(b) Sulphur	S ₀ -(0 kg S/ha)	5.82	7..47	9.69	3.31
	S ₁ -(10 kg S/ha)	6.00	7.74	10.04	3.36
	S ₂ -(20 kg S/ha)	6.24	8.26	10.13	3.59
	S ₃ -(30 kg S/ha)	6.49	8.56	10.32	3.67
	S. Em. (±)	1.52	0.88	0.77	0.83
	C.D. 5%	4.40	2.52	2.22	NS
(c) Interaction: (P x S)	S. Em. (±)	3.05	1.76	1.54	1.67
	C.D. 5%	NS	NS	NS	NS

NS – Non significant

Data presented in Table 4.3. indicated that the mean no. of green leaves of black gram per plant gradually increased with the advancement of growth period up to 60DAS. There was steep decline in the mean no. of green leaves per plant during the period from 60 DAS to harvesting. Mean no. of leaves increased significantly with increasing doses of phosphorus and sulphur, up to 60 DAS.

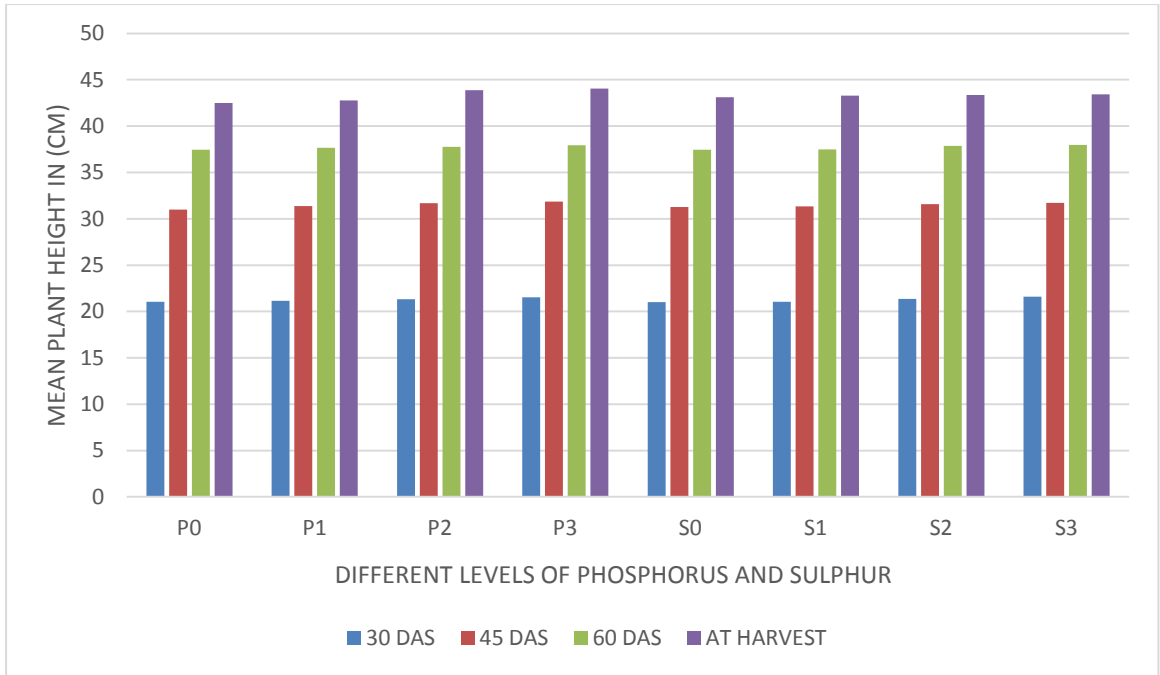


Fig-3 Mean plant height in (cm) of black gram at different treatments

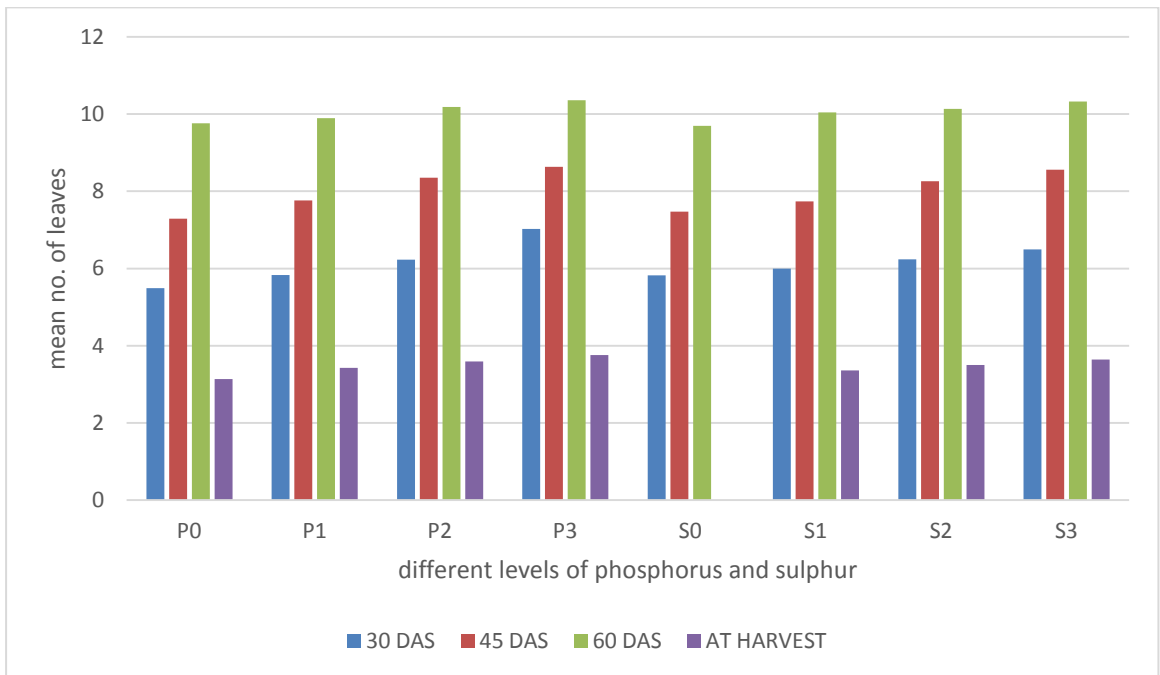


Fig- 4 Effect of different levels of phosphorus and sulphur on mean no. of leaves at different stages.

While, at harvest stage was not significantly different however, the impact of interaction of phosphorus and sulphur (P X S) did not show any significant effect on mean no. of leaves at any of the stage. While, the treated plot showed higher mean no. of leaves in comparison to the control plot at all the stages.

4.4. Effect of different levels of phosphorus and sulphur on mean no. of root Nodules/plant

Table- 4.4 Effect of different levels of phosphorus and sulphur on mean no. of root nodules of black gram at 30 DAS, 45 DAS, 60 DAS and at harvest stages.

Factors	Treatments	Mean no. of root nodules at different times		
		30DAS	45 DAS	60 DAS
(a) Phosphorus	P ₀ -(0 kg P/ha)	38.40	51.86	41.94
	P ₁ -(20 kg P/ha)	39.49	52.29	43.44
	P ₂ -(40kg P/ha)	40.90	53.07	45.29
	P ₃ -(60kg P/ha)	42.25	54.06	46.82
(b) Sulphur	S ₀ -(0 kg S/ha)	38.94	51.84	40.01
	S ₁ -(10 kg S/ha)	40.01	52.44	43.02
	S ₂ -(20 kg S/ha)	40.84	53.11	46.13
	S ₃ -(30 kg S/ha)	41.22	53.98	48.31
	S. Em. (±)	3.06	2.55	2.84
	C.D. 5%	8.86	7.38	8.21
(c) Interaction: (P x S)	S. Em. (±)	6.13	5.11	5.68
	C.D. 5%	NS	NS	NS

NS – Non significant

Data presented in Table 4.4. indicated the mean no. of root nodules of black gram per plant gradually increased with the advancement of growth period up to 45 DAS. There was steep decline in the mean no. of root nodules per plant during the period from 60 DAS to harvesting.

Mean no. of root nodules increased significantly with increasing doses of phosphorus and sulphur, up to 45 DAS. While, however the impact of

interaction of phosphorus and sulphur (P X S) did not show any significant effect on mean no. of root nodules at any of the stage. While, the treated plot showed high no. of root nodules in comparison to the control plot at all the stages.

4.5. Effect of different levels of phosphorus and sulphur on mean leaf area (cm²/plant)

Table-4.5 Effect of different levels of phosphorus and sulphur on mean leaf area in cm²/plant of black gram at 30 DAS,45 DAS, 60 DAS and at harvest stages.

Factors	Treatments	Mean leaf area in cm ² /plant at different times		
		30 DAS	45 DAS	60 DAS
(a) Phosphorus	P ₀ -(0 kg P/ha)	186.12	219.51	240.21
	P ₁ -(20 kg P/ha)	196.95	284.93	311.17
	P ₂ -(40kg P/ha)	206.05	334.86	380.56
	P ₃ -(60kg P/ha)	209.48	337.31	386.75
(b) Sulphur	S ₀ -(0 kg S/ha)	154.64	266.89	310.48
	S ₁ -(10 kg S/ha)	207.70	286.59	329.22
	S ₂ -(20 kg S/ha)	216.45	310.84	333.26
	S ₃ -(30 kg S/ha)	219.84	312.32	345.79
	S. Em. (±)	3.04	1.79	6.79
	C.D. 5%	8.80	5.80	19.62
(c) Interaction: (P x S)	S. Em±	6.09	3.58	13.5
	C.D. 5%	17.61	10.34	39.54

Data presented in Table 4.5 indicated that mean leaf area (cm²/plant) of black gram at 30 DAS, 45 DAS, and 60 DAS of the crop. increased significantly with increasing doses of phosphorus and sulphur, as well as the impact of interaction(Table 4.5.1) of phosphorus and sulphur (P X S) is also significantly effect on mean leaf area (cm²/plant) at all of the stages and the treated plot showed more mean leaf area in comparison to the control plot at all the

stages.

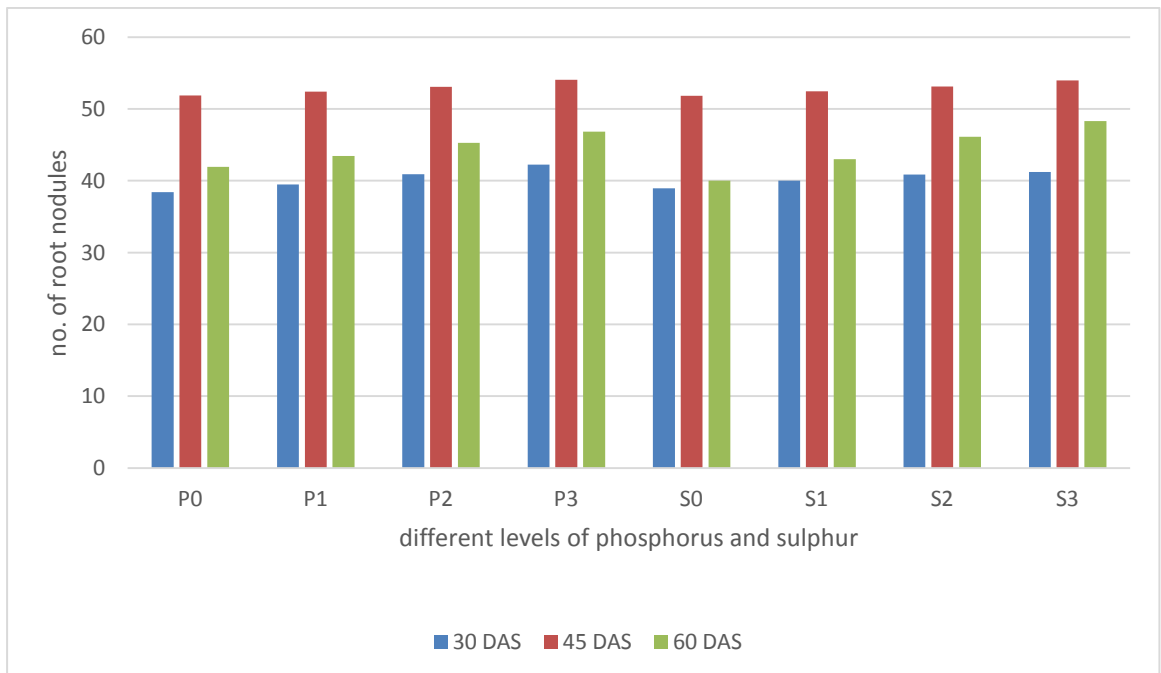


Fig. - 5 Different levels of phosphorus and sulphur on mean no. of root nodules at different stages

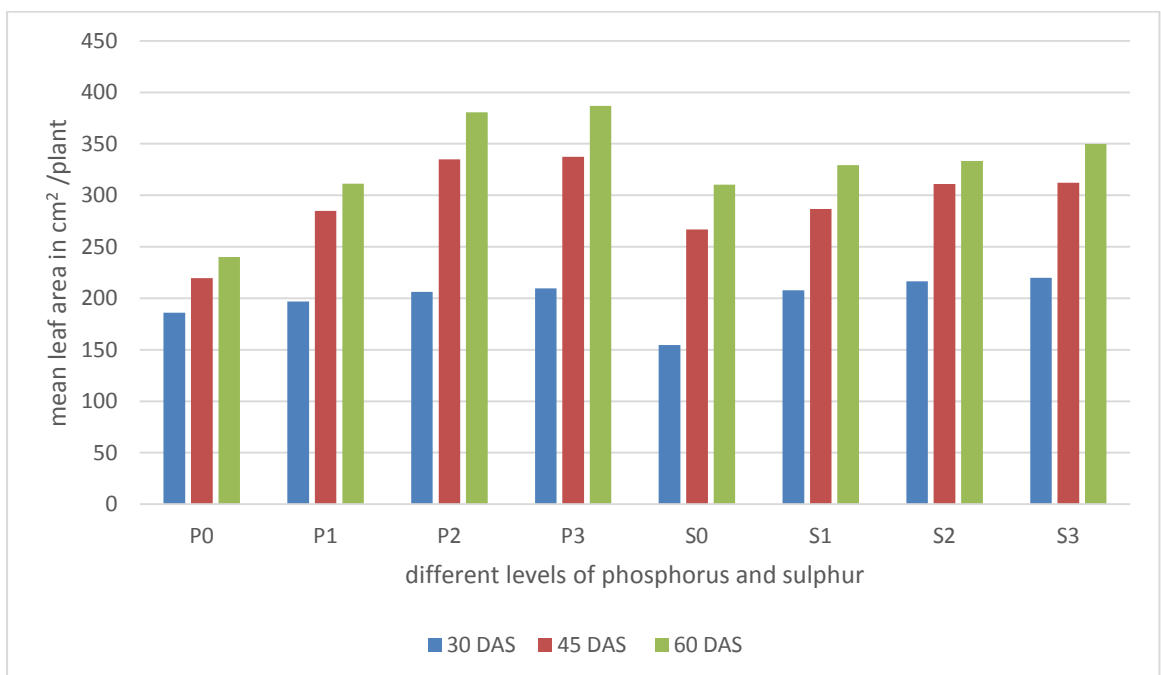


Fig- 6. Different levels of phosphorus and sulphur on mean leaf area in cm²/plant at different stages.

Table –4.5.1 two way Table for leaf area (in cm²/plant) on at 60 DAS due to P x S levels.

S levelss	P levels			
	P0	P1	P2	P3
S0	224.18	287.29	364.23	366.21
S1	238.04	298.29	390.55	389.98
S2	247.33	313.99	375.55	396.14
S3	245.28	345.14	391.93	394.66
S. Em±			13.58	
CD at 5%			39.24	

4.6. Effect of different levels of phosphorus and sulphur on mean Chlorophyll Content (SPAD)

Data presented in Table 4.6. indicated that the mean chlorophyll content in black gram increased significantly with increasing doses of phosphorus and sulphur, up to 45 DAS. While, at 60 DAS is no any significant difference as well as the impact of interaction of phosphorus and sulphur(P X S) did not show any significant effect on mean chlorophyll content (SPAD) at any of the stages. While, the chlorophyll content (SPAD) decreased with increase of the crop stages.

Table-4.6 Effect of different levels of phosphorus and sulphur on mean chlorophyll content (SPAD)in black gram leaves at 30 DAS, 45 DAS, 60 DAS and at harvest stages.

Factors	Treatments	Mean chlorophyll content in black gram leaves at different times		
		30 DAS	45 DAS	60 DAS
(a) Phosphorus	P ₀ -(0 kg P/ha)	47.53	43.94	36.62
	P ₁ -(20 kg P/ha)	49.95	46.12	37.47
	P ₂ -(40kg P/ha)	50.15	47.40	38.38
	P ₃ -(60kg P/ha)	51.33	48.25	38.07

(b) Sulphur	S ₀ –(0 kg S/ha)	47.58	44.09	37.45
	S ₁ -(10 kg S/ha)	48.91	46.25	37.60
	S ₂ –(20 kg S/ha)	50.61	47.19	37.68
	S ₃ –(30 kg S/ha)	51.89	48.19	37.82
	S. Em. (±)	4.85	2.67	2.91
	C.D. 5%	14.01	7.72	NS
(c) Interaction: (P x S)	S. Em. (±)	9.70	5.34	5.82
	C.D. 5%	NS	NS	NS

NS – Non significant

4.7. Effect of different levels of phosphorus and sulphur on mean

Light intensity by (lux meter)

Data presented in Table 4.7.1, 4.7.2, 4.7.3 indicated that the mean light intensity of black gram crop have no any significant effect of different levels of phosphorus and sulphur as well as their interaction at all the time as well as all the stages(i.e. 30,45,60 DAS).

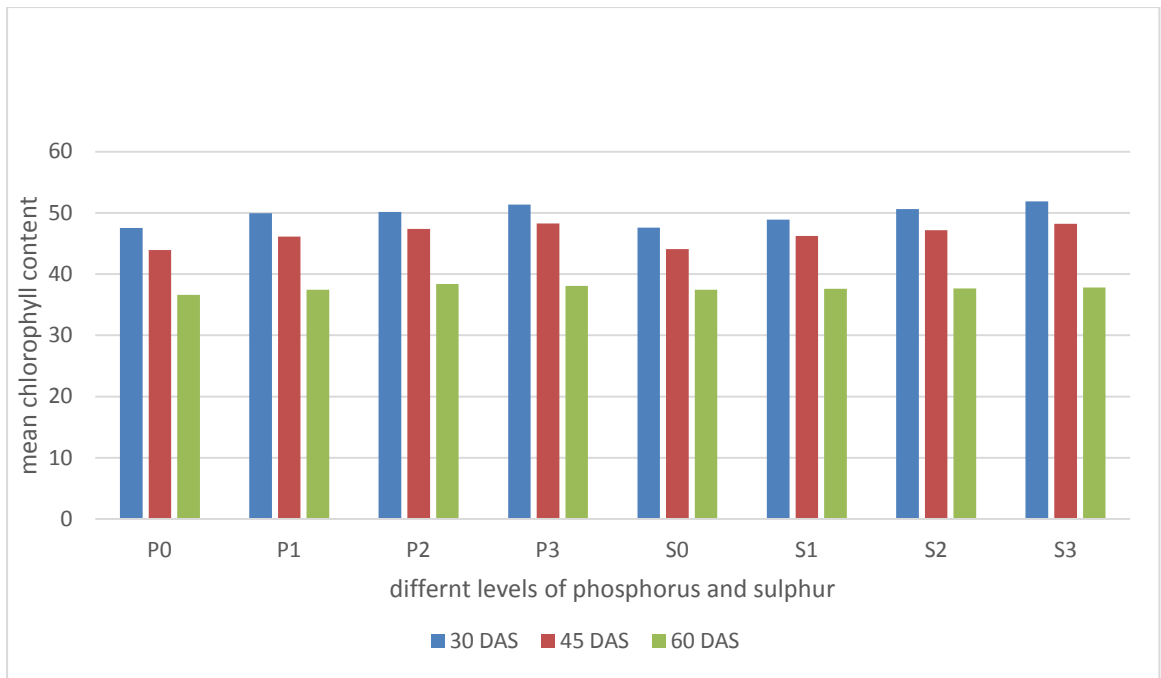


Fig - 7. Different levels of phosphorus and sulphur on mean chlorophyll content in different stages.

Table- 7.1 Effect of different levels of phosphorus and sulphur on mean Light intensity at upper leaves of black gram crop at 30 DAS, 45 DAS, 60 DAS on 10 am and 2 pm.

Factors	Treatments	Mean light intensity of upper leaves on 10 am and 2 pm					
		30 DAS		45 DAS		60 DAS	
		10 am	2 pm	10 am	2 pm	10 am	2pm
Phosphorus	P ₀	614.83	754.50	762.25	785.67	867.08	926.50
	P ₁	637.25	821.67	760.42	760.42	872.42	937.42
	P ₂	628.83	799.25	761.75	786.50	881.58	938.92
	P ₃	625.08	794.92	773.00	782.25	869.17	945.83
Sulphur	S ₀	644.41	807.83	759.25	773.16	869.91	929.25
	S ₁	614.41	781	772.25	791.52	862.16	952.66
	S ₂	616.58	815.5	758.58	769.66	865.16	933.41
	S ₃	630.58	766	766.83	780.5	892.91	933.33
	S. Em. (±)	5.95	7.18	3.27	2.91	3.77	3.87
	C.D. 5%	NS	NS	NS	NS	NS	NS
(P x S)	S. Em. (±)	17.23	25.78	14.49	22.31	14.69	20.89
	C.D. 5%	NS	NS	NS	NS	NS	NS

Table- 7.2 Effect of different levels of phosphorus and sulphur on mean Light intensity at middle leaves of black gram crop at 30 DAS, 45 DAS, 60 DAS on 10 am and 2 pm.

Factors	Treatments	Mean light intensity of middle leaves on 10 am and 2pm					
		30 DAS		45 DAS		60 DAS	
		10 am	2 pm	10 am	2 pm	10 am	2pm
Phosphorus	P ₀	401.50	527.42	589.50	458.17	485.25	653.75
	P ₁	398.75	536.75	594.42	446.25	502.08	667.25
	P ₂	380.83	522.50	591.33	460.92	468.42	637.50
	P ₃	387.50	515.08	581.58	481.67	485.83	656.33

Sulphur	S ₀	385.08	535.41	584.25	460.75	485.58	656.66
	S ₁	393.25	530.18	597.57	449.75	493.00	661.33
	S ₂	387.91	526.16	585.83	464.75	484.25	646.33
	S ₃	402.33	509.58	589.00	471.75	478.75	650.50
	S. Em. (±)	6.05	4.15	4.49	4.52	4.13	2.83
	C.D. 5%	NS	NS	NS	NS	NS	NS
(P x S)	S. Em. (±)	11.98	17.28	10.92	14.57	17.84	13.28
	C.D. 5%	NS	NS	NS	NS	NS	NS

Table- 7.3 Effect of different levels of phosphorus and sulphur on mean Light intensity at lower leaves of black gram crop at 30 DAS,45 DAS, 60 DAS on 10 am and 2 pm.

Factors	Treatments	Mean light intensity of lower leaves on 10 am and 2 pm					
		30 DAS		45 DAS		60 DAS	
		10 am	2 pm	10 am	2 pm	10 am	2pm
Phosphorus	P ₀	181.08	252.67	211.75	242.08	252.67	264.92
	P ₁	187.50	259.92	180.08	239.25	262.75	275.25
	P ₂	187.58	258.67	215.42	252.08	252.83	272.92
	P ₃	182.00	250.33	199.08	251.25	259.50	279.33
Sulphur	S ₀	180.75	244.83	203.14	251.91	258.75	267.41
	S ₁	178.50	259.25	210.83	246.41	260.75	280.41
	S ₂	190.08	264.16	205.58	241.83	261.33	276.08
	S ₃	188.83	253.33	186.50	244.50	246.91	268.50
	S. Em. (±)	4.23	2.62	5.23	3.43	3.10	4.57
	C.D. 5%	NS	NS	NS	NS	NS	NS
(P x S)	S. Em. (±)	20.38	14.22	15.55	7.98	9.32	14.20
	C.D. 5%	NS	NS	NS	NS	NS	NS

4.8. Effect of different levels of phosphorus and sulphur on mean dry matter/plant

Data presented in Table 4.8. indicated the mean dry matter/plant of black gram at 30 DAS, 45DAS, 60DAS of the crop. Increased significantly with increase in doses of phosphorus and sulphur, while, the impact of interaction of phosphorus and sulphur (P x S) is hadnon significant effect on mean dry matter/plant at all the stages. The treated plot showed high mean dry matter/plant in comparison to the control plot at all of the stages.

Table-4.8 Effect of different levels of phosphorus and sulphur on mean dry matter/plant of black gram at 30 DAS, 45 DAS, 60 DAS.

Factors	Treatments	Mean Dry matter/plant		
		30 DAS	45 DAS	60 DAS
(a) Phosphorus	P ₀ -(0 kg P/ha)	1.30	4.98	10.19
	P ₁ -(20 kg P/ha)	1.42	5.63	10.75
	P ₂ -(40kg P/ha)	1.51	5.91	11.62
	P ₃ -(60kg P/ha)	1.66	6.30	13.12
(b) Sulphur	S ₀ -(0 kg S/ha)	1.31	5.14	10.31
	S ₁ -(10 kg S/ha)	1.42	5.38	11.15
	S ₂ -(20 kg S/ha)	1.52	5.97	11.86
	S ₃ -(30 kg S/ha)	1.66	6.36	12.38
	S. Em. (±)	0.43	1.42	3.78
	C.D. 5%	1.24	4.12	10.92
(c) Interaction: (P x S)	S. Em. (±)	0.86	2.85	7.56
	C.D. 5%	NS	NS	NS

NS – Non significant

4.9.Effect of different levels of phosphorus and sulphur on Mean Crop

Growth Rate

Data presented in Table 4.9 indicated that mean Crop Growth Rate of black gram at 30 DAS, 45 DAS, and 60 DAS of the crop. It is obvious from the datathat the differences in mean Crop Growth Rate due to main factor as well as due to their interaction were statistically non significant.

Table- 4.9 Effect of different levels of phosphorus and sulphur on mean Crop Growth Rate of black gram at 30 DAS, 45 DAS, 60 DAS.

Factors	Treatments	Mean Crop Growth Rate at different times		
		15-30DAS	30-45DAS	45-60 DAS
(a) Phosphorus	P ₀ -(0 kg P/ha)	3.13	3.20	2.43
	P ₁ -(20 kg P/ha)	2.79	3.07	2.26
	P ₂ -(40kg P/ha)	2.94	3.19	2.11
	P ₃ -(60kg P/ha)	3.29	3.38	2.11
(b) Sulphur	S ₀ -(0 kg S/ha)	2.68	3.24	1.99
	S ₁ -(10 kg S/ha)	3.06	3.06	2.38
	S ₂ -(20 kg S/ha)	3.17	3.26	2.22
	S ₃ -(30 kg S/ha)	3.27	3.30	2.34
	S. Em. (±)	0.86	1.01	1.75
	C.D. 5%	NS	NS	NS
(c) Interaction:	S. Em. (±)	1.73	2.02	3.50
(P x S)	C.D. 5%	NS	NS	NS

NS – Non significant

4.10. Effect of Different level of phosphorus and sulphur on mean Relative Growth Rate

Data presented in table 4.10. indicated that mean Relative Growth Rate of black gram at 30 DAS, 45 DAS, and 60 DAS of the crop .It is obvious from the data that the differences in mean Relative Growth Rate due to main factor as well as due to their interaction were statistically non significant.

Table- 4.10 Effect of different levels of phosphorus and sulphur on mean relative Growth Rate of black gram at 30 DAS, 45 DAS, 60 DAS

Factors	Treatments	Mean Relative Growth Rate at different times		
		15-30DAS	30-45DAS	45-60DAS
(a) Phosphorus	P ₀ -(0 kg P/ha)	0.030	0.036	0.022
	P ₁ -(20 kg P/ha)	0.038	0.036	0.021

	P ₂ –(40kg P/ha)	0.031	0.036	0.019
	P ₃ –(60kg P/ha)	0.041	0.035	0.018
(b) Sulphur	S ₀ –(0 kg S/ha)	0.035	0.028	0.020
	S ₁ –(10 kg S/ha)	0.035	0.044	0.019
	S ₂ –(20 kg S/ha)	0.036	0.034	0.020
	S ₃ –(30 kg S/ha)	0.035	0.037	0.021
	S. Em. (±)	0.02	0.02	0.01
	C.D. 5%	NS	NS	NS
(c) Interaction: (P x S)	S. Em. (±)	0.04	0.05	0.03
	C.D. 5%	NS	NS	NS

NS – Non significant

B. Post harvest observation

4.11. Effect of different levels of phosphorus and sulphur on mean no of pods /plant

The data presented in Table 4.11 showed that the increasing doses of phosphorus and sulphur increased the mean no. of pods/plant significantly, while the impact of phosphorus and sulphur interaction (P x S) did not show any significant effect. In control plot (P0S0 – 0 kg P ha⁻¹ and 0 kg S ha⁻¹) the mean no. of pods/plant showed minimum value (i.e. 22.55) while the treated plot (P3S3 - 60 kg P ha⁻¹ and 30 kg S ha⁻¹) showed significant highest value (i.e. 26.33).

Table –4.11.Effect of different levels of phosphorus and sulphur on mean no of pods/plant.

S levels	P levels				
	P0	P1	P2	P3	Average
S0	22.55	24.66	25.00	25.55	24.44
S1	23.88	25.00	24.62	26.00	24.87
S2	24.66	25.22	25.77	26.00	25.41
S3	24.77	25.22	25.78	26.33	25.52

Average	23.96	25.02	25.29	25.96	
		S.Em. (±)		CD at 5%	
P	1.46		4.23		
S	1.46		4.23		
P x S	2.92		NS		

NS- non significant

4.12. Effect of different levels of phosphorus and sulphur on mean no. of Seeds/Pod

The data presented in Table 4.12 showed that the increasing doses of phosphorus and sulphur increased the mean no. of seeds/pod significantly, while the impact of phosphorus and sulphur interaction (P x S) did not show any significant effect. In control plot (P0S0 – 0 kg P ha⁻¹ and 0 kg S ha⁻¹) the mean no. pods/plant showed minimum value (i.e. 5.20) while the treated plot (P3S3 - 60 kg P ha⁻¹ and 30 kg S ha⁻¹) showed significant highest value (i.e. 6.27) over control.

Table –4.12 Effect of different levels of phosphorus and sulphur on mean no. of Seeds/Pod.

S levels	P levels				
	P0	P1	P2	P3	Average
S0	5.20	5.25	5.38	5.50	5.33
S1	5.26	5.36	5.60	5.74	5.49
S2	5.61	5.89	5.95	6.14	5.90
S3	5.64	5.93	6.06	6.27	5.98
Average	5.42	5.60	5.74	5.91	
		S.Em. (±)		CD at 5%	
P	0.62		1.81		

S	0.62	1.81
P x S	1.25	NS

NS – Non Significant

4.13. Effect of different levels of phosphorus and sulphur on mean seed index

The data presented in Table 4.13 showed that the increasing doses of phosphorus and sulphur increased the mean seed index significantly, while the impact of phosphorus and sulphur interaction (P x S) did not show any significant effect. The treated plot showed more mean seed index in comparison to the control plot.

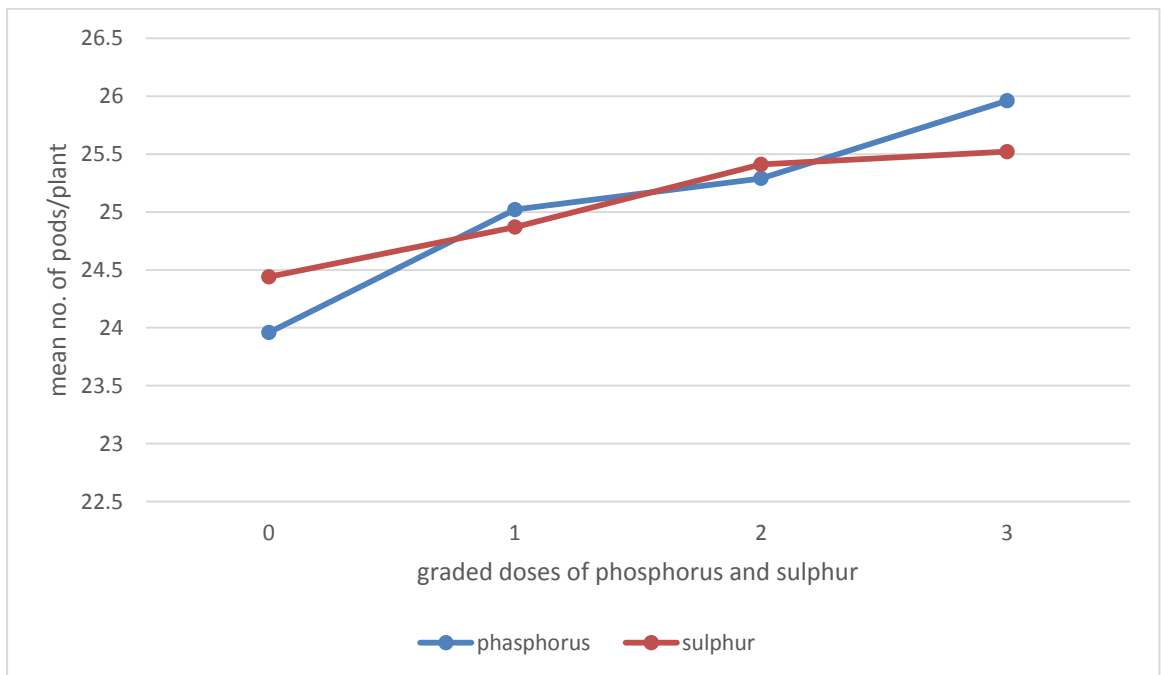


Fig.- 8. Different doses of phosphorus and sulphur on mean no. of pods/plant

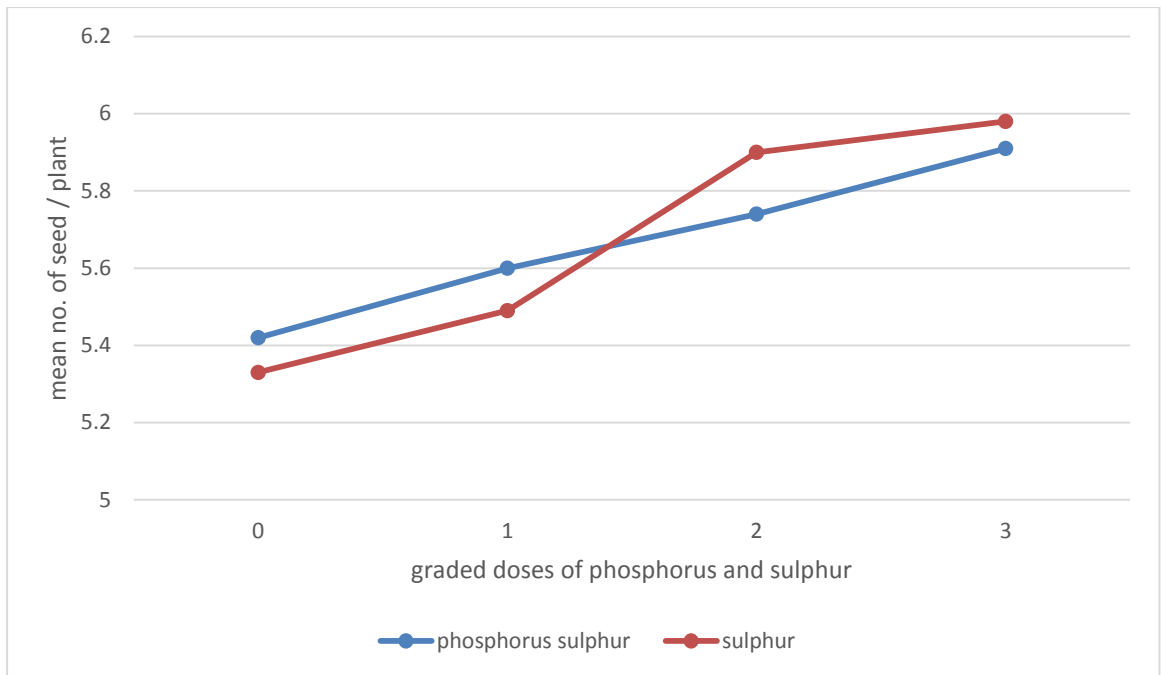


Fig- 9. Different doses of phosphorus and sulphur on mean no. of seed / pod.

Table – 4.13. Effect of different levels of phosphorus and sulphur on mean seed index. .

S levels	P levels				
	P0	P1	P2	P3	Average
S0	3.07	3.10	3.23	3.30	3.18
S1	3.13	3.20	3.27	3.33	3.23
S2	3.17	3.23	3.37	3.33	3.28
S3	3.17	3.30	3.40	3.47	3.33
Average	3.13	3.20	3.31	3.35	
		S.Em. (±)		CD at 5%	
P		0.17		0.50	
S		0.17		0.50	
P x S		0.35		NS	

NS – Non Significant

4.14. Effect of different levels of phosphorus and sulphur mean seed yield, Straw yield and biological yield (kg/ha)

The data presented in Table 4.14 indicated that the increasing doses of phosphorus increased the seed yield from 1067.16 to 1416.41 kg ha⁻¹ and sulphur increased the seed yield from 970.08 to 1405.83 kg ha⁻¹ significantly. Among all the treatment combination the P3S3 showed the higher yield (1614.41) but statistically was non significant.

The data presented in Table 4.14 indicated that, the increasing level of phosphorus significantly increased mean straw yield over P0 & P3, however S3 treatment showed significant increased mean straw yield over S0 & S3 treatment are on par but the interaction effect was found to have non significant effect.

Table-4.14.1 Effect of different levels of phosphorus and sulphur on mean yield in kg/ha of black gram.

Factors	Treatments	Yield (kg/ha)		
		Seed Yield	Straw yield	Biological yield
(a) Phosphorus	P ₀ -(0 kg P/ha)	1067.16	1553.83	2620.83
	P ₁ -(20 kg P/ha)	1156.91	1665.41	2822.33
	P ₂ -(40kg P/ha)	1258.75	1699.58	2948.33
	P ₃ -(60kg P/ha)	1416.41	1886.83	3303.25
(b) Sulphur	S ₀ -(0 kg S/ha)	970.08	1436.82	2406.50
	S ₁ -(10 kg S/ha)	1186.33	1663.25	2839.58
	S ₂ -(20 kg S/ha)	1337.00	1831.83	3168.83
	S ₃ -(30 kg S/ha)	1405.83	1874.17	3279.58
	S. Em. (±)	76.44	72.71	805.26
	C.D. 5%	220.75	209.98	2325.43
Interaction: (Pxs)	S. Em. (±)	152.89	145.43	1610.52
	C.D. 5%	NS	NS	NS

NS – Non significant

The data presented in Table 4.14 showed that increasing level of phosphorus and sulphur significantly increased mean biological yield but the interaction effect was found to have been Non significant effect.

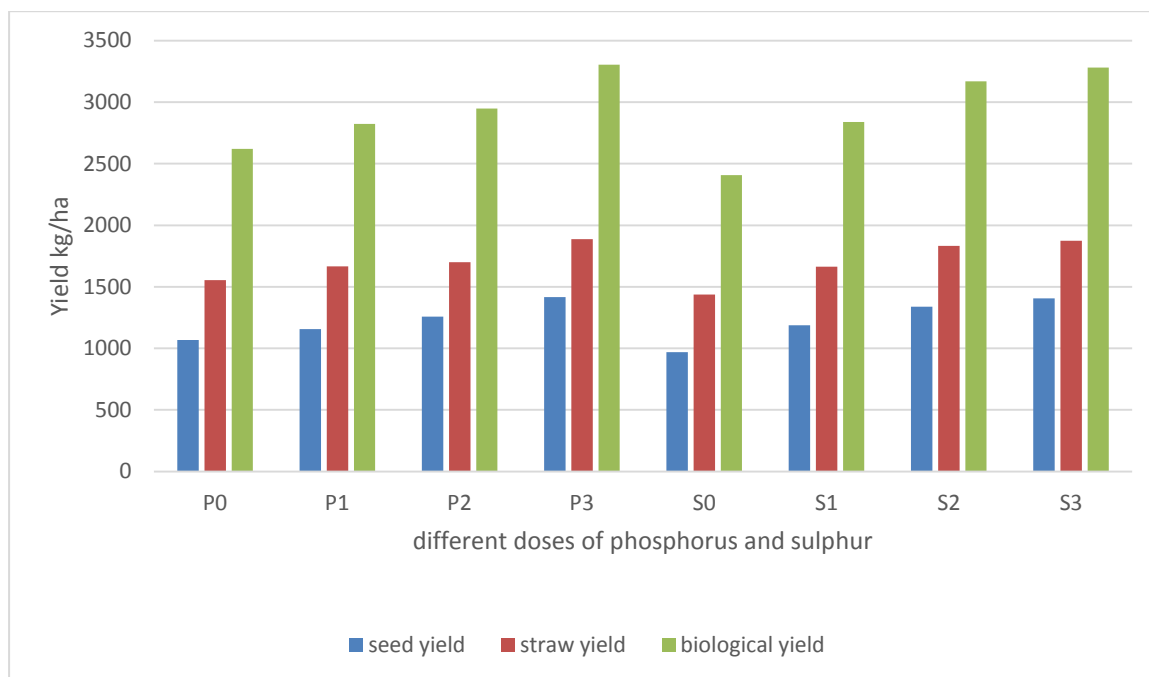


Fig- 10. Different doses of phosphorus and sulphur on mean seed yield, straw yield, and biological yield of black gram

Table-4.14.2 Effect of different levels of phosphorus and sulphur on mean yield in kg/plot of black gram.

Factors	Treatments	Yield (kg/plot)		
		Seed Yield	Straw Yield	Biological yield
(a) Phosphorus	P ₀ -(0 kg P/ha)	0.886	1.292	2.180
	P ₁ -(20 kg P/ha)	0.962	1.385	2.348
	P ₂ -(40kg P/ha)	1.047	1.414	2.453
	P ₃ -(60kg P/ha)	1.178	1.569	2.748
	S ₀ -(0 kg S/ha)	0.807	1.195	2.002

(b) Sulphur	S ₁ -(10 kg S/ha)	0.987	1.383	2.362
	S ₂ -(20 kg S/ha)	1.112	1.524	2.636
	S ₃ -(30 kg S/ha)	1.169	1.559	2.728
	S. Em. (±)	0.06	0.06	0.66
	C.D. 5%	0.18	0.17	1.93
Interaction: (Pxs)	C.D. 5%	NS	NS	NS

NS – Non significant

4.15. Effect of different levels of phosphorus and sulphur on mean Harvest Index

The data presented in Table 4.17 showed that increased levels phosphorus and sulphur was also increased harvest index but the data on the differences in mean harvest index due to main factors as well as due to their interaction were statistically non significant.

Table –4.15.Effect of different levels of phosphorus and sulphur on mean Harvest index.

S levels	P levels				
	P0	P1	P2	P3	Average
S0	37.46	39.85	43.03	41.33	40.41
S1	38.77	40.41	41.54	42.11	40.70
S2	40.54	42.87	42.20	43.94	42.38
S3	42.76	43.14	42.61	42.79	42.82
Average	39.88	41.57	42.35	42.54	

	S.Em. (\pm)	CD at 5%
Main factor	3.92	NS
Interaction P x S	7.84	NS

NS – Non Significant

4.16 Economics of treatment under study

Studies on the economics of the treatments are very important as they are of farmer's primary concerned for monetary returns and profitability of the crop. Recommendation and adoption of any practice of crop production for the farmer depends upon the economic viability of the treatments.

Hence, it becomes essential to work out the economics of Different treatments of the experiment conducted for determining the best treatment, which is as under.

Cost of cultivation

Total expenditure of each treatment is divided into two parts viz. common expenditure and treatments cost wise extra expenditure. Common expenditure include cost of field preparation, seed, sowing expenses, weeding, use of weedicide, insecticide, land revenue, spraying, watching, harvesting. Treatments cost wise extra expenditure i.e. fertilizer.

Gross and net monetary returns

The study of data in Table 4.18 revealed that maximum input of Rs 70210.66 was used in P3S3 treatment whereas the minimum Rs 31592.00 net return was incurred under S0P0 treatment.

A look at the Table no. 4.18 revealed that the maximum gross return of Rs 85010.66/ha was recorded from P3S3 treatment. However, the minimum gross return Rs 42912.00/ha was obtained from P0S0 treatment.

Benefit cost ratio (B : C Ratio)

It is evident from the data that maximum B: C Ratio 5.81 was obtained from P2S3 treatment. The lowest B: C ratio 3.79 was obtained in P0S0 treatment.

Table –4.16 Economics of treatment combination

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Gross income (Rs/ha)	Cost of cultivation (Rs/ha)	Net profit (Rs/ha)	B:C Ratio
P0S0	806.00	1306.00	42912.00	11320	31592.00	3.79
P0S1	1001.33	1510.00	53534.34	11680	41854.34	4.58
P0S2	1246.67	1734.67	65803.00	12040	53763.00	5.46
P0S3	1214.67	1664.67	64062.84	12400	51662.00	5.16
P1S0	883.33	1392.33	46951.16	11800	35157.16	3.97
P1S1	1128.33	1642.00	59700.5	12160	47540.50	4.90
P1S2	1300.00	1830.67	68661.34	12520	56141.34	5.48
P1S3	1316.00	1796.67	69393.34	12880	56133.34	5.38
P2S0	978.67	1430.33	51794.16	12280	39514.16	4.21
P2S1	1237.67	1689.67	65262.84	12640	52622.84	5.16
P2S2	1340.00	1798.33	70596.66	13000	57596.66	5.43
P2S3	1478.67	1880.00	77693.50	13360	64333.50	5.81
P3S0	1212.33	1617.00	63850.50	12760	51090.50	5.00
P3S1	1378.00	1811.33	75522.66	13120	62402.66	5.75
P3S2	1461.33	1963.67	76993.84	14440	62553.84	5.33
P3S3	1614.00	2155.33	85010.66	14800	70210.66	5.74

Market rate-

Seed – 50 Rs/kg , Straw – 2 Rs/kg

Table – 4.19 Soil fertility status after harvest of black gram as affected by various Treatments

S.No.	Treatment	Soil pH	Ec (dS/m)	O.C. %	Available nutrients in soil(kg/ha)			
					N	P	K	S
0	Initial	7.80	0.32	0.46	210.0	10.60	425.0	7.71
1	S0P0	7.81	0.29	0.48	216.0	10.40	480.5	6.26
2	S0P1	7.82	0.30	0.48	216.0	11.80	490.3	6.22
3	S0P2	7.80	0.31	0.49	220.5	12.20	487.5	6.22
4	S0P3	7.80	0.30	0.48	216.0	12.80	488.4	6.28
5	S1P0	7.84	0.30	0.49	220.5	9.80	495.3	6.20
6	S1P1	7.81	0.31	0.49	220.5	11.80	486.2	6.18
7	S1P2	7.82	0.30	0.52	222.0	12.60	488.4	6.16
8	S1P3	7.85	0.29	0.53	212.0	13.01	518.4	6.24
9	S2P0	7.83	0.30	0.54	216.0	9.50	516.9	6.32
10	S2P1	7.82	0.30	0.49	220.0	11.60	490.5	6.40
11	S2P2	7.81	0.31	0.50	200.0	12.40	495.6	6.28
12	S2P3	7.82	0.30	0.50	200.0	13.10	488.6	6.40
13	S3P0	7.83	0.29	0.48	216.0	10.01	468.2	6.46
14	S3P1	7.84	0.30	0.49	220.5	11.80	478.1	6.44
15	S3P2	7.83	0.30	0.49	220.5	12.80	498.0	6.48
16	S3P3	7.82	0.28	0.50	200.0	13.10	478.1	6.50

Table4.20: Effect of P and S on nutrients uptake of black gram at harvest stage

Treatments	N uptake	P uptake	K uptake	S uptake
P levels				
0	71.73	11.63	22.53	13.87
20	77.78	11.90	26.09	15.30
40	82.82	12.30	27.82	16.48
60	84.63	12.74	33.52	17.05
S levels				
0	73.98	11.66	26.99	13.76
10	78.40	12.05	29.60	15.46
20	81.55	12.15	29.82	16.59
30	83.00	12.34	34.02	16.92
S.E. \pm	2.03	0.23	0.30	0.27
C.D.(P= 0.05)	6.11	0.70	0.93	0.84
PxS	N.S.	N.S.	N.S.	N.S.

N.S.- Non Significant

DISCUSSION

CHAPTER-V

DISCUSSION

The results obtained from present experiments entitled “**Response of Black Gram (*Vigna mungo* L.) to Graded Doses of Phosphorus and Sulphur under Rainfed Conditions.**” have been presented in previous chapter and discussed in detail in the present chapter taking into account the research findings made earlier, if any, by other research workers on similar aspects.

From the result of this study it has clearly emerged that in general for realising highest productivity, production and profitability from the cultivation of black gram, optimum dose of phosphorus and sulphur are essential apart from other agronomical management practices including plant protection.

5.1 Pre harvest studies

Pre harvest observation on growth and development of plants were made from each treatment in order to assess the impact of different treatments. These included plant population, plant height, no. of leaves, no. of root nodules, leaf area, dry matter/plant CGR, RGR etc. This information was used to interpret the behaviour of productivity of black gram as influenced by different treatments as discussed in the following paragraphs

5.1.1 Plant population/m²

Levels of phosphorus, sulphur treatments and their interactions showed non significant differences. Such uniformity in plant population is foremost prerequisites for maintaining high level of accuracy of experimentation for testing the genuine effects of treatments. The similar finding has been reported by **Kokani et al.** (2014).

5.1.2. Plant height in (cm)

Mean plant height (cm) was significantly affected due to different levels of phosphorus and sulphur. Progressive increase in plant height with the advancement of growth stages until harvest was observed but maximum elongation of plants took place up to 60 DAS and afterwards the rate of elongation was slow regardless of the treatments. Phosphorus application

played a significant role in the elongation of plants of black gram.

Tripathi and Yadav (2003). This could be due to synergistic effect of P and S supplied through different treatments under consideration. **Mir et al.** (2013).

5.1.3. Number of leaves

The no. of green leaves of black gram per plant gradually increased with the advancement of growth period up to 60DAS. There was steep decline in the no. of green leaves per plant during the period from 60 DAS to harvesting. Similar result have been found by **Mir et al.** (2013). Mean no. of leaves increased significantly with increasing doses of phosphorus and sulphur, up to 60 DAS. While, at harvest stage was not significantly different however the impact of interaction of phosphorus and sulphur (P X S) did not show any significant effect on mean no. of leaves at any of the stage. While, the treated plot showed more no. of leaves in comparison to the control plot at all the stages.

5.1.4. Number of root Nodules/plant

The no. of root nodules of black gram per plant gradually increased with the advancement of growth period up to 45DAS. There was steep decline in the no. of root nodules per plant during the period from 60 DAS to harvesting. **Shirinivasan et al.** (2000) pointed out that sulphur fertilization had a significant effect on root nodulation in black gram. They further reported that there was a linear response of 40 kg S/ha in lateritic soils to root nodules when given through gypsum. Mean no. of root nodules increased significantly with increasing doses of phosphorus and sulphur, up to 45 DAS. While, however the impact of interaction of phosphorus and sulphur (P X S) did not show any significant effect on mean no. of root nodules at any of the stage. While, the treated plot showed more no. of root nodules in comparison to the control plot at all the stages. Similar result reported by **Teotia et al.** (2001).

5.1.5 Mean leaf area (cm²/plant)

Mean leaf area (cm²/plant) of black gram at 30 DAS, 45 DAS, and 60 DAS of the crop increased significantly with increasing doses of phosphorus and sulphur, as well as the impact of interaction of phosphorus and sulphur (P X S) was also significantly effect on leaf area (cm²/plant) at all of the stages.

The treated plots showed more leaf area in comparison to the control plot at all the stages. Application of S in different treatments led to enlargement in the green leaves per plant as compared to the control treatments. The present findings are in the conformity with the findings of **Sengupta (2001)**, **Umesh et al. (1997)**.

5.1.6. Mean Chlorophyll Content(SPAD)

The chlorophyll content in black gram increased significantly with increasing doses of phosphorus and sulphur, up to 45 DAS. While, at 60 DAS is no any significant difference as well as the impact of interaction of phosphorus and sulphur (P X S) did not show any significant effect on mean chlorophyll content (SPAD) at any of the stages. While, the chlorophyll content (SPAD) is decreasing with increasing of the crop stages. Same result reported by **Limbakai and Netravati (2015)**.

5.1.7 Mean light intensity by lux meter

The mean light intensity of plant is non significant all the stages of crop. This factor is fully depended on climatic condition of the particular environment. It is depended on weather condition and the intensity of the light because black gram is a kharif crops so weather condition is abnormal and differ time to time. The effect of phosphorus and sulphur as well as their interaction was non significant. Similar result reported has been **Kumar et al. (2013)**

5.1.8. Mean dry matter/plant

Mean dry matter/plant of black gram at 30 DAS, 45 DAS, and 60 DAS of the crop increased significantly with increasing doses of phosphorus and sulphur, while, an impact of interaction of phosphorus and sulphur (P X S) was non significant effect on mean dry matter/plant at all of the stages. The treated plot showed more mean dry matter/plant in comparison to the control plot at all the stages.

Sing and Ranbir (2004) reported that application of S and P individually increased the grain, straw and total dry matter yield of black gram (*Vigna mungo*) but decreased when S and P were applied in different combination.

5.1.9. Mean Crop Growth Rate and Relative Growth Rate

Mean Crop Growth Rate and Relative growth rate of black gram at 30 DAS, 45 DAS, and 60 DAS of the crop was all the stages are non significant. It is obvious from the data that the differences in mean Crop Growth Rate and Relative growth rate due to main factor as well as due to their interaction were statistically non significant. **Kumawat, et al.** (2005) examined the effect of application of different levels of sulphur and iron on dry matter accumulation, crop growth rate (CGR), specific leaf weight (SLW) and LAI. The application of 40 or 60 kg sulphur/ha significantly increased dry matter accumulation & LAI, CGR and SLW at various growth stages as compared to plant growth without sulphur and with 20 kg/ha.

5.2 Post harvest studies

Post harvest observations on different parameters related to different yield attributes, seed and straw yield in relation to main and sub treatments were taken and the same are discussed in the following paragraphs:

5.2.1 Number of pods/plant, seeds/pod, harvest index and 100 seed weight (g)

The increasing doses of phosphorus and sulphur increased the no. of pods/plant significantly, while the impact of phosphorus and sulphur interaction (P x S) did not show any significant effect. In control plot (P0S0) the no. pods/plant showed minimum value (i.e. 22.55) while the treated plot (P3S3) showed significant highest value (i.e. 26.33) over control. Similar result has been reported by **Yadav and Tripathi** (2003)

The number of pods per plant in mung bean cv. MUM 2 increased with increasing sulphur rates. Basal dose of 40 kg S/ha recorded the highest number of pods per plant (34.2), which was at par with 40 kg S/ha (half applied as basal + half as side dressing (32.5) and 30 kg S /ha as basal (30.7) (**Siag and Yadav** 2003).

The increasing doses of phosphorus and sulphur increased the no. of seeds/pod significantly, while the impact of phosphorus and sulphur interaction (P x S) did not show any significant effect. In control plot the no. pods/plant showed minimum value (i.e. 5.20) while the treated plot (P3S3)

showed significant highest value (i.e. 6.27) over control. The no. of pods/plant and number of seeds/pod is although governed by the genetic characteristics of any variety or genotype still some minor changes may be possible due to management practices including agronomical management practices and balanced nutrition of plants under the same environmental conditions. Difference in seed weight per plant is mainly influenced by the interaction of management factors and genetic characteristics. These findings are in agreement with the findings of **Chettri and Mondal (2004)**, **Budhar and Tamilselvan (2001)**, **Srinivasan et al.(2000)**, **Srinivasan and Shankaran (2001)**.

The increasing doses of phosphorus and sulphur increased the mean seed index significantly, while the impact of phosphorus and sulphur interaction (P x S) did not show any significant effect. The treated plot showed more mean seed index in comparison to the control plot. Same result found on study by **Niraj and Prakash (2014)**.

The increasing level of phosphorus and sulphur is also increasing harvest index but the differences in mean Harvest index due to main factors as well as due to their interaction were statistically non significant. These findings are in agreement with the findings of **Teotia et al. (2001)**,

5.2.2 Seed yield, Straw yield and Biological yield

The increasing doses of phosphorus increased the seed yield significantly from 1067.16 to 1416.41 kg ha⁻¹ and sulphur increased the seed yield from 970.08 to 1405.83 kg ha⁻¹. Among all the treatment combination the P3S3 showed higher yield (1614.41) but statistically was non significant.

The increasing level of phosphorus (P₀- 2620.58) to (P₃-3303.25) and sulphur (S₀-2406.50 to S₃-3279.58) significantly increased mean biological yield but the interaction effect was found non significant.

The increasing level of phosphorus significantly increased straw yield over P₀ & P₃, however S₃ treatment showed significant increased straw yield over S₀ & S₃ treatment but the interaction effect was found non significant.

A field experiment was conducted at Allahabad Agricultural Institute-Deemed University, Allahabad to study the effect of levels of phosphorus,

sulphur and Phosphorus Solubilizing Bacteria (PSB) on growth, yield and nutrient content of black gram for consecutive two years 2004 and 2005. The crop growth parameters *viz.*; plant height, number of nodules and number of leaves per plant, yield and nutrient content increased significantly with the application of high levels of phosphorus, sulphur with or without bio-fertilizer inoculation. **Mir *et al.*** (2013).

The similar results were reported by **Abraham and Lal**(2004), **Chaudhry *et al.*** (2016), **Karache *et al.***(2012), **Kokani *et al.*** (2014).

Gupta, and Sharma (2006) reported the results of a study which revealed inoculation with PSB and Phosphorus fertilization ($60\text{kg P}_2\text{O}_5\text{ha}^{-1}$) in influencing the seed yield .

5.2.3 Economics of treatments

The cost of production varied according to the cost of inputs incurred for employing a particular treatment as prescribed (Table 4.16) the mean cost of production incurred on the main treatments factors *i.e.* phosphorus and sulphur levels was Rs 11320, Rs 11800, Rs 12280, Rs 12760 ha^{-1} for P levels P_0 - (0kg/ha), P_1 - (20kg ha^{-1}), P_2 - (40kg ha^{-1}), P_3 - (60 kg ha^{-1}) and Rs11320, Rs 11680, Rs 12040, Rs 12400 ha^{-1} respectively for S levels of S_0 - (0kg ha^{-1}), S_1 - (10kg ha^{-1}), S_2 - (20kg ha^{-1}), S_3 – (30kg ha^{-1}).The corresponding values of gross returns for these treatments were Rs. 42912, Rs 46951.16, Rs 51794.16, Rs. 63850.50, Rs 42912, Ra 53534.34, Rs 65803.00, Rs 64062.84 respectively (table 4.16).

The mean net returns due to P treatments of P_0 - (0kg ha^{-1}), P_1 - (20kg ha^{-1}), P_2 - (40kg ha^{-1}), P_3 - (60 kg ha^{-1}) was, Rs 31592.00, Rs 35157.16, Rs 39514.16, Rs 51090.50, respectively along with B : C Ratio of 3.79 , 3.97, 4.21, 5.00 for the same P treatments. The increases in mean net returns due to P treatments P_1 - (20kg ha^{-1}), P_2 - (40kg ha^{-1}) and P_3 - (60 kg ha^{-1}) over P_0 - (0kg ha^{-1}),

The mean net returns due to S treatments of S_0 - (0kg ha^{-1}), S_1 - (10kg ha^{-1}), S_2 - (20kg ha^{-1}) and S_3 – (30kg ha^{-1}) was, Rs 31592, Rs 41854.34, Rs 53763, Rs 51662, respectively along with B : C ratio 3.79, 4.58, 5.46, 5.16 for the same S treatments. The increases in mean net returns due to S treatments

S₁- (10kg ha⁻¹), S₂- (20kg ha⁻¹) and S₃ – (30kg ha⁻¹) over S₀- (0kg ha⁻¹) . These findings are in agreement with the findings of **Chettri and Mondal** (2004), **Srinivasan and Shankaran**(2001).

SUMMARY,
CONCLUSION AND
SUGGESTIONS FOR
FURTHER WORK

CHAPTER – VI

Summary, Conclusion and suggestion for further work

The present experiment entitled “Response of Black Gram (*Vigna mungo* L.) to Graded Doses of Phosphorus and Sulphur under Rainfed Conditions.” was laid out at the research field of AICRP on Pulses, Rajmata Vijayaraje Sciendia Krishi Vishwa Vidhyalaya, College of Agriculture, Indore (M.P.). The findings have been summarized as under:

6.1 Summary

1. Levels of phosphorus, sulphur treatments and their interaction showed no significant differences on plant population. The observations indicated the uniformity in plant population/m² throughout the crop growth period.
2. The mean plant height (cm) increased significantly with increasing doses of phosphorus and sulphur while interaction of phosphorus and sulphur (PxS) was non significant at all the crop growth stages.
3. The mean no. of leaves increased with increasing doses of phosphorus and sulphur up to 60 DAS but at harvest stage was non significant also interaction of phosphorus and sulphur (PxS) was non significant all of the crop growth stages.
4. The mean no. of root nodules increased with increasing of doses of phosphorus and sulphur while interaction of phosphorus and sulphur was non significant all of the crop growth stages.
5. The mean leaf area (cm²/plant) increased with increasing of doses of phosphorus and sulphur as well as their interaction all of the crop growth stages.
6. The mean chlorophyll content in black gram leaves increased with increasing of doses of phosphorus and sulphur up to 45 DAS and the 60 DAS was non significant as well as their interaction was non significant all of the crop growth stages.
7. The mean light intensity of the crop was non significant at all the stages in

all the treatments.

8. The mean dry matter/plant increased significantly with increasing doses of phosphorus and sulphur, while, the impact of interaction of phosphorus and sulphur (P X S) was non significant at all the stages.

9. The mean Crop Growth Rate due to doses of phosphorus and sulphur and also their interaction was non significant.

10. The mean Relative Growth Rate due to doses of phosphorus and sulphur and also their interaction was non significant.

11. The mean no. of pods/plant significantly increased with increasing doses of phosphorus and sulphur while their interaction was non significant.

12. The mean no. of seeds/pod significantly increased with increasing doses of phosphorus and sulphur while their interaction was non significant.

13. The mean seed index significantly increased with increasing doses of phosphorus and sulphur while their interaction was non significant.

14. The mean biological yield, seed yield and straw yield (kg/ha) is significantly increased with increasing doses of phosphorus and sulphur while their interaction was non significant.

15. The mean harvest index (%) did not show any significant effect among all treatment combination.

6.2 Conclusion

1. Increasing doses of phosphorus up to 60 kg increased the growth and yield of black gram.

2. Increasing doses of sulphur up to 30 kg increased the growth and yield of black gram.

3. Among the different treatment combinations, a combination of P_3S_3 (60kg P ha^{-1} & 30kg S ha^{-1}) proved its superiority in increasing the growth and seed yield of black gram.

4. The result lead to conclude that for achieving higher production, as well as net return, gross return from the crop may be fertilized with 60 kg P and 30 kg S ha^{-1} .

6.3 Suggestions for further work

On farm studies may be conducted to confirm the results seeking farmer's participation. In such studies other nutrients particularly N,P,K and Zinc and boron may also be combined and tried.

The similar study can be tried in other pulses like pigeon-pea, lentil, pea and cowpea and also intercropping with black gram e.g. sorghum + black gram, cotton + black gram, etc.

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APPENDIX

Appendix-I:

Cost of different treatments (Rs/ha): N= Rs 8/kg, P= Rs 24/kg, Rs= 18/kg, Rs= 36/kg, Cost of price= 90/kg,

treatments	Field preapration	Price of seed	Seed treatment	N	P	K	S	Sowing cost	Plant protection	Weeding	harvesting	Total cost Rs/ha
P0S0	3850	2250	50	160	0	360	0	750	900	1500	1500	11320
P0S1	3850	2250	50	160	0	360	360	750	900	1500	1500	11680
P0S2	3850	2250	50	160	0	360	720	750	900	1500	1500	12040
P0S3	3850	2250	50	160	0	360	1080	750	900	1500	1500	12400
P1S0	3850	2250	50	160	480	360	0	750	900	1500	1500	11800
P1S1	3850	2250	50	160	480	360	360	750	900	1500	1500	12160
P1S2	3850	2250	50	160	480	360	720	750	900	1500	1500	12520
P1S3	3850	2250	50	160	480	360	1080	750	900	1500	1500	12880
P2S0	3850	2250	50	160	960	360	0	750	900	1500	1500	12280
P2S1	3850	2250	50	160	960	360	360	750	900	1500	1500	12640
P2S2	3850	2250	50	160	960	360	720	750	900	1500	1500	13000
P2S3	3850	2250	50	160	960	360	1080	750	900	1500	1500	13360
P3S0	3850	2250	50	160	1440	360	0	750	900	1500	1500	12760
P3S1	3850	2250	50	160	1440	360	360	750	900	1500	1500	13120
P3S2	3850	2250	50	160	1440	360	720	750	900	1500	1500	14440
P3S3	3850	2250	50	160	1440	360	1080	750	900	1500	1500	14800

Appendix-II:

Analysis of variance showing mean sum of squares for plant population/m² and plants height (cm)

SN	Source of variation	D.f.	Plant population/m ²		Plants height (cm)			
			Days after sowing		Days after sowing			
			15 DAS	At Harvest	30 DAS	45 DAS	60 DAS	At Harvest
1.	Replication	2	0.81	1.31	0.09	0.13	0.06	0.06
2.	Treatments:							
a.	P	3	2.47	6.91	0.60	1.71	0.53	7.42
b.	S	3	0.14	3.63	0.93	0.54	0.79	0.23
c.	P x S	9	2.31	3.15	0.11	0.06	0.02	0.01
3.	Error	30	3.37	2.89	0.07	0.12	0.15	0.03
4.	Total	47						

Note :- P= Phosphorus levels, S = Sulphur levels, D.f.= degrees of freedom

Appendix-III:

Analysis of variance showing mean sum of squares for number of leaves per plant and mean no. of root nodules/plants

SN	Source of variation	D. F.	No. of leaves /plants				No. of root nodules/plants		
			30 DAS	45 DAS	60 DAS	At Harvest	30 DAS	45 DAS	60 DAS
1.	Replication	2	0.05	0.24	0.03	0.18	0.43	2.06	0.38
2.	Treatments:								
a.	P	3	5.22	4.34	0.88	0.65	33.70	10.82	54.37
b.	S	3	1.02	2.94	0.85	0.26	12.23	10.15	157.74
c.	P x S	9	0.05	0.15	0.04	0.02	1.97	0.41	1.63
3.	Error	30	0.29	0.31	0.24	0.28	3.77	2.61	3.24
4.	Total	47							

Note :- P= Phosphorus levels, S = Sulphur levels, D.f.= degrees of freedom

Appendix-IV:

Analysis of variance showing mean sum of squares for leaf area (cm²) and chlorophyll content (SPAD)

SN	Source of Variation	D.F.	Leaf area (cm ²)			Chlorophyll content		
			30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
1.	Replication	2	3.09	5.38	23.48	14.98	0.71	3.18
2.	Treatments							
a.	P	3	11119.9	5636.37	2560.3	42.95	36.73	0.29
b.	S	3	1311.06	36703.2	56774.2	30.40	42.15	7.18
c.	P x S	9	1770.72	812.76	292.22	1.20	1.56	0.82
3.	Error	30	3.72	1.28	18.47	9.43	2.86	3.39
4.	Total	47						

Note :- P= Phosphorus levels, S = Sulphur levels, D.f.= degrees of freedom

Appendix-V:

Analysis of Variance showing mean sum of square for dry matter/plant

SN	Source of Variation	D.F.	dry matter / plant		
			30 DAS	45 DAS	60 DAS
1.	Replication	2	0.001	0.50	1.05
2.	Treatments				
a.	P	3	0.26	3.71	9.66
b.	S	3	0.29	3.74	19.66
c.	P x S	9	0.01	0.18	0.76
3.	Error	30	0.07	0.82	2.50
4.	Total	47			

Appendix-VI:

Analysis of variance showing mean sum of square for no. of pods/plant, no. of seeds/plant, seed index, and harvest index .

SN	Source of Variation	D.F.	No. of pods/plant	No. of seeds/pod	Seed index	Harvest index
1.	Replication	2	3.45	0.001	0.001	5.93
2.	Treatments					
a.	P	3	8.29	0.51	0.13	17.57
b.	S	3	3.03	1.16	0.05	17.32
c.	P X S	9	0.54	0.01	0.001	3.97
3.	Error	30	0.69	0.16	0.01	6.15
4.	Total	47				

Appendix-VII:

Analysis of variance showing mean sum of square for seed yield, straw yield and biological yield

SN	Source of Variation	D.F.	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
1.	Replication	2	6734.81	40982.52	73849.75
2.	Treatments				
a.	P	3	269303.85	229838.17	987279.58
b.	S	3	446888.69	474131.06	1845258.92
c.	P x S	9	6371.22	8418.30	23727.68
3.	Error	30	70127.37	63451.48	259379.17
4.	Total	47			

VITA

VITA

The author of thesis JITENDRA SINGH JAISWAL S/O Shri Dhool Singh Jaiswal was born on 1st Nov. 1993 at vil. Hajipur the. Ashta dist. Sehore (M.P.). He has completed primary education at native place. He has passed High School and Higher Secondary School in first division in 2008 and 2010 respectively from M.P. Board, Bhopal. In 2011, he joined the JNKVV, College of Agriculture, Ganjbasoda (Vidisha, M.P.) and successfully completed his B.Sc. (Ag) in the year 2015 with an OGPA of 7.55 out of 10 point scale. Subsequent to the post graduation he joined Agronomy section at College of Agriculture, Indore of RVSKVV, Gwalior for M.Sc. (Ag) in the year 2015. For partial fulfillment of Master Degree he was allotted a research problem on, response of black gram (*Vigna mungo* L.) to graded doses of phosphorus and sulphur under rainfed conditions which was successfully completed by him and presented in the form of this thesis. He has completed his M.Sc. (Ag) Course with an OGPA of 7.30 out of 10 point scale.