SEED TREATMENT AND FOLIAR NUTRITION FOR ENHANCED PRODUCTIVITY OF BLACKGRAM (*Vigna mungo* L.)

by

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DECLARATION

I, hereby declare that this thesis entitled **"SEED TREATMENT AND FOLIAR NUTRITION FOR ENHANCED PRODUCTIVITY OF BLACKGRAM (*Vigna mungo* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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Vaddula Yamini

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LIST OF ABBREVIATIONS

B	:	Boron
B: C ratio	:	Benefit cost ratio
Ca	:	Calcium
$Ca(NO_3)_2$	:	Calcium nitrate
CD (0.05)	:	Critical difference at 5 % level
cm	:	Centimetre
DAP	:	Diammonium phosphate
DAS	:	Days after sowing
DAT	:	Days after transplanting
DMP	:	Dry matter production
EDTA	:	Ethylene diamine tetra acetic acid
et al.	:	Co-workers/ Co-authors
Fe	:	Iron
$FeSO_4$	:	Iron sulphate
FYM	:	Farm yard manure
g	:	Gram
g^{-1}	:	Per gram
g kg^{-1}	:	Gram per kilogram
g L^{-1}	:	Gram per litre
g $plant^{-1}$	:	Gram per plant

g $plot^{-1}$	:	Gram per plant
ha^{-1}	:	Per hectare
H_3BO_3	:	Boric acid
HI	:	Harvest index
K	:	Potassium
KAU	:	Kerala Agricultural University
KCl	:	Potassium chloride
kg ha^{-1}	:	Kilogram per hectare
KNO_3	:	Potassium nitrate
LAI	:	Leaf area index
M	:	Molar
m	:	Meter
m^{-2}	:	Per meter square
mg	:	Milligram
mg g^{-1}	:	Milligram per gram
mg kg^{-1}	:	Milligram per kilogram
mg $plant^{-1}$	:	Milligram per plant
mm	:	Millimeter
Mo	:	Molybdenum
MoO_4^-	:	Molybdate
MOP	:	Muriate of potash
N	:	Nitrogen
NAA	:	Naphthalene acetic acid

NS	:	Non significant
P	:	Phosphorus
pH	:	Potenz hydrogen
POP	:	Package of practices
ppm	:	Parts per million
PSB	:	Phosphorus solubilizing bacteria
q ha^{-1}	:	Quintal per hectare
RDF	:	Recommended dose of fertilizer
S	:	Sulphur
SEm	:	Standard error of mean
SSP	:	Single super phosphate
t ha^{-1}	:	Tonnes per hectare
viz.	:	Namely
Zn	:	Zinc
$ZnSO_4$	:	Zinc sulphate

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
°C	:	Degree Celsius
₹	:	Rupee

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Introduction

1. INTRODUCTION

Pulses are generally referred as food legumes which are considered secondary to cereals in case of production and consumption in India. They have immense potential in improving human health, conserving soil, protecting the environment and contributing global food security. India accounts for 3 per cent of world area and 22 per cent of world production of pulses. Because of the cheapest sources of vegetable protein, pulses occupy unique position in the diet of most vegetarian population of India. They are considered as poor man's vegetable due to its high protein content and other essential nutrients such as Ca, Fe, and some of vitamins *viz.*, carotene, riboflavin, niacin and thiamine. In addition, pulses are also known to increase fertility of soil and also productivity of succeeding crop. They have symbiotic association with bacterium called *Rhizobium* which helps in fixing atmospheric nitrogen.

The World Health Organization recommends per capita consumption of pulses at 80 g day^{-1} and the Indian Council of Medical Research has recommended minimum consumption of 47 g day^{-1} (Shashikumar, 2012). To meet the pulse demand of ever increasing population, there is a need to increase production of pulses either by increasing land area or by increasing production per unit area. However, increase in acerage under pulses in India is practically not possible; and the only option left to meet the demand is to push up the yield ha^{-1} per unit time.

In Kerala, pulses are mostly cultivated during autumn, winter and summer seasons. These are part of healthy and balanced diet of Kerala people and also known to treat several illnesses. The area under pulse cultivation shows a declining trend in the state; therefore more proactive steps are needed to augment the pulse production in the state.

Among pulses, blackgram is an important short duration crop which is grown throughout India. It accounts for 13 per cent of total pulse area and 10 per cent of total pulse production in the country. It contains about 24 per cent protein which is almost twice as cereals, 60 per cent carbohydrates, 1.3 per cent fat, 0.194 per cent Ca, 0.192 per cent Mg, 0.526 per cent K, 0.44 per cent P, 0.09 per cent Fe and 0.0241 mg of vitamin C 100 g^{-1}. It is also rich in essential amino acids *viz.,* 0.43 per cent lysine and 0.07 per cent tryptophan where cereals are normally deficient and it is also rich in phosphoric acid (Kokani, 2014).

Though blackgram is used as source of human food, animal feed and also for enhancing soil fertility, the yield potential is very low as it is mainly grown in rainfed areas with poor management practices. Poor productivity is also due to various physiological, biochemical and inherent factors associated with this crop. The physiological factors *viz.,* poor pod setting due to the flower abscission, insufficient partitioning of assimilates and lack of essential nutrients during critical stages of crop growth play a major role in declined blackgram production coupled with a number of diseases and pests (Mahala *et al*., 2001).

Seed treatment can improve seedling establishment and better crop stand; it also improves plants ability to tolerate stress at early growth stages. Seed treatment also helps to reduce the environmental impact on production process; it helps in decreasing number of spray applications of agrochemicals thus reducing exposure to non-target species. Micronutrients when applied as seed treatment enhances the performance of fertilizer, also supplies nutrients to soil and improves plant growth. Boron (B) plays an important role in sugar translocation, nitrogen fixation, protein synthesis, sucrose synthesis, cell wall composition, membrane stability and K^+ transportation. Molybdenum (Mo) is associated with ammonia reduction and nitrogen fixation and its deficiency adversely affects plant growth and yield. Seed treatment with these micronutrients is a cost effective practice for enhancement of productivity of pulses.

Foliar nutrition can improve the physiological and photosynthetic ability of crop, thus plays a significant role in improving production potential of crops. Foliar application has the advantage of quick and efficient utilization of nutrients, elimination of nutrient losses through leaching and fixation in soil and also helps in regulating the uptake of nutrients by plants (Manonmani and Srimathi, 2009). It is effective in correcting the midseason discrepancies in crop growth which may be due to inadequate or inappropriate supply of nutrients from the soil under abiotic stress conditions. Foliar application of major nutrients using completely water soluble fertilizers is one of the possible ways to enhance productivity of blackgram.

Keeping the above facts in view, the present investigation entitled "Seed treatment and foliar nutrition for enhanced productivity of blackgram (*Vigna mungo* L.)" was conducted at the Instructional Farm, attached to College of Agriculture, Vellayani during *Rabi* 2018 with the objective to evaluate the influence of seed treatment and foliar nutrition on the growth and yield of blackgram and also to work out the economics of production.

Review of Literature

2. REVIEW OF LITERATURE

The major reason for low yield potential of blackgram is mainly due to inappropriate use of essential plant nutrients. Hence, the present study was undertaken with an objective to evaluate the influence of seed treatment and foliar nutrition on the growth and yield of blackgram and also to work out the economics of production. The current state of knowledge regarding the effect of seed treatment with micronutrients and foliar spray with water soluble fertilizers on the growth characters, yield parameters, grain quality and economics of blackgram are reviewed here.

2.1 SEED TREATMENT WITH MICRONUTRIENTS

2.1.1 Boron Nutrition in Pulses

Boron is the most important among all micronutrients involved in pollen germination, maintenance of structural integrity, pollen tube development and seed filling (Narkhede and Patil, 1989; Bhilegoankar *et al.*, 1995). Boron can be applied as seed treatment, soil application and foliar spray, but information regarding dose and time of application are limited.

Boron deficiency in legume crops has resulted in drastic reduction of nodulation, growth and yield due to inadequate supply of carbohydrates to bacteria present in root nodules. Boron application improves yield and quality of legumes and also oilseed crops (Kumar *et al.*, 2018).

2.1.1.1 Effect of Boron on Growth Characters

The tallest plants (55.94 cm) were documented when treated with 1.50 kg B ha^{-1} in aggregation with blanket application of 24: 20: 30: 15 kg ha^{-1} nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) in mungbean (Alam and Islam, 2016). Adhikary *et al.* (2018) opined that foliar spray of borax (0.5 % solution) at 15, 40 days after sowing (DAS) and at flower initiation stage along with 20: 40: 20 kg ha^{-1} NPK had showed the tallest plants (38.86 cm) in lentil.

Masuthi *et al.* (2009) opined that seed pelleting with borax @ 100 mg kg^{-1} seed resulted in the highest leaf number per plant (14.42) at harvest in soyabean. Two foliar sprays of H_3BO_3 @ 0.4 per cent and 0.6 per cent registered significantly higher number of branches (8.0) in french bean (Mahadule *et al.*, 2019).

Adhikary *et al.* (2018) opined that the highest leaf area index (LAI) (5.38) was recorded in lentil when treated with 0.5 per cent solution of borax as foliar spray at 15 and 40 DAS and at flowering in combination with basal dose of 20: 40: 20 kg ha^{-1} NPK respectively.

Parry *et al.* (2016) revealed that nodule number per plant was significantly influenced when treated with different levels of B and maximum number (34.70) was recorded with 3 kg B ha^{-1}. Foliar application of B (0.2 %) at 20 and 35 DAS sequencing with soil application of zinc (Zn) @ 5 kg ha^{-1} recorded the highest number of nodules (20.60) and dry weight of nodules (8.48) per plant at 60 DAS in greengram (Praveena *et al.*, 2018). Application of H_3BO_3 @ 6 kg ha^{-1} recorded maximum nodule number (10.39) and also maximum nodule weight per plant (0.15 g) at 45 DAS in greengram (Janaki *et al.*, 2018).

2.1.1.2 Effect of Boron on Yield Parameters

Vimalan *et al.* (2017) reported that among different B treatments, soil application with 1.5 kg ha^{-1} at time of sowing recorded the highest number of pods per branch (3.84) in greengram. Boron @ 1 kg ha^{-1} as soil application in mungbean produced the highest seed number per pod (9.68) (Quddus *et al.*, 2011). El-Dahsouri *et al.* (2017) conducted a study on different levels of foliar sprays of B and Ca, of which B @ 250 ppm before flowering produced maximum seed number per pod

(4.60) in common bean. The maximum seeds per pod (7.48) were recorded when mungbean plants were fertilized with 1 kg ha^{-1} of B (Islam *et al.*, 2017).

Borax @ 1.5 kg ha^{-1} as soil application in mungbean has maximum seed index of 13.2 g (Saxena and Nainwal, 2010). Significant increase in yield of vegetable cowpea was noticed when seeds were pelleted with borax (100 mg kg^{-1}); this treatment recorded the paramount grain yield (1536 kg ha^{-1}) at harvest (Masuthi *et al.*, 2009).

The highest straw yield (4.72 t ha^{-1}) was obtained with soil application of solubor @ 10 kg ha^{-1} in groundnut (Ansari *et al.*, 2013). Kamboj and Malik (2018) investigated influence of P and B on greengram, the studies revealed that the highest haulm yield (73.27 g per pot) obtained when applied with P @ 100 mg kg^{-1} soil along with B @ 0.5 mg kg $^{-1}$ soil. The maximum haulm yield (30.20 g per pot) was obtained when french bean was treated with H_3BO_3 @ 0.6 per cent as foliar spray at 25 and 55 DAS (Mahadule *et al.*, 2019).

The maximum harvest index (69.86 %) was recorded in mungbean when applied with B @ 1 kg ha^{-1} (Islam *et al.*, 2017).

Total dry matter production of 53.91 kg ha^{-1} was registered when applied with B @ 1 kg ha^{-1} in combination with S @ 45 kg ha^{-1} in French bean (Ganie *et al.*, 2014). Praveena *et al.* (2018) evaluated various levels of B and Zn on greengram and revealed that the highest dry matter production (DMP) per plant (8.48 g) was reported when treated with B @ 0.2 per cent as foliar spray at 20 and 35 DAS along with Zn @ 5 kg ha^{-1} as soil application.

2.1.1.3 Effect of Boron on Grain Quality

The highest crude protein content (24.50%) in seed was observed when common bean was treated with Ca @ 2500 ppm along with B @ 250 ppm before and after flowering (El-Dahsouri *et al.*, 2017). Application of B @ 1.5 kg ha^{-1} also showed the highest seed protein content in greengram (Vimalan *et al.*, 2017).

2.1.1.4 Effect of Boron on Nutrient Uptake

Application of diverse levels of B influenced the nutrient content in seed of which H_3BO_3 @ 2 kg ha^{-1} recorded maximum nutrient content in seed with N, P, K and B values of 4.3 per cent, 0.27 per cent, 0.4 per cent and 28 ppm respectively in field pea (Quddus *et al.*, 2018). Kamboj and Malik (2018) opined that higher boron content in seed (77.38 mg g^{-1}) was recorded from application of borax @ 1 mg kg^{-1} soil and P @ 100 mg kg $^{-1}$ soil in greengram.

2.1.1.5 Effect of Boron on Available Nutrient Status of Soil

Reddy *et al.* (2007) revealed that boron @ 4 g kg^{-1} as seed treatment and soil application (10 and 20 kg ha^{-1}) had significantly increased the availability of nutrients.

2.1.1.6 Economics of Boron Nutrition

Among different levels of borax as soil application, the highest net returns (₹ 1,16,231 ha^{-1}) and B: C ratios (2.25) were documented with borax @ 3 kg ha^{-1} (Parry *et al.,* 2016). Borax @ 0.2 per cent applied as foliar at 15 and 40 DAS and at flowering stage recorded the highest net returns (₹ 23,360 ha^{-1}) and B: C ratio (2.06) in lentil (Adhikary *et al.*, 2018).

2.1.2 Molybdenum Nutrition in Pulses

Molybdenum has several functions in leguminous plants *viz.,* nitrogen fixation, nodulation and metabolism. It is a constituent of nitrogenase enzyme which fixes N_2. It is also a constituent of nitrate reductase enzyme and also involved in N assimilation (Hristozkova *et al.*, 2006). Hansch and Mendel (2009) pointed out that *Rhizobium* bacteria required molybdenum for N fixation and also application of Mo in soils which are deficient helps in encouraging nitrogen fixation and nodule formation.

Molybdenum availability in soils depends on several factors *viz.,* soil pH, and concentration of adsorbing oxides, drainage, and organic compounds. Mo is mostly accessible to plants in anionic form as MoO_4^- mostly in alkaline soils, and its availability gradually decreases in acidic soils with pH < 5.5 (Reddy *et al.*, 1997).

2.1.2.1 Effect of Molybdenum on Growth Characters

Gupta and Gangwar (2012) ascertained that seed treatment with ammonium molybdate and $FeSO_4$ @ 1 g kg^{-1} seed along with *Rhizobium*, phosphorus solubilizing bacteria (PSB) and recommended dose of fertilizer (RDF) recorded the highest plant height (41.7 cm) in chickpea.

Singh *et al.* (2008) observed that Mo @ 2 kg ha^{-1}, S @ 40 kg ha^{-1} in succession with *Rhizobium* treatment as soil application has recorded maximum trifoliate leaves per plant (65) at 90 DAS in blackgram. Soil application of 60: 1.5: 1.0 kg ha^{-1} P_2O_5, Mo and Co resulted in the highest number of leaves (48.62) at harvest in mungbean (Awomi *et al.*, 2011).

Ammonium molybdate @ 2 kg ha^{-1}, S @ 40 kg ha^{-1} along with *Rhizobium* recorded maximum branches per plant (32) at 90 DAS in blackgram (Singh *et al.*, 2008).

Togay *et al.* (2008) evaluated different levels of Mo on lentil and observed that seed treatment of Mo @ 6 g kg^{-1} resulted in maximum nodule number per plant (15.27). The highest nodule number (11.17) was observed when the seeds of blackgram were treated with sodium molybdate (4 g kg^{-1} seed) (Tahir *et al.*, 2014). The highest nodule weight (0.122 g per plant) was registered with the application of Mo @ 1.5 kg ha^{-1} which was statistically comparable with Mo @ 2.25 kg ha^{-1} in greengram (Janaki *et al.*, 2018).

2.1.2.2 Effect of Molybdenum on Yield Parameters

Tahir *et al.* (2014) evaluated different levels of Mo for seed treatment. Treating blackgram seeds with sodium molybdate @ 6 g kg^{-1} registered maximum pod number per plant (26.20). The maximum average pod number per plant was achieved when pea seeds were treated with sodium molybdate along with N fertilization (Brkic *et al.*, 2004). Reddy *et al.* (2007) evaluated various levels of molybdenum. The maximum pod number per plant (214) was observed with soil application of sodium molybdate @ 3 kg ha^{-1} aggregation with 20: 50: 20: 20 kg ha^{-1} N, P, K and S respectivrly.

Among different levels of Mo as seed treatment, lentil seeds with 6 g kg^{-1} registered mximum number of seeds (18.6) per plant (Togay *et al.*, 2008). Priming of cowpea seeds with ammonium molybdate @ 10^{-3} M registered more seeds (15.3) per pod (Arun *et al.*, 2017).

Molybdenum @ 0.1 ppm along with Zn @ 2 ppm applied to leaves at vegetative stage in chickpea registered the highest 100 seed weight of 47.77 g (Bozoglu *et al.*, 2007). Sodium molybdate @ 3 kg ha^{-1} applied to soil along with 20: 50: 20: 20 kg ha^{-1} N, P, K and S registered maximum 100 seed weight (11.5 g) in pigeon pea (Reddy *et al.*, 2007).

The maximum yield of 24.96 g per plant was observed from plants supplied with Mo @ 1 kg ha^{-1} along with bacterial inoculums, however further increase in Mo level decreased the yield of soyabean (Jabbar *et al.*, 2013). Chickpea seeds treated with ammonium molybdate @ 1 g kg^{-1} seed along with *Rhizobium* and PSB (*Bacillus subtilis*) registered the highest grain yield of 1882 kg ha^{-1} (Poonia and Pithia, 2014). There was significant increase in grain yield of blackgram with increase in levels of molybdenum. However, maximum grain yield of 1016 kg ha^{-1} was noticed with sodium molybdate @ 3 g kg^{-1} seed (Tahir *et al.*, 2014).

The maximum stover yield of 4.5 q ha^{-1} was observed when mungbean was applied with P, Mo and Co @ 60: 1.5: 1.0 kg ha^{-1} respectively (Awomi *et al*., 2011). Straw yield increased significantly with different levels of molybdenum of which maximum yield of 16.14 g per plant was noticed with Mo @ 1.5 kg ha^{-1}(Janaki *et al*., 2018).

Seed treatment of Mo @ 6 g kg^{-1} registered maximum harvest index of 33.6 per cent in lentil (Togay *et al*., 2008). Blackgram seeds treated with sodium molybdate @ 2 g kg^{-1} resulted in maximum harvest index of 16.33 (Tahir *et al*., 2014). Arun *et al*. (2017) studied the effect of seed priming using different chemicals in cowpea of which the highest harvest index (0.31) was observed when seeds were primed with ammonium molybdate 10^{-3} M.

Shoot and root dry weight increased significantly when mungbean seeds were inoculated with P and Mo @ 25 and 1.5 kg ha^{-1}, in aggregation with *Rhizobium* (Rabbani *et al*., 2005). Application of ammonium molybdate @ 1 kg ha^{-1} with *Rhizobium,* PSB and recommended dose of fertilizer had registered significantly higher dry weight (2.56 g per plant) in chickpea (Gupta and Gangwar, 2012).

2.1.2.3 Effect of Molybdenum on Grain Quality

Significant increase in protein content of chickpea with different levels of sodium molybdate seed treatment of which maximum (20.2%) was reported from seed treatment with 5.25 g kg^{-1} (Deo and Kathari, 2002). Gangwar and Dubey (2012) stated that among various treatments, the highest grain protein (22.49%) content was reported with ammonium molybdate @ 1 kg ha^{-1} as soil application with *Rhizobium*, PSB and RDF in chickpea.

2.1.2.4 Effect of Molybdenum on Nutrient Uptake

Greengram seeds inoculated with sodium molybdate @ 0.16 mg g^{-1} and cobalt chloride @ 0.008 mg g^{-1} showed significant improvement in nutrient uptake

(Pattanayak *et al.*, 2000). The highest NPK content of 4.44, 0.56 and 1.87 per cent in seed were obtained from soil application of P, Mo and Co @ 60: 1.5: 1.0 kg ha^{-1} (Awomi *et al.*, 2011). Maximum concentration of N (4.60% and 4.84%) in shoot biomass was observed when seeds of chickpea genotypes were treated with Mo @ 0.5 and Fe @ 2 kg ha^{-1} respectively (Khan *et al.*, 2014).

2.1.2.5 Effect of Molybdenum on Available Nutrient Status of Soil

Application of ammonium molybdate significantly improved the available N status of soil; maximum soil available N (173.2 kg ha^{-1} was observed when chickpea seeds were treated with sodium molybdate @ 5.25 g kg^{-1} seed (Deo and Kathari, 2002). Availability of N, P, K and Mo status in soil increased with application of sodium molybdate @ 3 kg ha^{-1} in pigeon pea (Reddy *et al.*, 2007).

2.1.2.6 Molybdenum Nutrition on Economics

Gupta and Gangwar (2012) stated that maximum net returns of ₹ 7,532 ha^{-1} was obtained from ammonium molybdate @ 1.0 g and $FeSO_4$ @ 1.0 g kg^{-1} seed in aggregation with *Rhizobium*, PSB and RDF.

2.2 INTERACTION BETWEEN BORON AND MOLYBDENUM

2.2.1 Interaction Effect on Growth Characters

Shinde *et al.* (2018) evaluated the effect of various seed treatments on chickpea and revealed that maximum height (48.7 cm) at 75 DAS, maximum number of primary branches (9.2 per plant) and the highest LAI (4.114) at 60 DAS, maximum nodule number (55) and effective nodules (25.5) per plant were noticed with combined application of seed treatment of $ZnSO_4$, B, ammonium molydate and $FeSO_4$ @ 2 g kg^{-1} seed each.

Chatterjee and Bandyopadhyay (2015) observed maximum number of nodules (27.83) and nodule dry weight (199. 34 mg) per plant when cowpea seeds were treated with Mo @ 0.5 g kg^{-1} seed, *Rhizobium* and PSB in combination with foliar spray of B at four weeks after planting.

2.2.2 Interaction Effect on Yield Parameters

Janaki *et al.* (2018) evaluated various levels of B and Mo and their interaction on soil application and revealed that the highest pod number (14.33 per plant) was recorded with combined application of H_3BO_3 @ 4 kg ha^{-1} and ammonium molybdate @ 1.5 kg ha^{-1} as soil application.

Patra and Bhattacharya (2009) tested four levels of B and three levels of Mo as foliar application on mungbean and the results ascertained that application of ammonium molybdate @ 0.05 per cent and borax at 0.2 per cent recorded maximum seed yield (726.7 kg ha^{-1}) compared to control treatment (78.4 % increase).

2.2.3 Interaction Effect on Grain Quality

Interaction effect of B and Mo had significant influence on seed protein content of chickpea, among different combinations maximum protein content of 20.10 per cent was recorded with combined application of H_3BO_3 @ 2 kg ha^{-1} and ammonium molybdate @ 1.5 kg ha^{-1} (Rahman *et al.*, 2014).

2.2.4 Interaction Effect on Uptake and Soil Available Nutrients

Jain *et al.* (2007) revealed that maximum content of N and P (4.03 % and 0.59 %) in mungbean plants were reported with applicaton of P, Zn, B and Mo @ 40, 4, 0.1 and 0.6 kg ha^{-1} respectively along with *Rhizobium* inoculation.

Chatterjee and Bandyopadhyay (2015) showed that interaction between Mo, B and biofertilizers had significant influence on available nutrient content in soil. Availability of NPK was maximum (191.12, 26.79 and 129.23 kg ha^{-1} respectively) when cowpea seeds treated with Mo and biofertilizers in combination with B as foliar spray six weeks after planting.

2.2.5 Interaction Effect on Economics

The maximum B: C ratio of 1.97 was registered with combined spray of DAP, NAA, B and Mo @ 2 per cent, 40 ppm, 0.2 per cent and 0.05 per cent respectively as foliar spray in greengram (Dixit and Elamathi, 2007).

2.3 SIGNIFICANCE OF FOLIAR NUTRITION IN PULSES

Vital input in agriculture for boosting crop yields is fertilizer. Foliar nutrition is considered as effective method among different methods of fertilizer application. Foliar nutrition is the application of completely water soluble fertilizers on the foliage of standing crops with suitable concentrations. In many cases it is preferred and gives quicker and better results than soil application (Jamal *et al.*, 2006). Foliar application facilitates easy absorption and rapid penetration of nutrients, helps in reduction of leaching losses and fixation and also regulates nutrient uptake (Manonmani and Srimathi, 2009).

Foliar spray is useful in early maturing short duration crops, where the applied fertilizer applied to soil may not be fully available to crop before it reaches maturity. As top dressing or placement is not feasible in many cases due to soil and climatic constraints, foliar fertilization is the best suited for *Rabi* pulses (Rahman *et al.*, 2015)

2.3.1 Effect of Urea Foliar Spray on Pulses

2.3.1.1 Effect of Foliar Spray of Urea on Growth Characters

Dudhade and Patil (2003) studied different levels of urea in chickpea and observed that the tallest plants (18.9 cm) was registered with 3 per cent foliar spray of urea at ten days before flower initiation and 15 days after first spray. Among different bio-organic and urea fertilizers used as foliar spray, the tallest plants (10.25 cm) were recorded when mungbean plants were sprayed with urea @ 1 per cent (Khalilzadeh *et al.*, 2012). In groundnut, foliar spray of urea in combination with diammonium phosphate (DAP) and muriate of potash (MOP) @ 2, 0.7 and 0.7 per cent each registered maximum plant height of 23.94 cm at harvest (Kumar and Salakinkop, 2017). The highest numbers of trifoliate leaves per plant (11.5) at 45 days in cowpea were observed when sprayed with urea @ 2 per cent (Dey *et al.*, 2017).

Significant influence on branching of chickpea due to foliar spray of urea and DAP and maximum number of branches (6.93 per plant) was registered with foliar spray of urea at 75 DAS (Venkatesh *et al.*, 2012). Das and Jana (2016) evaluated five levels of foliar spray of 2 per cent urea in lentil and concluded that two sprays at branching and pod initiation recorded maximum primary branches per plant (6.3).

Significant influence on leaf area of blackgram was noticed from vegetative to pod filling stage with 2 per cent urea as foliar spray (Sritharan *et al.*, 2005). LAI significantly increased up to 90 DAS in groundnut and decreased later. At harvest maximum leaf area index of 2.97 was noticed when urea @ 2 per cent was applied as foliar spray in combination with DAP and MOP @ 0.7 per cent each (Kumar and Salakinkop, 2017).

Aggarwal *et al.* (2015) evaluated 2 per cent urea as foliar spray at various growth stages on chickpea and observed maximum nodule number and nodule dry weight (40 and 137.3 mg per plant) when 2 per cent urea was sprayed at vegetative and flower initiation stage. Jadhav (2017) also confirmed the significance of foliar spray at 45 and 75 DAS in soyabean with 2 per cent urea in enhancing nodule number per plant (58.76 and 60. 85).

2.3.1.2 Effect of Urea Foliar Spray on Yield Parameters

Aliloo *et al.* (2012) revealed significant increase in pod number in chickpea and maximum pod number (29.4 per plant) was noticed when plants were treated with 2 per cent urea as foliar spray after flowering. Jadhav (2017) observed that pod number per plant was increased from 75 DAS to harvest in soyabean with different foliar sprays. Among them, maximum pods (24.94, 27.42 and 28.11 per plant) were observed at 75, 90 DAS and at harvest with 2 per cent urea as foliar spray at 30 and 45 DAS.

Foliar spray of urea @ 2 per cent had registered maximum seed number per pod (6.87) in blackgram (Rao, 2013). Brijnandan *et al.* (2014) evaluated urea @ 2 per cent as foliar application at various growth stages on chickpea and observed that maximum seed number per pod (1.9) was obtained with two foliar sprays at flowering and 10 days after first spray.

Rao (2013) evaluated foliar application of various chemicals in blackgram and observed maximum test weight of 3.98 g when urea was applied as 2 per cent foliar spray.

In chickpea, foliar spray of urea @ 1 per cent at pod filling stage had recorded maximum seed yield of 1273 and 1648 kg ha^{-1} under low density (26 plants m^{-2}) and high density (50 plants m^{-2}) planting (Bahr, 2007). Application of urea @ 1.5 per cent as foliar spray three times during reproductive stage recorded maximum seed yield in soyabean (Mondal *et al.*, 2012).

Kumawat *et al.* (2015) stated that foliar application of 1 per cent urea both at flowering and after flowering registered maximum straw yield (1635 kg ha^{-1}) in clusterbean. Meena *et al.* (2017) evaluated different foliar nutrition practices in urdbean and concluded that maximum straw yield (3780 kg ha^{-1}) registered in the treatment combination of 2 per cent urea, 2 per cent SSP, 0.1 per cent zinc EDTA and 0.2 per cent B as foliar spray.

Bahr (2007) evaluated plant densities and urea foliar spray on chickpea and concluded that maximum harvest index (0.5) was obtained with 1 per cent urea foliar spray at pod filling stage for both plant densities (25 and 50 plants m^{-2}).

Aliloo *et al.* (2012) evaluated different levels of urea foliar spray for two cultivars (ILC 482 and Azad) in chickpea. The study revealed that maximum dry matter production was recorded when urea was sprayed after flowering @ 2 and 4 per cent for ILC 482 and Azad respectively.

2.3.1.3 Effect of Urea Foliar Spray on Grain Quality

Protein content is higher (40.4 %) in soyabean seeds when urea was applied as foliar spray @ 0.5 per cent (Ashour and Thalooth, 1983). The maximum protein content of 23.5 per cent in seeds of chickpea was noticed with 1 per cent urea foliar spray at pod setting in high density planting of 5 plants m^{-2} (Bahr, 2007).

Palta *et al.* (2005) opined that urea foliar spray at different growth stages in chickpea and reported maximum N content (445.2 mg per plant) at maturity. 2 per cent urea as foliar spray at flowering and 10 days after flowering have registered maximum N and protein content (3.09 and 19.31 per cent) in chickpea seeds (Brijnandan *et al.*, 2014).

2.3.1.4 Effect of Urea Foliar Spray on Available Nutrient Status of Soil

Afifi *et al.* (2011) observed maximum available N, P and K status of soil (22.87, 4, 17.53 kg ha^{-1} respectively) when maize plants were applied with N @ 100 per cent as soil application along with urea foliar spray.

2.3.1.5 Effect of urea foliar spray on economics

Foliar spray of 2 per cent urea at different stages in chickpea had significantly influenced net returns and B: C ratio and among all, foliar spray at pod initiation stage had recorded maximum net income (₹ 59,200 ha^{-1}) and B: C ratio of 1.96 (Aggarwal *et al.*, 2015).

2.3.2 Foliar Spray of KNO_3 in Pulses

2.3.2.1 Effect of Foliar Spray of KNO_3 on Growth Characters

Treatment combination with KCl and KNO_3 @ 1 per cent as foliar spray recorded maximum height of plant (48.6 cm) (Govindan and Thirumurugan, 2000). Bardhan *et al.* (2007) evaluated various growth promoting chemicals on chickpea and reported that among different chemicals applied KNO_3 @ 200 ppm as foliar at 40 and 60 DAS showed significant increase in plant height. Blackgram treated with foliar spray of KNO_3 @ 1 per cent has given maximum plant height of 20.21 cm (Rao, 2013).

Soyabean plants when applied with KNO_3 @ 1 per cent at 25 to 30 and 55 to 60 DAS recorded the highest leaf number per plant (17.47) at 60 DAS (Marksole, 2016).

Zanje (2015) observed maximum number of branches (10.00 per plant) when soyabean plants treated with KNO_3 @ 2 per cent at 30 and 45 DAS. Soyabean and pigeonpea when treated with KNO_3 @ 2 per cent as foliar spray in intercropping system of 2: 1 has recorded maximum number of branches at harvest (5.29) (Dilip, 2017).

In soyabean, higher leaf area of 2044.89 cm^2 was registered with foliar spray of KNO_3 @ 2 per cent at 30 and 45 DAS (Zanje, 2015).

Foliar application of KNO_3 on soyabean revealed significant increase in nodule number per plant from branching to pod formation stage and gradually decreased towards maturity, maximum nodule number per plant (51.30) were registered with KNO_3 spray @ 1 per cent at 45 and 60 DAS (Sanjeev, 2015).

2.3.2.2 Effect of KNO_3 Foliar Spray on Yield Parameters

Significantly lesser number of days (41.84) for 50 per cent flowering was noticed in soyabean when KNO_3 (2 %) was given as foliar spray at 30 and 45 DAS (Zanje, 2015).

Blackgram plants sprayed with KNO_3 @ 2 per cent registered maximum seed number per pod (25.33) compared to water spray (Rao, 2013). The maximum number of pods per plant (53.4) was obtained when greengram planted at 30 cm x 30 cm was sprayed with 1 per cent KNO_3 in combination with RDF, farm yard manure (FYM) and $ZnSO_4$ (Keerthy *et al.*, 2015). Dilip (2017) opined that in 2: 1 intercropping system of soyabean and pigeonpea the highest numbers of pods (30.58) at harvest were observed with foliar spray of 2 per cent KNO_3

Govindan and Thirumurugan (2000) worked on response of greengram to foliar nutrition and observed maximum number of seeds per pod (10.77) when KCl and KNO_3 @ 1 per cent were applied as foliar spray. Keerthy *et al.* (2015) also stated that greengram plants when treated with 1 per cent KNO_3 along with RDF, FYM and $ZnSO_4$ recorded the highest seed number (13.23 per pod).

The maximum weight of 100 seeds (4 g) was recorded when greengram plants were treated with KNO_3 and KCl @ 1 per cent as foliar spray (Govindan and Thirumurugan, 2000). Vekaria *et al.* (2013) stated that application of KNO_3 as foliar spray @ 0.4 per cent significantly improved 100 seed weight (3.96 g) in greengram compared to control.

Govindan and Thirumurugan (2000) opined that higher seed yield of 777 kg ha^{-1} was obtained when greengram plants were treated with KNO_3 in combination with KCl @ 1 per cent as foliar spray. Seed yield of soyabean had improved significantly compared to control.

Zanje (2015) revealed that soyabean plants performed superiorly with foliar spray of KNO_3 @ 2 per cent showing maximum haulm yield (26.52 q ha^{-1}). Marskole (2016) evaluated various foliar sprays on soyabean and observed the highest haulm yield of 3390 kg ha^{-1} with foliar spray of KNO_3 @ 1 per cent at 25 to 30 and 55 to 60 DAS.

Foliar application of KNO_3 @ 2 per cent had registered maximum harvest index of 19.3 per cent in Egyptian clover at weekly intervals starting from flower initiation (Kumar *et al*., 2013). The maximum values for harvest index (0.23) for greengram were observed with foliar application of KNO_3 @ 0.4 per cent at 40 and 60 DAS on foliage (Vekaria *et al.,* 2013).

Rao (2013) reported that there was gradual increase in root dry weight of blackgram plants when treated with KNO_3 @ 1 per cent as foliar spray. Keerthy *et al.* (2015) opined that there was rapid increase in DMP from 30 DAS to harvest with the highest value of 2865 kg ha^{-1} when greengram plants were treated with KNO_3 @ 1 per cent as foliar spray in combination with plant spacing of 30cm x 30 cm, RDF, FYM @ 12.5 t ha^{-1} and $ZnSO_4$ as basal @ 25 kg ha^{-1}. In an intercropping system of soyabean and pigeonpea (2: 1), the mean dry weight of soyabean plant was higher (20.41 g) at harvest with foliar spray of 2 per cent KNO_3 (Dilip, 2017).

2.3.2.3 Effect of KNO_3 Foliar Spray on Grain Quality

Protein content did not significantly differ when 19: 19: 19 @ 1 per cent and KNO_3 @ 2 per cent were applied as foliar spray at 30 and 45 DAS; both the treatments recorded maximum protein content in soyabean grain (37.54 %) (Zanje, 2015).

2.3.2.4 Effect of KNO_3 Foliar Spray on Uptake of Nutrients

There was significant increase in NPK uptake by soyabean plant from branching to maturity and maximum uptake of 80.75, 13.77 and 50.90 kg ha^{-1} of NPK respectively were observed with foliar spray with 1 per cent KNO_3 at 45 and 60 DAS (Sanjeev, 2015).

2.3.2.5 Effect of KNO_3 Foliar Spray on Available Nutrient Status of Soil

NPK status in soil after experiment was found to be high, *i.e.,* 193.53, 20.29, 397.62 kg ha^{-1} NPK respectively, when soyabean plants were treated with 2 per cent KNO_3 as foliar spray at 30 and 45 DAS (Zanje, 2015).

2.3.2.6 Influence of KNO_3 Foliar Spray on Economics

The maximum net income (₹ 2043 ha^{-1}) and B: C ratios of 2.69 were noted with KNO_3 @ 0.4 per cent as foliar spray at 40 and 60 DAS (Vekaria *et al.*, 2013). Keerthy *et al.* (2015) evaluated different spacings and foliar nutrition on greengram and reported that the highest net returns (₹ 57,806 ha^{-1}) and B: C ratio (2.43) were observed with foliar spraying of KNO_3 @ 1 per cent in combination with plant spacing of 30cm x 30 cm, RDF, FYM @ 12.5 t ha^{-1} and $ZnSO_4$ as basal @ 25 kg ha^{-1}.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Seed treatment and foliar nutrition for enhanced productivity of blackgram (*Vigna mungo* L.)" was conducted during *Rabi* 2018 (September to December, 2018) at the Instructional Farm, College of Agriculture, Vellayani, Kerala, India. The study aimed to evaluate the influence of seed treatment and foliar nutrition on the growth and yield of blackgram and also to work out the economics of production.

3.1 DETAILS OF EXPERIMENT

3.1.1. Location of Study Area

The study was conducted at the Instructional Farm in block IV attached to the College of Agriculture, Vellayani, Kerala, India located at 8.5° North latitude and 76.9° East longitude and at an altitude of 29 m above mean sea level.

3.1.2. Climate

A warm humid climate prevailed during the cropping period. The daily weather parameters *viz.*, mean temperature, relative humidity (RH), rainfall and evaporation were recorded during the cropping period. The rainfall received during the crop season extending from 26/09/2018 to 18/12/2018 was 580.6 mm in 25 rainy days. The mean maximum and minimum temperature recorded during the crop season were 31.75 and 24.08°C respectively. The data on weather parameters *viz.*, temperature, relative humidity, rainfall and sunshine hours during cropping season were recorded and furnished in Appendix I and Fig. 1.

3.1.3. Cropping Season

The study was conducted during *Rabi* 2018 from September to December, 2018.

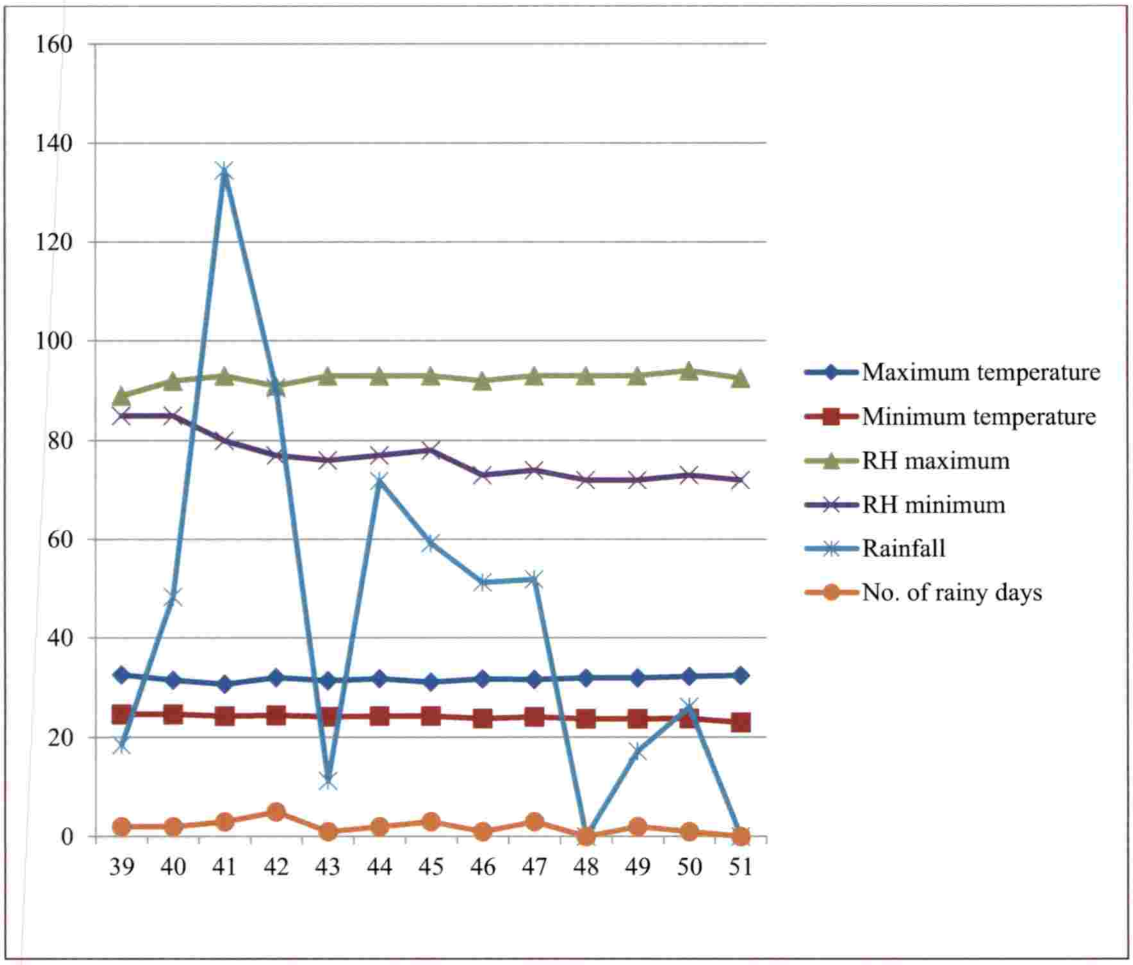

Fig. 1. Weather data during the crop season (26/09/2018 to 18/12/2018)

3.1.4. Soil

Prior to the investigation, the initial soil nutrient status was assessed. For this, a composite soil sample was collected from a depth of 0 to 15 cm and mechanical composition and chemical properties were analyzed. The data on the mechanical composition and chemical properties of the soil of the study area are given in Table 1.

3.1.5 Cropping History of Field

The field was lying fallow before the experiment for a period of three months

3.2. MATERIALS

3.2.1. Crop Variety

Co-6, a high yielding short duration (60-65 days) variety, released from Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, with an average yield of 733 kg ha^{-1} was used for the trial. It has determinate and synchronous maturity. The variety is moderately resistant to diseases like mungbean yellow mosaic virus, stem necrosis and root rot. It is also tolerant to pests like aphids, stem fly and spotted pod borer.

3.2.2. Source of Seed

The seeds required for the experiment were procured from Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

3.2.3. Manures and Fertilizers

Dried cow dung powder with nutrient content of 0.45 per cent N, 0.17 per cent P_2O_5 and 0.50 per cent K_2O was used for the experiment. Urea (46% N), rajphos (20% P_2O_5) and muriate of potash (60% K_2O) were used as sources for N, P and K. Borax (11.4% B) and sodium molybdate (40% Mo)

Table 1.Physico-chemical properties of soil before the experiment

Particulars	Value	Method used
a. Physical properties of soil		
Bulk density (Mg m^{-3})	1.59	Core method (Gupta and Dakshinamoorthy, 1980)
Particle size composition		
Coarse sand (%)	16.92	International pipette method (Piper, 1967)
Fine sand (%)	30.52	
Silt (%)	23.85	
Clay (%)	27.81	
Texture	Sandy clay loam	
b. Chemical properties of soil		
pH	5.44 (strongly acid)	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1973)
Organic carbon (%)	0.99 (high)	Walkley and Black method (Jackson, 1973)
Available N (kg ha^{-1})	225.79 (low)	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P(kg ha^{-1})	26.16 (high)	Brays colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	347.12 (high)	Neutral normal ammonium acetate extract using Flame photometer (Jackson, 1973)
Available B (mg kg^{-1} soil)	0.732 (medium)	Hot water extraction and colorimetry using Azomethine-H (Hesse, 1971)
Available Mo (mg kg^{-1} soil)	0.005 (low)	Ammonium oxalate (Tamm's or Griggs reagent at pH 3.0) method (Grigg, 1953)

were used as sources of B and Mo.

3.3 METHODS

3.3.1. Layout of the Experiment

Design : RBD

Treatments : 6 x 2 = 12

Replication : 3

Season :*Rabi* 2018 (September to December 2018)

Spacing : 25 cm x 15 cm

Gross plot size : 3 m x 2.4 m

Net plot size : 2.25 m x 1.8 m

Total number of plots : 36

3.3.2. Details of Experiment

1. Factor A- Seed treatment (S)-6

s_0 - Without seed treatment

s_1 - Seed treatment with borax (1 g kg^{-1} seed)

s_2 - Seed treatment with borax (2 g kg^{-1} seed)

s_3 - Seed treatment with sodium molybdate (1g kg^{-1} seed)

s_4 - Seed treatment with sodium molybdate (1.5 g kg^{-1} seed)

s_5 - Seed treatment with borax (1 g kg^{-1} seed) and sodium molybdate (1 g kg^{-1} seed)

2. Factor B. Nutrient schedule (N) - 2

n_1- ½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS as per POP (KAU, 2016)

n_2- ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS.

Recommended dose of 20: 30: 30 kg NPK ha^{-1} was adopted (KAU, 2016) and urea @ 2 per cent and 13:0:45 @ 2 per cent was used for spraying.

3.3.3. Land Preparation and Layout

The area selected for the experiment was ploughed twice, brought to fine tilth, and laid into plots of 3 m x 2.4 m. The layout plan is shown in Fig. 2.

3.3.4. Seed Treatment and Sowing

For treating the seeds, borax and sodium molybdate at rates as per the experimental schedule were mixed thoroughly with rice gruel as sticking agent and shade dried on the day before sowing. On the day of sowing the seeds were treated with *Rhizobium* culture, common to all treatments, shade dried and dibbled into soil at spacing of 25 cm x 15 cm.

3.3.5. Application of Manures and Fertilizers

Before sowing the seeds, dried cow dung powder was applied uniformly to all plots @ 20 t ha^{-1}. N and K fertilizers were applied as per treatments and entire dose of phosphorous (20 kg P_2O_5 ha^{-1}) was applied uniformly to all plots.

N ↑

R_1	R_2	R_3
s_2n_1	s_0n_1	s_2n_1
s_3n_1	s_1n_1	s_3n_1
s_4n_1	s_2n_1	s_1n_1
s_5n_1	s_3n_1	s_0n_1
s_0n_1	s_4n_1	s_0n_2
s_0n_2	s_5n_1	s_2n_2
s_2n_2	s_5n_2	s_4n_2
s_3n_2	s_0n_2	s_3n_2
s_4n_2	s_1n_2	s_5n_1
s_5n_2	s_2n_2	s_5n_2
s_1n_1	s_3n_2	s_4n_1
s_1n_2	s_4n_2	s_1n_2

2.4 m

3m

Fig. 2. Layout of experimental field

Plate 1. General view of experimental plot

3.3.6. After Cultivation

Germination per cent was recorded from 3 DAS. The crop was thinned one week after emergence. The crop was given two weedings at 15 and 30 DAS. Irrigation was given twice; first immediately after sowing and second at flowering. Twenty days after sowing, five plants in each plot were selected randomly and tagged as observational plants. The general view of experimental plot and crop at various growth stages are presented in plate 1 and 2.

3.3.7. Plant Protection

Tobacco caterpillar (*Spodoptera litura*) incidence was noticed at 20 DAS and was controlled by quinolphos @ 2 mL L^{-1}. At pod maturity stage, there was the incidence of spotted pod borer (*Maruca vitrata*) which was controlled by spraying coragen (chlorantraniliprole) @ 3 mL $10L^{-1}$.

3.3.8. Harvest

Harvest was carried out in three pickings. The total crop duration was 85 days. The dry pods from each net plot were picked, sun dried and threshed separately plot wise and yield of grain and haulm yield recorded. One day prior to harvest, the observational plants were pulled out and recorded observations.

3.4. GROWTH CHARACTERS

3.4.1 Plant Height

The mean values of the height of five marked plants in each plot were computed at interval of every 20 days and recorded. The height of plant was taken from base of plant to the tip and expressed in cm.

3.4.2 Number of Leaves per Plant

The mean values for number of trifoliate leaves per plant were computed from the five observational plants at every 20 days interval and were recorded.

3.4.3 Number of Branches per Plant

The mean values for number of branches per plant were computed from five observational plants in each plot at every 20 days interval and were recorded.

3.4.4 Leaf Area Index (LAI)

Leaf area per plant was computed by using length and breadth measurement method. The leaf area was recorded at 20, 40 and 60 DAS and expressed in cm^2.

$$\text{Leaf area} = L \times B \times K \times n$$

Where,

L = length of leaf (cm)

B = breadth of leaf (cm)

K (constant value) = 0.631 (Montgomery, 1911)

n = number of leaves

Based on the recorded leaf area per plant, the LAI was computed using the following formula,

$$\text{LAI} = \frac{\text{Leaf area per plant } (cm^2)}{\text{Land area occupied by the plant } (cm^2)}$$

3.4.5 Number of Nodules per Plant

The number of nodules per plant was recorded at flowering stage. Two plants were uprooted from each plot from the rows set apart for this observation. The roots of the plants were washed and made free of soil particles. The nodules were removed from plants and counted separately and recorded.

3.4.6 Number of Effective Nodules per Plant

The nodules separated from each plant were cut and observed for colour. The nodules with pink colour were identified as effective and nodules with green colour were considered ineffective (Jordan, 1962).

3.4.7 Weight of Nodules per Plant

The nodules separated from each plant at flowering were oven dried to a constant weight and weight of nodules per plant was recorded and expressed in mg.

3.4.8 Root Length

At flowering stage, two plants were uprooted from each plot from the rows set apart for this observation. The roots of the plants were washed and made free of soil particles and measured the length. The mean value was calculated and expressed in cm.

3.4.9 Root Spread

The length of the largest lateral root on both sides of the taproot was measured. The mean values were worked out and expressed in cm.

3.4.10 Root Weight per Plant

At flowering stage, two plants were uprooted from uniform depth in each plot from the rows set apart for this observation. The roots of the plants were washed and

At 15 DAS

At 30 DAS

At flowering

At pod maturity stage

Plate 2. Experimental field at different growth stages

made free of soil particles and dried in hot air oven at 65 ± 5°C to constant weight and expressed in g.

3.5 YIELD PARAMETRES

3.5.1 Days to 50 per cent Flowering

The number of days taken for 50 per cent flowering was recorded for each treatment and expressed as number of days.

3.5.2 Number of Pods per Plant

Pods were collected separately from the observational plants from each plot and mean worked out and recorded.

3.5.3 Length of Pod

Ten pods were selected randomly from the observational plants of each treatment for length measurements and averages were worked out and expressed in cm.

3.5.4 Number of Seeds per Pod

Pods used for measuring the length were threshed separately and number of seeds in each pod was counted and the averages worked out.

3.5.5 100 Seed Weight

100 seeds were selected randomly from each net plot, weighed and values were recorded in g.

3.5.6 Pod Yield

Yield of pods obtained from each net plot was recorded separately after drying the pods and expressed in kg ha^{-1}

3.5.7 Grain Yield

Yield of grain obtained from each net plot was recorded separately after drying the grains to a moisture content of 12 per cent and expressed in kg ha^{-1}.

3.5.8 Haulm Yield

The plants were uprooted uniformly from each net plot, pods were picked and the plants were dried under sun uniformly and weighed and expressed in kg ha^{-1}.

3.5.9 Harvest Index

It was worked out based on grain, husk and bhusa yield from the net plot using the following formula and expressed in per cent as suggested by Nichiporovich (1960)

$$HI = \frac{\text{Seed yield}}{(\text{Seed yield} + \text{Haulm yield})}$$

3.5.10 Dry Matter Production

The observational plants from each plot were uprooted. The shoot portion and grains were separated, sun dried and then dried to constant weight in hot air oven at $65 \pm 5^{0}C$ for 48 hours. The weight of different plant parts were added to get DMP and expressed in kg ha^{-1}.

3.6. QUALITY ANALYSIS

3.6.1 Protein Content of Grain

The protein content of grain was calculated by multiplying N per cent with the factor 6.25 (Simpson *et al.*, 1965). The protein content was recorded and expressed in percentage.

3.7. CHEMICAL ANALYSIS

3.7.1 Plant Analysis

At harvest, observational plants from each plot were uprooted separately, sun dried and then dried to constant weight in hot air oven at 65 ± 5 ^{0}C, ground to fine powder and used for analyzing total N, P, K, B and Mo. The finely grounded samples were weighed accurately, digested by acid and used for determining N, P, K, B and Mo.

3.7.1.1 Nitrogen Uptake

The total N content in shoot and grain was estimated by modified microkjeldahl method (Jackson, 1973). The uptake was calculated by multiplying the N content of shoot and grain with their total DMP and expressed as kg ha^{-1}.

3.7.1.2 Phosphorus Uptake

The total P content in the shoot and grain were estimated colorimetrically, after wet digestion and colour development using vanadomolybdate phosphoric yellow colour method and intensity of colour was read using spectrophotometer (Jackson, 1973). The total P uptake was calculated by multiplying the P content of shoot and grain with their total DMP and expressed as kg ha^{-1}.

3.7.1.3 Potassium Uptake

The total K content in shoot and grain were estimated using flame photometer (Jackson, 1973). The uptake was estimated by multiplying the K content of shoot and grain with their total DMP and expressed as kg ha^{-1}.

3.7.1.4 Boron Uptake

The total B content in shoot and grain were estimated by azomethine-H calorimetric method (Wolf, 1971). The total uptake was calculated by multiplying the total B content of shoot and grain with their total DMP and expressed as mg kg^{-1}.

3.7.2 Soil Analysis

For analysis of soil before experiment, soil samples were collected from five different spots at a depth of 15 cm from the experimental area, dried under shade and composite samples were prepared by quartering. After the harvest of crop, the composite soil samples were collected from each plot uniformly from 15 cm depth and samples were shade dried for analysis of available N, P, K, B and Mo.

3.7.2.1 Organic Carbon

The soil samples for organic carbon estimation were sieved through 0.2 mm sieve and analyzed using rapid titration method (Walkley and Black, 1934).

3.7.2.2 Available Nitrogen

Soil samples for available N were analyzed by alkaline potassium permanganate method (Subbiah and Asija, 1956).

3.7.2.3 Available Phosphorus

Soil samples for available P were analyzed by Dickman and Brays molybdenum blue method using spectrophotometer (Jackson, 1973).

3.7.2.4 Available Potassium

Soil samples for available K were analyzed by extraction with neutral normal ammonium acetate and estimated by using flame photometer (Jackson, 1973).

3.7.2.5 Available Boron

Soil samples were analyzed for available B by hot water extraction and colorimetry using Azomethine-H (Hesse, 1971).

3.7.2.6 Available Molybdenum

Soil samples were analyzed for available Mo by Ammonium oxalate (Tamm's or Griggs reagent, pH – 3.0) method. (Grigg, 1953).

3.8 INCIDENCE OF PEST AND DISEASES

Observations on the incidence of major pest and diseases during cropping period were recorded.

3.9 ECONOMIC ANALYSIS

The economics of blackgram cultivation was worked out based on the cost of cultivation and the prevailing market price of produce.

3.9.1 Net Income

The net returns was calculated using formula

Net income (₹ ha^{-1}) = Gross income – cost of cultivation

3.9.2 B: C Ratio

B: C ratio was calculated using the formula

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$$\text{Benefit: Cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.10 STATISTICAL ANALYSIS

The data were statistically analyzed using analysis of variance technique (F-test) as per methods suggested by (Panse and Sukhatme, 1985). Wherever significant differences among the treatments were observed, CD values at 5 per cent level of significance were calculated for comparison of means.

Results

4. RESULTS

The field experiment was conducted during *Rabi* 2018 (September to December 2018) at the Instructional farm, College of Agriculture, Vellayani, Kerala, India with an objective to study the influence of seed treatment and foliar nutrition on the growth and yield of blackgram and also to work out economics of production. The results of the present investigation entitled "Seed treatment and foliar nutrition for enhanced productivity of blackgram (*Vigna mungo* L.) are presented below.

4.1 GROWTH ATTRIBUTES

4.1.1 Plant Height

The effect of seed treatment, nutrient schedule and their interaction on height of plant at different growth stages are depicted in Table 2a and 2b.

Seed treatment did not significantly influence height of plant at 20 DAS, at 40 DAS, 60 DAS and at harvest, height of plant was influenced by seed treatment. At 40 DAS, s_5 (seed treatment with borax @ 1 g kg^{-1} seed and sodium molybdate @ 1 g kg^{-1} seed) recorded the highest (103.24 cm), which was at par with s_1 (seed treatment with borax @ 1 g kg^{-1} seed) and the smallest plants (88.02) were recorded in s_0 (without seed treatment). Similarly, at 60 DAS and at harvest, the tallest plants were seen with s_5 and the smallest plants were seen in s_0.

Nutrient schedule had no significant at 20 DAS, 60 DAS and at harvest. At 40 DAS, plant height was significantly influenced by nutrient schedule, the tallest plants (99.16) was seen with n_1 (½ N + full P + full K (basal) as soil application + ½ N

Table 2a. Effect of seed treatment and nutrient schedule on plant height at different growth stages, cm

Treatments	Plant height			
	20 DAS	40 DAS	60 DAS	At harvest
Seed treatment (S)				
s_0	38.68	88.02	99.14	106.51
s_1	38.38	102.17	115.29	122.33
s_2	37.62	96.57	112.69	119.34
s_3	38.45	101.06	117.30	123.91
s_4	37.64	96.48	113.78	118.16
s_5	38.82	103.24	128.12	135.84
SEm (±)	0.54	0.60	0.90	1.10
CD (0.05)	NS	1.784	2.665	3.254
Nutrient schedule (N)				
n_1	38.08	99.16	114.98	120.87
n_2	38.45	96.69	113.79	121.17
SEm (±)	0.31	0.35	0.52	0.64
CD (0.05)	NS	1.030	NS	NS

Table 2b. Interaction effect of seed treatment and nutrient schedule on plant height at different growth stages, cm

Treatments	Plant height			
	20 DAS	40 DAS	60 DAS	At harvest
S X N interaction				
s_0n_1	37.27	84.24	96.44	105.02
s_0n_2	40.10	91.81	101.83	108.01
s_1n_1	37.60	101.58	112.75	119.28
s_1n_2	39.17	102.76	117.83	125.38
s_2n_1	37.13	96.58	114.81	120.31
s_2n_2	38.10	96.57	110.57	118.37
s_3n_1	38.90	102.56	119.19	123.48
s_3n_2	38.01	99.56	115.42	124.34
s_4n_1	37.51	99.38	113.03	116.76
s_4n_2	37.77	93.58	114.53	119.57
s_5n_1	40.07	110.62	133.65	140.35
s_5n_2	37.57	95.86	122.58	131.33
SEm (±)	0.77	0.85	1.28	1.56
CD (0.05)	2.269	2.523	3.768	4.602

as foliar spray of urea at 15 and 35 DAS). The smallest plants (96.69) were recorded in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule was found significant at all growth stages. At 20 DAS, the tallest plants (40.10) were seen in s_0n_2, which was statistically comparable with s_5n_1, s_1n_2, s_3n_1, s_2n_2 and s_3n_2; the shortest plants (37.13 cm) were recorded in s_2n_1. At 40 and 60 DAS and at harvest the tallest plants were seen in s_5n_1 and the smallest plants were recorded in s_0n_1.

4.1.2 Leaves per Plant

The observation on number of trifoliate leaves per plant at different growth stages are imparted in Table 3a and 3b.

Seed treatment had no significant influence on number of leaves per plant at 20 and 40 DAS. At 60 DAS and at harvest, seed treatment had shown significant influence on leaf number. At 60 DAS and at harvest, the highest number of leaves per plant (16.05 and 7.61 respectively) were seen with s_5 (seed treatment with borax @ 1 g kg^{-1} seed and sodium molybdate @ 1 g kg^{-1} seed) and the lowest number of leaves per plant (12.02 and 5.62 respectively) in s_0 (without seed treatment).

Nutrient schedule also had no significant effect on number of leaves per plant at 20 and 40 DAS. At 60 DAS and at harvest, nutrient schedule had shown significant influence on leaf number. At 60 DAS, the highest number of leaves per plant (14.61) were recorded with n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS) and the lowest leaves in n_2. At harvest, the highest number of leaves per plant (6.68) was seen with n_2 and the lowest with n_1.

Interaction between seed treatment and nutrient schedule also had no significant influence on number of leaves per plant at 20, 40 and 60 DAS. Interaction effect was significant only at harvest. At harvest the highest number of leaves (7.89) was recorded in s_5n_2 and was on par with s_5n_1 and the lowest number of leaves (5.06) was seen with s_0n_1.

4.1.3 Branches per Plant

The results obtained on number of branches per plant at different growth stages are presented in Table 4a and 4b. There is appreciable increase in the number of branches per plant with advancing growth stages.

Seed treatments did not significantly influence the branches number per plant at 20 and 40 DAS. At 60 DAS and at harvest, seed treatment had significantly influenced the number of branches per plant. At 60 DAS, the highest number of branches per plant (7.14) were recorded in s_1 (seed treatment with borax @ 1 g kg^{-1} seed) and the lowest (4.18) in s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed). At harvest, the highest (6.39) and the lowest (5.10) number of branches per plant were recorded in s_5 and s_1 respectively.

Nutrient schedule did not significantly influence the branches per plant at 20 and 40 DAS. At 60 DAS and at harvest nutrient schedule significantly influenced number of branches per plant. At 60 DAS, the highest number of branches (5.86) was recorded in n_2 and the lowest (4.53) in n_1. At harvest, the highest number of branches (5.89) recorded with n_1 and the lowest (5.62) with n_2.

Interaction between seed treatment and nutrient schedule significantly influenced number of branches per plant at 20 and 60 DAS and at harvest. At 20 DAS, the highest numbers of branches (2.40) was recorded in s_3n_2 and s_1n_2 which were at par with s_5n_1, s_4n_1, s_2n_2, s_3n_2, s_0n_1, s_2n_1, s_3n_1. At 60 DAS the highest numbers of branches (9.92) was seen in s_1n_2 and the lowest number of branches (3.55) was recorded in s_2n_1. At harvest, the highest (6.78) and the lowest number of branches (4.77) were recorded in s_5n_1 and s_1n_2 respectively.

Table 3a. Effect of seed treatment and nutrient schedule on number of trifoliate leaves per plant at different growth stages

Treatments	Leaves per plant			
	20 DAS	40 DAS	60 DAS	At harvest
Seed treatment (S)				
s_0	3.43	9.72	12.02	5.62
s_1	3.57	11.50	14.22	6.52
s_2	3.63	10.80	14.44	5.94
s_3	3.57	11.82	14.65	6.15
s_4	3.33	10.04	13.99	7.03
s_5	3.43	11.75	16.05	7.61
SEm (±)	0.16	0.56	0.44	0.14
CD (0.05)	NS	NS	1.289	0.419
Nutrient schedule (N)				
n_1	3.59	11.08	14.61	6.28
n_2	3.40	10.79	13.85	6.68
SEm (±)	0.09	0.32	0.25	0.08
CD (0.05)	NS	NS	0.744	0.242

Table 3b. Interaction effect of seed treatment and nutrient schedule on number of trifoliate leaves per plant at different growth stages

Treatments	Leaves per plant			
	20 DAS	40 DAS	60 DAS	At harvest
S X N interaction				
s_0n_1	3.60	10.00	12.94	5.06
s_0n_2	3.27	9.45	11.11	6.19
s_1n_1	3.40	12.12	13.33	6.52
s_1n_2	3.73	10.88	15.11	6.53
s_2n_1	3.73	11.12	15.11	5.30
s_2n_2	3.53	10.48	13.77	6.58
s_3n_1	3.60	11.42	14.97	6.19
s_3n_2	3.53	12.22	14.33	6.11
s_4n_1	3.40	9.92	14.77	7.28
s_4n_2	3.27	10.17	13.22	6.78
s_5n_1	3.80	11.92	16.55	7.33
s_5n_2	3.07	11.58	15.55	7.89
SEm (±)	0.23	0.79	0.62	0.20
CD (0.05)	NS	NS	NS	0.593

Table 4a. Effect of seed treatment and nutrient schedule on number of branches per plant at different growth stages

Treatments	Branches per plant			
	20 DAS	40 DAS	60 DAS	At harvest
Seed treatment (S)				
s_0	2.07	2.53	5.02	5.45
s_1	2.23	2.95	7.14	5.10
s_2	2.20	2.95	4.22	5.91
s_3	2.23	2.97	4.18	5.75
s_4	2.13	2.91	5.05	5.91
s_5	2.03	3.15	5.54	6.39
SEm (±)	0.09	0.14	0.17	0.11
CD (0.05)	NS	NS	0.510	0.322
Nutrient schedule (N)				
n_1	2.18	2.90	4.53	5.89
n_2	2.12	2.92	5.86	5.62
SEm (±)	0.05	0.08	0.10	0.06
CD (0.05)	NS	NS	0.294	0.186

Table 4b. Interaction effect of seed treatment and nutrient schedule on number of branches per plant at different growth stages

Treatments	Branches per plant			
	20 DAS	40 DAS	60 DAS	At harvest
S X N interaction				
s_0n_1	2.20	2.62	5.61	5.55
s_0n_2	1.93	2.44	4.44	5.36
s_1n_1	2.07	2.84	4.36	5.44
s_1n_2	2.40	3.06	9.92	4.77
s_2n_1	2.13	2.85	3.55	5.80
s_2n_2	2.27	3.05	4.89	6.03
s_3n_1	2.07	2.72	4.26	5.72
s_3n_2	2.40	3.22	4.11	5.77
s_4n_1	2.27	2.94	5.18	6.03
s_4n_2	2.00	2.88	4.92	5.80
s_5n_1	2.33	3.44	4.20	6.78
s_5n_2	1.73	2.87	6.89	5.99
SEm (±)	0.13	0.20	0.24	0.15
CD (0.05)	0.392	NS	0.721	0.455

4.1.4 Leaf Area Index

The data on effect of treatments and their interaction on LAI at different growth stages are organized in Table 5a and 5b. There is appreciable increase in the LAI upto 60 DAS.

Seed treatment had not significantly influenced LAI at 20 DAS. At 40 and 60 DAS, it had significant influence onLAI. At 40 DAS the highest LAI (2.69) was recorded in s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed) which was on par with s_5 (2.58) and s_1 (2.47), the lowest (1.82) was recorded in s_0 (without seed treatment). At 60 DAS, the highest LAI (2.71) was recorded in s_5 (seed treatment with borax @ 1 g kg^{-1} seed and sodium molybdate @ 1 g kg^{-1} seed).

Nutrient schedule significantly influenced LAI at 20 and 60 DAS. At 20 DAS maximum LAI (0.30) noticed in n_1 and at 60 DAS n_2 registered maximum (2.32). However, it had no significant influence at 40 DAS.

Interaction between seed treatment and nutrient schedule also showed significant effect at 20 DAS and 60 DAS. At 20 DAS, the treatment combination s_5n_1 had the highest LAI (0.37) which was on par with s_4n_1 (0.33). At 60 DAS, s_5n_2 was superior with a LAI of 2.88.

4.1.5 Number of Nodules per Plant at Flowering

Data furnished in Table 6a and 6b represents the effect of seed treatment, nutrient schedule and their interaction on nodule number per plant at flowering.

Seed treatment had significant influence on number of nodules per plant. The highest number of nodules (41.83) was reported in s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed) and the lowest (18.83) in s_0 (without seed treatment).

Table 5a. Effect of seed treatment and nutrient schedule on leaf area index at different growth stages

Treatments	Leaf area index		
	20 DAS	40 DAS	60 DAS
Seed treatment (S)			
s_0	0.26	1.82	1.64
s_1	0.29	2.47	2.37
s_2	0.25	2.23	2.19
s_3	0.29	2.69	2.49
s_4	0.28	1.91	2.18
s_5	0.31	2.58	2.71
SEm (±)	0.01	0.15	0.05
CD (0.05)	NS	0.451	0.135
Nutrient schedule (N)			
n_1	0.30	2.33	2.21
n_2	0.26	2.24	2.32
SEm (±)	0.01	0.09	0.03
CD (0.05)	0.026	NS	0.078

Table 5b. Interaction effect of seed treatment and nutrient schedule on leaf area index at different growth stages

Treatments	Leaf area index		
	20 DAS	40 DAS	60 DAS
S x N interaction			
s_0n_1	0.26	1.97	1.62
s_0n_2	0.25	1.67	1.67
s_1n_1	0.29	2.64	2.44
s_1n_2	0.30	2.31	2.31
s_2n_1	0.25	2.41	2.38
s_2n_2	0.25	2.05	2.01
s_3n_1	0.29	2.52	2.45
s_3n_2	0.30	2.87	2.54
s_4n_1	0.33	1.83	1.86
s_4n_2	0.23	1.99	2.49
s_5n_1	0.37	2.61	2.54
s_5n_2	0.25	2.55	2.88
SEm (±)	0.02	0.22	0.06
CD (0.05)	0.064	NS	0.191

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Nutrient schedule also showed significant influence on nodule number per plant at flowering. The highest number of nodules (32.89) was recorded in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule also showed significant effect on number of nodules per plant with the highest number of nodules (50.33) was recorded in the treatment combination s_3n_2 and the lowest number (16.68) was recorded with s_0n_2.

4.1.6 Number of Effective Nodules per Plant at Flowering

The perusal of data stating the influence of seed treatment, nutrient schedule and their interaction on number of effective nodules per plant at flowering is cited in Table 6a and 6b.

Seed treatment had significantv influence on number of effective nodules per plant, maximum number of effective nodules (33.83) were reported in s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed) and the lowest (13.33) with s_0 (without seed treatment).

Nutrient schedule also showed significant influence on effective nodule number per plant at flowering, maximum number of effective nodules (25.33) were recorded in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule also showed significant effect on number of effective nodules per plant with maximum number of nodules (42.33) recorded in the treatment combination s_3n_2 and minimum (12) recorded in s_0n_2.

4.1.7 Weight of Nodules per Plant at Flowering

Given below was the data related to weight of nodules per plant at flowering, expressed in mg and declared in Table 6a and 6b.

Weight of nodules per plant, maximum weight of nodules (58.83 mg) was reported with s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed) and minimum (47.33 mg) with s_0 (without seed treatment).

Nutrient schedule also showed significant influence on weight of nodules per plant at flowering, maximum weight of nodules (53.56 mg) was recorded with n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule also showed significant influence on nodule weight per plant. Among different treatment combinations, s_3n_2 showed maximum weight (64.67 mg) and minimum (46.00 mg) with s_0n_2.

4.1.8 Number of Roots per Plant

The observation on number of roots per plant at flowering is taken and affirmed in Table 7a and 7b.

The maximum number of roots (13.33) observed in s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed) which was statistically comparable with s_1 (13.17) and s_5 (12.67) and minimum (10.67) in s_0 (without seed treatment) and s_2 (seed treatment with borax (2 g kg^{-1} seed).

Table 6a. Effect of seed treatment and nutrient schedule on nodule number, effective nodule number and weight of nodules per plant at flowering

Treatments	Nodule number per plant	Effective nodule number per plant	Weight of nodules per plant (mg)
Seed treatment (S)			
s_0	18.83	13.33	47.33
s_1	28.50	21.00	51.83
s_2	31.00	24.50	51.67
s_3	41.83	33.83	58.83
s_4	30.33	24.50	52.67
s_5	31.83	27.00	51.50
SEm (±)	2.27	1.15	0.87
CD (0.05)	6.709	3.385	2.583
Nutrient schedule (N)			
n_1	27.89	22.72	51.06
n_2	32.89	25.33	53.56
SEm (±)	1.31	0.66	0.50
CD (0.05)	3.874	1.954	1.492

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Table 6b. Interaction effect of seed treatment and nutrient schedule on nodule number, effective nodule number and weight of nodules per plant at flowering

Treatments	Nodule number per plant	Effective nodule number per plant	Weight of nodules per plant (mg)
S X N interaction			
s_0n_1	21.00	14.68	48.67
s_0n_2	16.68	12.00	46.00
s_1n_1	23.00	17.67	51.00
s_1n_2	34.00	24.33	52.67
s_2n_1	26.00	20.33	48.33
s_2n_2	36.00	28.67	55.00
s_3n_1	33.33	25.33	53.00
s_3n_2	50.33	42.33	64.67
s_4n_1	35.00	28.67	54.33
s_4n_2	25.67	20.33	51.00
s_5n_1	29.00	29.67	51.00
s_5n_2	34.68	24.33	52.00
SEm (±)	3.21	1.62	1.24
CD (0.05)	9.488	4.787	3.654

Nutrient schedule had significant influence on number of roots per plant with maximum number of roots per plant (12.44) recorded in n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS).

Interaction between seed treatment and nutrient schedule had significant influence on number of roots per plant with maximum number of roots per plant (14.67) recorded in s_3n_2 which was statistically comparable with s_1n_2 (13.67), s_4n_1 (13.33) and s_5n_1 (13.33), whereas minimum number of roots per plant (9.33) was recorded in s_0n_2.

4.1.9 Root Length

Table 7a and 7b depicts the treatments and their interaction effects on average length of root at flowering.

Seed treatment had significant influence on length of root per plant at flowering with the highest length of root (14.88 cm) observed in s_4 and the lowest (11.15 cm) was recorded in s_2 (seed treatment with borax @ 2 g kg^{-1} seed).

Nutrient schedule had significant influence on length of root per plant with the longest root (13.23 cm) recorded in n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS).

Interaction effect on length of root per plant with the longest root (15.50 cm) recorded in s_4n_1 which was statistically comparable with s_4n_2 (14.27 cm), s_1n_2 (13.90 cm) and s_5n_1 (13.77 cm), whereas the shortest root (9.37 cm) was recorded in s_2n_2.

4.1.10 Root Spread

Root spread per plant at flowering was recorded at flowering, expressed in, cm and presented in Table 7a and 7b.

Seed treatment had significant influence on root spread per plant at flowering with maximum root spread (28.10 cm) observed in s_2 (seed treatment with borax @ 2 g kg^{-1} seed) which was statistically comparable with s_3 (27.85 cm) and minimum (19.45 cm) was recorded in s_0 (without seed treatment).

Nutrient schedule had significant influence on root spread per plant with maximum spread (24.45 cm) recorded in n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS).

Interaction between seed treatment and nutrient schedule had significant influence on root spread per plant with maximum spread of root (32.40 cm) recorded in s_3n_2, whereas minimum root spread (16.33 cm) recorded in the treatment combination s_0n_2.

4.1.11 Weight of Roots per Plant

Weight of root per plant at flowering was recorded, expressed in g and presented in Table 7a and 7b.

Seed treatment had significant influence on weight of root per plant at flowering with maximum root weight (3.12 g) observed in s_2 (seed treatment with borax @ 2 g kg^{-1} seed) and was on par with s_3. Minimum (2.30 g) in s_0 (without seed treatment).

Nutrient schedule had significant influence on root weight per plant with maximum root weight (2.91 g) recorded in n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS).

Interaction between seed treatment and nutrient schedule had significant influence on root weight per plant with maximum weight of root (3.65 g per plant) recorded in s_3n_1, and was on par with s_2n_2. Minimum root weight (2.14 g per plant) was recorded in the treatment combination s_0n_1.

Table 7a. Effect of seed treatment and nutrient schedule on number, length, spread and weight of roots per plant at flowering

Treatments	Root number per plant	Root length (cm)	Root spread (cm)	Root weight per plant (g)
Seed treatment (S)				
s_0	10.67	12.48	19.45	2.30
s_1	13.17	12.60	22.63	2.67
s_2	10.67	11.15	28.10	3.12
s_3	13.33	11.73	27.85	2.98
s_4	11.50	14.88	22.60	2.77
s_5	12.67	12.78	24.27	2.72
SEm (±)	0.49	0.42	0.52	0.07
CD (0.05)	1.468	1.242	1.547	0.197
Nutrient schedule (N)				
n_1	12.44	13.23	24.45	2.91
n_2	11.56	11.98	23.85	2.61
SEm (±)	0.29	0.24	0.30	0.04
CD (0.05)	0.848	0.717	NS	0.114

Table 7b. Interaction effect of seed treatment and nutrient schedule on number, length, spread and weight of roots per plant at flowering

Treatments	Root number per plant	Root length (cm)	Root spread (cm)	Root weight per plant (g)
S X N interaction				
s_0n_1	12.00	13.93	22.57	2.14
s_0n_2	9.33	11.03	16.33	2.47
s_1n_1	12.67	11.30	20.73	2.64
s_1n_2	13.67	13.90	24.53	2.70
s_2n_1	11.33	12.93	28.30	2.97
s_2n_2	10.00	9.37	27.90	3.27
s_3n_1	12.00	11.97	23.30	3.65
s_3n_2	14.67	11.50	32.40	2.30
s_4n_1	13.33	15.50	24.93	3.34
s_4n_2	9.67	14.27	20.27	2.20
s_5n_1	13.33	13.77	26.87	2.72
s_5n_2	12.00	11.80	21.67	2.73
SEm (±)	0.70	0.59	0.74	0.09
CD (0.05)	2.077	1.757	2.187	0.278

4.2 YIELD ATTRIBUTES

4.2.1 Days to 50 per cent Flowering

The observation on days to 50 per cent flowering was contemplated in Table 8a and 8b.

Seed treatment had significant influence on days to 50 per cent flowering. The plants from s_0 seeds had taken more number of days (44) for 50 per cent flowering whereas plants from seeds treated with borax @ 1g kg^{-1} and sodium molybdate @ 1 g kg^{-1} seed had taken lesser number of days (40) for 50 per cent flowering which was on par with s_1.

Nutrient schedule also had significant influence on days to 50 per cent flowering. Nutrient application of (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS) had resulted a lesser number of days for 50 per cent flowering (40.88) compared to n_1 (42.22).

Interaction between seed treatment and nutrient schedule had no significant influence on days to 50 per cent flowering

4.2.2 Number of Pods per Plant

The data on number of pods per plant at harvest as influenced by treatments and their interaction were recorded and perceived in Table 8a and 8b.

Seed treatment had significant influence on number of pods per plant at harvest with maximum number of pods (24.16) recorded in s_5 (seed treatment with borax @ 1 g kg^{-1} seed and sodium molybdate @ 1 g kg^{-1} seed) and the lowest number (14.99) recorded in s_0 (without seed treatment). Nutrient schedule did not significantly influence the number of pods per plant.

Interaction between seed treatment and nutrient schedule had also significantly influenced number of pods per plant with the highest number of pods (24.99) recorded in s_5n_1 which was on par with s_5n_2 (23.33) and s_3n_2 (21.99), whereas the lowest number of pods (13.11) was seen in the treatment combination s_1n_2.

4.2.3 Length of Pod

Length of pods per plant at harvest was marked, expressed in cm and perceived in Table 8a and 8b.

Seed treatment had significant influence on length of pods per plant at harvest with the longest pods (5.23 cm) recorded in s_5 (seed treatment with borax @ 1 g kg^{-1} seed and sodium molybdate @ 1 g kg^{-1} seed), which was statistically comparable with s_3 (5.15 cm), s_1 (5.12 cm) and s_4 (5.07 cm), whereas the shortest pods (4.82 cm) were recorded in s_0 (without seed treatment). Nutrient schedule did not significantly influence length of pods per plant.

Interaction between seed treatment and nutrient schedule had also significantly influenced length of pods per plant with longer pods (5.59 cm) recorded in s_5n_2, whereas shorter pods (4.61 cm) in the treatment combination s_0n_1.

4.2.4 Number of Seeds per Pod

The observation on number of seeds per pod at harvest were noted and revealed in Table 8a and 8b.

Seed treatment had significant influence on number of seeds per pod at harvest with maximum number of seeds (7.33) recorded in s_1 which was statistically comparable with s_4 (7.22), s_3 (7.19) and s_5 (7.11), whereas minimum number (6.67) recorded in s_0 (without seed treatment). Nutrient schedule did not significantly influence number of seeds per pod.

Table 8a. Effect of seed treatment and nutrient schedule on days to 50 % flowering, number of pods per plant, length of pod, number of seeds per pod and 100 seed weight at harvest

Treatments	Days to 50 % flowering	Pods per plant	Length of pod (cm)	Seeds per pod	100 seed weight (g)
Seeds treatment (S)					
s_0	44.00	14.99	4.82	6.67	6.30
s_1	40.02	15.55	5.12	7.33	6.22
s_2	42.33	18.80	4.98	6.90	6.29
s_3	41.33	20.61	5.15	7.19	6.31
s_4	41.67	16.05	5.07	7.22	6.33
s_5	40.00	24.16	5.23	7.11	6.74
SEm (±)	0.25	0.89	0.08	0.08	0.08
CD (0.05)	0.747	2.633	0.243	0.238	0.229
Nutrient schedule (N)					
n_1	42.22	18.22	5.01	7.04	6.21
n_2	40.88	18.51	5.11	7.10	6.52
SEm (±)	0.15	0.51	0.05	0.05	0.04
CD (0.05)	0.431	NS	NS	NS	0.132

Table 8b. Interaction effect of seed treatment and nutrient schedule on days to 50 % flowering, number of pods per plant, length of pod, number of seeds per pod and 100 seed weight at harvest

Treatments	Days to 50 % flowering	Pods per plant	Length of pod (cm)	Seeds per pod	100 seed weight (g)
S X N interaction					
s_0n_1	44.33	15.00	4.61	6.57	6.19
s_0n_2	43.66	14.99	5.04	6.77	6.41
s_1n_1	40.67	17.99	5.19	7.40	6.09
s_1n_2	39.33	13.11	5.05	7.27	6.35
s_2n_1	43.33	17.77	5.09	7.13	6.19
s_2n_2	41.33	19.83	4.87	6.67	6.38
s_3n_1	42.33	19.22	5.17	7.20	5.95
s_3n_2	40.33	21.99	5.13	7.19	6.68
s_4n_1	42.33	14.33	5.14	7.20	6.12
s_4n_2	41.00	17.77	5.01	7.25	6.55
s_5n_1	40.33	24.99	4.88	6.77	6.72
s_5n_2	39.67	23.33	5.59	7.45	6.76
SEm (±)	0.36	1.26	0.12	0.11	0.11
CD (0.05)	NS	3.724	0.344	0.337	NS

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Interaction between seed treatment and nutrient schedule had also significantly influenced seed number per pod with maximum number of seeds (7.45) recorded in s_5n_2 which was statistically comparable with s_1n_1, s_1n_2, s_4n_2, s_4n_1, s_3n_1, s_3n_2 and s_2n_1, whereas minimum number of seeds (6.57) was seen in s_0n_1.

4.2.5 100 Seed Weight

Table 8a and 8b shows the influence of seed treatment, nutrient schedule and their interaction on 100 seed weight at harvest.

Seed treatment had significant influence on 100 seed weight with maximum weight (6.74 g) recorded in s_5 and the lowest (6.22 g) recorded in s_1.

Nutrient schedule also significantly influenced 100 seed weight with the highest value (6.52 g) recorded in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule had no significant influence on 100 seed weight.

4.2.6 Pod Yield

The results on pod yield at harvest was contemplated in Table 9a and 9b.

Seed treatment significantly influenced pod yield at harvest. Seed treatment with s_1 had registered the highest pod yield (1833 kg ha^{-1}) which was at par with s_5 and s_3. The lowest pod yield (1435 kg ha^{-1}) was recorded in s_4.

Nutrient schedule had no significant influence on pod yield at harvest. Interaction between seed treatment and nutrient schedule had significantly influenced pod yield at harvest. The highest pod yield (1929 kg ha^{-1}) was recorded in s_5n_2, which was statistically comparable with s_1n_1, s_3n_1, s_1n_2, s_0n_2 and s_2n_1. The treatment combination s_0n_1 documented the lowest yield (1278 kg ha^{-1}).

4.2.7 Grain Yield

The figures relating to the effect of seed treatment, nutrient schedule and their interaction on grain yield at harvest were recorded, expressed in, kg ha^{-1} and ascertained in Table 9a and 9b.

Seed treatment had significant influence on grain yield at harvest with the highest yield (1005 kg ha^{-1}) recorded in s_5, and was on par with s_1, whereas the lowest yield (714 kg ha^{-1}) was recorded in s_2.

Nutrient schedule had significant influence on grain yield at harvest with the highest yield (872 kg $^{-1}$) recorded in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule had significant influence on grain yield at harvest. The highest grain yield (1130 kg ha^{-1}) was recorded in the treatment combination s_5n_2 which was statistically comparable with s_1n_1 (978 kg ha^{-1}), whereas the lowest grain yield (563 kg ha^{-1}) was recorded in the treatment combination s_0n_1.

4.2.8 Haulm Yield

Haulm yield at harvest was documented, expressed in kg ha^{-1} and conferred in Table 9a and 9b.

Seed treatment had significant effect on haulm yield at harvest with the highest yield (1854 kg ha^{-1}) registered in s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed), whereas the lowest yield (1607 kg ha^{-1}) was recorded in s_0 (without seed treatment).

Nutrient schedule significantly influenced haulm yield at harvest with the highest yield (1750 kg^{-1}) recorded in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule had@significant influence on haulm yield at harvest. The highest haulm yield (1899 kg ha^{-1}) was recorded in s_3n_2 which was on par with s_5n_2, s_2n_2, s_3n_1, s_2n_1, s_0n_2 and s_1n_1, whereas the lowest haulm yield (1437 kg ha^{-1}), was recorded in the treatment combination s_4n_1.

4.2.9 Harvest Index

Table 9a and 9b evidences the effect of seed treatment, nutrient schedule and their interaction on HI.

Seed treatment had significant effect on HI and the highest HI (0.38) was recorded in s_5, which was statistically comparable with s_1 (0.36) and s_4 (0.33) whereas the lowest HI (0.28) was recorded in s_2 (seed treatment with borax @ 2 g kg^{-1} seed).

Nutrient schedule and interaction between treatments had no significant influence on harvest index.

4.2.10 Dry Matter Production

The inspection on effect of seed treatment, nutrient schedule and their interaction on DMP was documented, expressed in kg ha^{-1} and given in table 10. 10b.

Seed treatment had significantly influenced DMP at harvest. s_3 recorded the highest DMP (2657 kg ha^{-1}) which was on par with s_5, s_1 and s_2, whereas the lowest DMP (2324 kg ha^{-1}) was documented in s_0 (without seed treatment).

Nutrient schedule also influenced DMP, with the highest DMP (2622 kg ha^{-1}) observed in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule had significantly influenced DMP at harvest. The highest dry matter production (2933 kg ha^{-1}) was

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Table 9a. Effect of seed treatment and nutrient schedule on pod yield, grain yield, haulm yield and harvest index

Treatments	Pod yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
Seed treatment (S)				
s_0	1455	716	1607	0.30
s_1	1833	940	1665	0.36
s_2	1435	714	1809	0.28
s_3	1649	803	1854	0.30
s_4	1435	762	1546	0.33
s_5	1668	1005	1624	0.38
SEm (±)	98	45	55	0.01
CD (0.05)	289.6	135.7	164.5	0.045
Nutrient schedule (N)				
n_1	1583	775	1618	0.32
n_2	1576	872	1750	0.33
SEm (±)	56	26	32	0.01
CD (0.05)	NS	78.3	94.9	NS

Table 9b. Interaction effect of seed treatment and nutrient schedule on pod yield, grain yield, haulm yield and harvest index

Treatments	Pod yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
S X N interaction				
s_0n_1	1278	563	1470	0.27
s_0n_2	1633	870	1744	0.33
s_1n_1	1911	978	1744	0.36
s_1n_2	1755	904	1585	0.36
s_2n_1	1611	733	1807	0.29
s_2n_2	1259	696	1811	0.27
s_3n_1	1815	818	1807	0.31
s_3n_2	1485	789	1899	0.30
s_4n_1	1474	681	1437	0.32
s_4n_2	1396	844	1655	0.34
s_5n_1	1407	881	1444	0.38
s_5n_2	1929	1130	1803	0.38
SEm (±)	138	64	78	0.02
CD (0.05)	409.6	191.8	232.6	NS

Table 10. Effect of seed treatment, nutrient schedule and their interaction on DMP, kg ha^{-1}

Treatments	DMP
Seed treatment (S)	
s_0	2324
s_1	2605
s_2	2524
s_3	2657
s_4	2309
s_5	2630
SEm (±)	67.604
CD (0.05)	199.556
Nutrient schedule (N)	
n_1	2394
n_2	2622
SEm (±)a	39.031
CD (0.05)	115.214
S X N interaction	
s_0n_1	2033
s_0n_2	2615
s_1n_1	2722
s_1n_2	2489
s_2n_1	2540
s_2n_2	2507
s_3n_1	2626
s_3n_2	2689
s_4n_1	2118
s_4n_2	2500
s_5n_1	2325
s_5n_2	2933
SEm (±)	95.607
CD (0.05)	282.215

observed in the treatment combination, s_5n_2, which was at par with s_1n_1 and s_3n_2. The lowest dry matter production (2033 kg ha^{-1}) was recorded in s_0n_1.

Nutrient schedule did not significantly influence protein content of seed. Interaction between seed treatment and nutrient schedule had significantly influenced protein content of seed. Among the different treatment combinations, s_5n_2 had the highest protein content (22.75 %), which was statistically comparable with other combinations s_2n_2 (22.52 %) and s_3n_1 (22.05 %), whereas the lowest protein content (20.30 %) was recorded in s_0n_0.

4.4 NUTRIENT UPTAKE BY CROP

4.4.1 N Uptake

The observation on N uptake was documented, expressed in kg ha^{-1} and furnished in Table 12a and 12b.

Seed treatment had significant influence on N uptake. Seed treatment with s_5 had the highest N uptake (36.84 kg ha^{-1}), which was statistically comparable with s_3 (35.41 kg ha^{-1}), s_2 (33.92 kg ha^{-1}) and s_1 (33.61 kg ha^{-1}), while the lowest uptake (27.91 kg ha^{-1}) was documented in s_0 (without seed treatment).

Nutrient schedule also had significant influence on N uptake with the highest uptake (34.70 kg ha^{-1}) in n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule also had significant influence on total N uptake. Among different treatment combinations s_5n_2 had recorded the highest N uptake (40.65 kg ha^{-1}), which was statistically on par with s_3n_1 (37.75 kg ha^{-1}) and s_4n_2 (35.84 kg ha^{-1}) and s_2n_1 (34.53 kg ha^{-1}), whereas the lowest N uptake (24.14 kg ha^{-1}) was recorded in s_0n_1.

Table 11. Effect of seed treatment, nutrient schedule and their interaction on grain protein content, per cent

Treatments	Grain protein content
Seed treatment (S)	
s_0	20.65
s_1	21.70
s_2	21.93
s_3	21.64
s_4	21.29
s_5	22.28
SEm (±)	0.17
CD (0.05)	0.515
Nutrient schedule (N)	
n_1	21.45
n_2	21.72
SEm (±)a	0.10
CD (0.05)	NS
S X N interaction	
s_0n_1	20.30
s_0n_2	21.00
s_1n_1	21.93
s_1n_2	21.47
s_2n_1	21.35
s_2n_2	22.52
s_3n_1	22.05
s_3n_2	21.24
s_4n_1	21.23
s_4n_2	21.35
s_5n_1	21.82
s_5n_2	22.75
SEm (±)	0.25
CD (0.05)	0.729

4.4.2 P Uptake

Data regarding to P uptake as influenced by the effect of seed treatment, nutrient schedule and their interaction was taped, expressed in kg ha^{-1} and revealed in Table 12a and 12b.

Seed treatment significantly influenced P uptake. Seed treatment with borax (1 g kg^{-1} seed) and sodium molybdate (1 g kg^{-1} seed) had the highest P uptake (11.24 kg ha^{-1}) which was statistically comparable with s_3 and s_1. The lowest P uptake (7.22 kg ha^{-1}) was noticed in control (without seed treatment).

Nutrient schedule had no significant influence on P uptake. Interaction between seed treatment and nutrient schedule had significant influence on P uptake at harvest. Among the different treatment combinations, s_5n_2 had the highest P uptake (12.89 kg ha^{-1}), which was statistically comparable with s_1n_1 (11.21 kg ha^{-1}) and the lowest P uptake (6.42 kg ha^{-1}) was recorded in s_0n_1.

4.4.3 K Uptake

Data pertaining to the influence of seed treatment, nutrient schedule and their interaction on K uptake were recorded, expressed in kg ha^{-1} and presented in Table 12a and 12b.

Seed treatment had no significant influence on K uptake. Nutrient schedule had significant influence on K uptake. Nutrient level n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS) had higher K uptake (32.54 kg ha^{-1}).

Interaction between seed treatment and nutrient schedule had no significant influence on K uptake. The treatment combination s_5n_2 had the highest K uptake (42.72 kg ha^{-1}) while the lowest K uptake (17.97 kg ha^{-1}) was documented in treatment combination s_0n_1.

4.4.4 B Uptake

The results depicted in Table 12a and 12b reveals the B uptake.

Seed treatment had significant influence on B uptake. Seed treatment with s_2 had the highest B uptake (70.51 mg kg^{-1}) and it was on par with s_1, whereas, the lowest B uptake (31.80 mg kg^{-1}) was registered in s_0 (without seed treatment).

Nutrient schedule had no significant influence on B uptake. Nutrient level n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS) had maximum uptake of B (50.11 mg kg^{-1} seed).

Interaction between seed treatment and nutrient schedule had no significant influence on the B uptake. The treatment combination s_2n_1 had the highest B uptake (72.04 mg kg^{-1}) while the lowest B uptake (30.96 mg kg^{-1}) was recorded in treatment combination s_0n_1.

4.5 NUTRIENT STATUS OF SOIL AFTER THE EXPERIMENT

4.5.1 Organic Carbon Content of Soil

The observation on organic carbon content of soil after the experiment was documented, expressed in per cent and furnished in Table 13a and 13b.

Seed treatment and nutrient schedule had no significant influence on organic carbon content of soil after the experiment.

Interaction between seed treatment and nutrient schedule had significantly influenced organic carbon content in soil. Among the different treatment combinations, s_1n_1 documented the highest organic carbon content in soil (1.59 %), which was statistically comparable with s_4n_2 (1.32 %). The lowest value was documented in s_0n_1 (0.77 %).

Table 12a. Effect of seed treatment and nutrient schedule on N, P, K and B uptake

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	B uptake (mg kg^{-1})
Seed treatment (S)				
s_0	27.91	7.22	24.38	31.80
s_1	33.61	9.64	30.58	61.08
s_2	33.92	8.85	28.81	70.51
s_3	35.41	9.62	30.05	46.35
s_4	30.80	9.39	25.30	38.10
s_5	36.84	11.24	36.40	51.80
SEm (±)	1.66	0.64	3.01	4.14
CD (0.05)	4.905	1.876	NS	13.050
Nutrient schedule (N)				
n_1	31.47	9.09	25.97	50.11
n_2	34.70	9.56	32.54	49.77
SEm (±)	0.96	0.37	1.73	2.39
CD (0.05)	2.832	NS	5.122	NS

Table 12b. Interaction effect of seed treatment and nutrient schedule on N, P, K and B uptake

Treatments	N uptake (kg ha^{-1})	P uptake (kg ha^{-1})	K uptake (kg ha^{-1})	B uptake (mg kg^{-1})
S X N interaction				
s_0n_1	24.14	6.42	17.97	30.96
s_0n_2	31.69	8.03	30.79	32.64
s_1n_1	33.58	11.21	34.34	59.80
s_1n_2	33.65	8.07	26.82	62.36
s_2n_1	34.53	8.72	28.78	72.04
s_2n_2	33.32	8.98	28.85	68.97
s_3n_1	37.75	10.03	25.56	50.63
s_3n_2	33.06	9.21	34.54	42.08
s_4n_1	25.77	8.58	19.11	40.97
s_4n_2	35.84	10.20	31.49	35.22
s_5n_1	33.03	9.59	30.09	46.23
s_5n_2	40.65	12.89	42.72	57.37
SEm (±)	2.35	0.89	4.25	5.86
CD (0.05)	6.937	2.654	NS	NS

4.5.2 Soil Available N

The availability of N in soil after the experiment was inscribed, expressed in kg ha^{-1} and given in Table 13a and 13b.

Seed treatment had significantly influenced available N status of soil. Among different levels of seed treatment, s_3 (seed treatment with sodium molybdate @ 1g kg^{-1} seed) had high soil available N (265.51 kg ha^{-1}), which was statistically comparable with s_5 (257.15 kg ha^{-1}), s_1 (250.88 kg ha^{-1}) and s_2 (248.79 kg ha^{-1}). Soil available N was the lowest (223.70 kg ha^{-1}) in plots where seed treatment was not carried out.

Nutrient schedule had significant influence on soil available N after the experiment. The highest soil available N (255.76 kg ha^{-1}) was noted in n_2 ((½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule had no significant influence on soil available N after the experiment.

4.5.3 Soil Available P

Given below were the details of soil available P after the experiment, expressed in kg ha^{-1} and revealed in Table 13a and 13b.

Seed treatment had no significant influence on soil available P after the experiment.

Nutrient schedule significantly influenced soil available P. Nutrient level n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS) had high available P (29.55 kg ha^{-1}).

Interaction between seed treatment and nutrient schedule also had significant influence on soil available P after the experiment. Treatment combination s_0n_1 had high soil available P (32.53 kg ha^{-1}), which was statistically on par with s_3n_1 (30.50 kg ha^{-1}), s_5n_1 (30.41 kg ha^{-1}) and s_5n_2 (30.07 kg ha^{-1}), whereas the lowest soil available P (24.56 kg ha^{-1}) was recorded in s_0n_2.

4.5.4 Soil Available K

The observations on soil available K after the experiment was tabulated, expressed in, kg ha^{-1} and published in Table 13a and 13b.

Seed treatment had significant influence on soil available K after the experiment. Seed treatment with s_4 showed high soil available K (240.10 kg ha^{-1}), which was statistically on par with s_2 (236.22 kg ha^{-1}) and s_5 (221.20 kg ha^{-1}). The lowest soil available K (175.02 kg ha^{-1}) was recorded in s_1.

Nutrient schedule had significant influence on soil available K after the experiment. Nutrient level n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS) had high soil available K (221.32 kg ha^{-1}).

Interaction between seed treatment and nutrient schedule had significant influence on soil available K after the experiment. The treatment combination s_2n_1 had shown high soil available K (286.96 kg ha^{-1}), whereas the lowest soil available K (143.13 kg ha^{-1}) was recorded in s_1n_1.

4.5.5 Soil available B

Data pertaining to the effect of seed treatment, nutrient schedule and their interaction on soil available B after the experiment were inscribed, expressed in, mg kg^{-1} and depicted in Table 14a and 14b.

Seed treatment had significant influence on soil available B after the experiment. Seed treatment with borax @ 1 g kg^{-1} seed – s_1 showed high soil

Table 13a. Effect of seed treatment and nutrient schedule on organic carbon and available N, P, K status of soil after the experiment

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Seed treatment (S)				
s_0	1.16	223.70	28.54	213.54
s_1	1.21	250.88	27.07	175.02
s_2	1.04	248.79	28.24	236.22
s_3	1.19	265.51	28.58	203.56
s_4	1.04	240.43	27.84	240.10
s_5	1.02	257.15	30.24	221.20
SEm (±)	0.15	7.25	0.89	6.83
CD (0.05)	NS	21.415	NS	20.154
Nutrient schedule (N)				
n_1	1.01	239.73	29.55	208.55
n_2	1.22	255.76	27.89	221.32
SEm (±)	0.09	4.19	0.52	3.94
CD (0.05)	NS	12.364	1.524	11.636

Table 13b. Interaction effect of seed treatment and nutrient schedule on organic carbon and available N, P, K status of soil after the experiment

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
S X N interaction				
s_0n_1	0.77	213.25	32.53	189.27
s_0n_2	1.18	234.16	24.56	237.81
s_1n_1	1.59	246.70	28.44	143.13
s_1n_2	1.02	255.06	25.70	206.91
s_2n_1	1.22	229.97	28.45	286.96
s_2n_2	1.01	267.60	28.03	185.48
s_3n_1	0.89	259.24	30.50	194.55
s_3n_2	0.99	271.78	26.65	212.57
s_4n_1	0.87	238.34	26.97	240.04
s_4n_2	1.32	242.52	28.71	240.16
s_5n_1	0.96	250.88	30.41	197.38
s_5n_2	1.25	263.42	30.07	245.01
SEm (±)	0.10	10.26	1.26	9.66
CD (0.05)	0.29	NS	3.733	28.502

available B (0.764 mg kg^{-1}), which was on par with s_2 (0.690 mg kg^{-1}). The lowest soil available B (0.394 mg kg^{-1}) was recorded in s_0.

Nutrient schedule had no significant influence on soil available B after the experiment. Nutrient level n_1 (½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS) had high soil available B (0.604 mg kg^{-1}).

Interaction between seed treatment and nutrient schedule had significant influence on soil available B after the experiment. The treatment combination s_2n_1 had shown high soil available B (0.868 mg kg^{-1}), and it as on par with s_1n_2 whereas the lowest soil available B (0.372 mg kg^{-1}) was recorded in s_0n_1.

4.5.6 Soil Available Mo

Table 14a and 14b represents the effect of seed treatment; nutrient schedule and their interaction on soil available Mo after the experiment.

Seed treatment had significant influence on soil available Mo after the experiment. s_4 showed the highest soil available Mo (0.054 mg kg^{-1}), whereas the lowest soil available Mo (0.005 mg kg^{-1}) was recorded in s_0.

Nutrient schedule had no significant influence on available Mo status of soil after the experiment.

Interaction between seed treatment and nutrient schedule had significant influence on soil available Mo after the experiment. The treatment combination s_4n_1 had shown higher soil available Mo (0.070 mg kg^{-1}), and it was on par with s_5n_2 whereas the lowest soil available Mo (0.005 mg kg^{-1}) was recorded in s_0n_1.

100

Table 14a. Effect of seed treatment and nutrient schedule on available B and Mo status of soil after the experiment, mg kg^{-1}.

Treatments	Available B	Available Mo
Seed treatment (S)		
s_0	0.394	0.005
s_1	0.764	0.007
s_2	0.690	0.006
s_3	0.532	0.041
s_4	0.546	0.054
s_5	0.610	0.037
SEm (±)	0.03	0.003
CD (0.05)	0.085	0.009
Nutrient schedule (N)		
n_1	0.604	0.025
n_2	0.575	0.025
SEm (±)a	0.02	0.002
CD (0.05)	NS	NS

Table 14b. Interaction effect of seed treatment and nutrient schedule on available B and Mo status of soil after the experiment, mg kg^{-1}.

Treatments	Available B	Available Mo
S X N interaction		
s_0n_1	0.372	0.005
s_0n_2	0.416	0.006
s_1n_1	0.732	0.006
s_1n_2	0.796	0.008
s_2n_1	0.868	0.003
s_2n_2	0.512	0.009
s_3n_1	0.500	0.055
s_3n_2	0.564	0.027
s_4n_1	0.532	0.070
s_4n_2	0.560	0.038
s_5n_1	0.620	0.014
s_5n_2	0.600	0.061
SEm (±)	0.04	0.004
CD (0.05)	0.121	0.013

4.6 ECONOMIC ANALYSIS

4.6.1 Net Income

The reports pertaining to the effect of seed treatment, nutrient schedule and their interaction on net income were calculated and put forward as ₹ ha^{-1} in Table 15a and 15b.

Seed treatment had significant influence on net income, the seed treatment level s_5 had the highest net returns (₹ 16,907 ha^{-1}), which was statistically on par with s_1 whereas the lowest net returns was obtained from s_2 (₹ -483 ha^{-1}).

Nutrient schedule had no significant influence on net income. Maximum net income (₹ 6,507 ha^{-1}) was recorded with n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Interaction between seed treatment and nutrient schedule had significant influence on net income ha^{-1}. Among the different treatment combinations, s_5n_2 had the highest net returns (₹ 21,914 ha^{-1}), which was statistically on par with s_1n_1 (₹ 17,723 ha^{-1}) and s_5n_1 (₹ 11,901 ha^{-1}), whereas the treatment combination s_0n_1 recorded the lowest net income (₹ -7,154 ha^{-1}).

4.6.2 B: C Ratio

The effect of seed treatment, nutrient schedule and their interaction on B: C ratios were documented in Table 15a and 15b.

Seed treatment had significantly influenced B: C ratio. The highest B: C ratio (1.38) was recorded by the treatment s_5 (seed treatment with borax @ 1 g kg^{-1} seed and sodium molybdate @ 1 g kg^{-1} seed), which was statistically comparable with s_1 (1.31) and the lowest B: C ratio (0.99) was registered in s_2 (seed treatment with borax @ 2 g kg^{-1} seed).

Nutrient schedule had no significant influence on B: C ratio. Interaction between seed treatment and nutrient schedule had significant influence on B: C ratio. Among different treatment combinations s_5n_2 had the highest ratio (1.48), which was statistically on par with s_1n_1, s_5n_1, s_0n_2, s_3n_1 and s_1n_2, whereas the lowest ratio was documented in the treatment combination s_0n_1 (0.83).

4.7 INCIDENCE OF PEST AND DISEASES

Tobacco caterpillar (*Spodoptera litura*) incidence was noticed at 20 DAS and was controlled by quinolphos @ 2 mL L^{-1}. At pod maturity stage, there was the incidence of spotted pod borer (*Maruca vitrata*) which was controlled by spraying coragen (chlorantraniliprole) @ 3 mL $10L^{-1}$.

Table 15a. Effect of seed treatment and nutrient schedule on net income and benefit cost ratio

Treatments	Net income (₹ ha^{-1})	B: C ratio
Seed treatment (S)		
s_0	-367	1.04
s_1	13,079	1.31
s_2	-483	0.99
s_3	4,800	1.11
s_4	2,693	1.06
s_5	16,907	1.38
SEm (±)	2,758	0.08
CD (0.05)	8,143.4	0.224
Nutrient schedule (N)		
n_1	5,702	1.14
n_2	6,507	1.16
SEm (±)	1,592	0.04
CD (0.05)	NS	NS

Table 15b. Interaction effect of seed treatment and nutrient schedule on net income and benefit cost ratio

Treatments	Net income (₹ ha^{-1})	B: C ratio
S X N interaction		
s_0n_1	-7,154	0.83
s_0n_2	6,419	1.25
s_1n_1	17,723	1.43
s_1n_2	8,436	1.18
s_2n_1	3,040	1.07
s_2n_2	-4,007	0.91
s_3n_1	8,104	1.20
s_3n_2	1,497	1.03
s_4n_1	601	1.01
s_4n_2	4,786	1.10
s_5n_1	11,901	1.29
s_5n_2	21,914	1.48
SEm (±)	3,901	0.11
CD (0.05)	11,516.6	0.316

Discussion

5. DISCUSSION

The present investigation was conducted to evaluate the influence of seed treatment and foliar nutrition on the growth and yield of blackgram and also to work out the economics of production. The results of the study are discussed in this chapter.

5.1 EFFECT OF SEED TREATMENT ON BLACKGRAM

Seed treatment had significant influence on growth characters, yield parameters, grain quality and nutrient content of blackgram.

5.1.1 Effect on Growth Characters

Seed treatment significantly improved various growth attributing characters like plant height, number of leaves and branches per plant, leaf area index, number of nodules, effective nodule number and weight of nodules per plant.

The data on plant height indicated that seed treatment increased plant height at 40, 60 DAS and at harvest (Table 2a). Seed treatment with s_5 recorded significantly taller plants of 103.24, 128.12 and 135.84 cm at 40, 60 DAS and at harvest respectively compared to control. Similar to height, seed treatment with borax and sodium molybdate @ 1 g kg^{-1} seed each recorded significantly higher number of leaves (16.05, 7.61) and higher number of branches per plant (5.54, 6.39) at 60 DAS and at harvest respectively (Table 3a and 4a). The increase in plant height, number of leaves and number of branches per plant (Fig. 3) and the highest LAI (2.71) at 60 DAS might be due to involvement of micronutrients in cell enlargement and cell division resulting in root and shoot elongation. This had enhanced the plant growth through development of vigorous and stronger root system thereby enabling the plant to derive available soil moisture and nutrients and resulting in increased plant height and branches per plant and better canopy formation resulted in larger LAI. Similar results were also reported by Dixit and Elamathi (2007), Rahman *et al.* (2014) in chickpea with B (2 g) and Mo (1.5 g) kg^{-1} seed, Shinde *et al.* (2018) in chickpea and Janaki *et al.* (2018) in greengram.

Seed treatment also influenced nodule number, effective nodule number and weight of nodules per plant (Table 5a and 6a). The highest number of nodules, effective nodules and weight of nodules per plant (Table 6a) were recorded with s_3 (Fig. 4). The increase in nodulation, effective nodule number and weight of nodules per plant by Mo seed treatment were due to enhancement of N fixation by *Rhizobium*. Similar results were also reported by Deo and Kathari (2002) in chickpea with sodium molybdate @ 5.25 g kg^{-1} seed, Togay *et al.* (2008) in lentil @ 6 g kg^{-1} seed, Tahir *et al.* (2014) in blackgram with Mo @ 4 g kg^{-1} seed and Zhou *et al.* (2017) in alfalfa.

Seed treatment had significant influence on root parameters (Table 7a). Borax @ 2 g kg^{-1} seed registered maximum root spread and root weight per plant which were on par with s_3. The maximum number and length of roots were recorded with seed treatment of sodium molybdate @ 1g and 1.5 g kg^{-1} seed respectively.

5.1.2 Effect of Seed Treatment on Yield Parameters and Grain Quality

All yield attributing characters *viz.,* days to 50 per cent flowering, number of pods per plant and seeds per pod, length of pod, hundred seed weight, grain yield, haulm yield and harvest index were significantly influenced by seed treatment (Table 8a and 9a).

Seed treatment with borax and sodium molybdate each @ 1 g kg^{-1} seed recorded lesser number of days (40) for 50 per cent flowering than control (44 days). This might be due to the role of B in flowering and fruit retention. Similar results were also observed by Ansari *et al.* (2013) in groundnut, Alam and Islam (2016) in mungbean and Mahadule *et al.* (2019) in French bean.

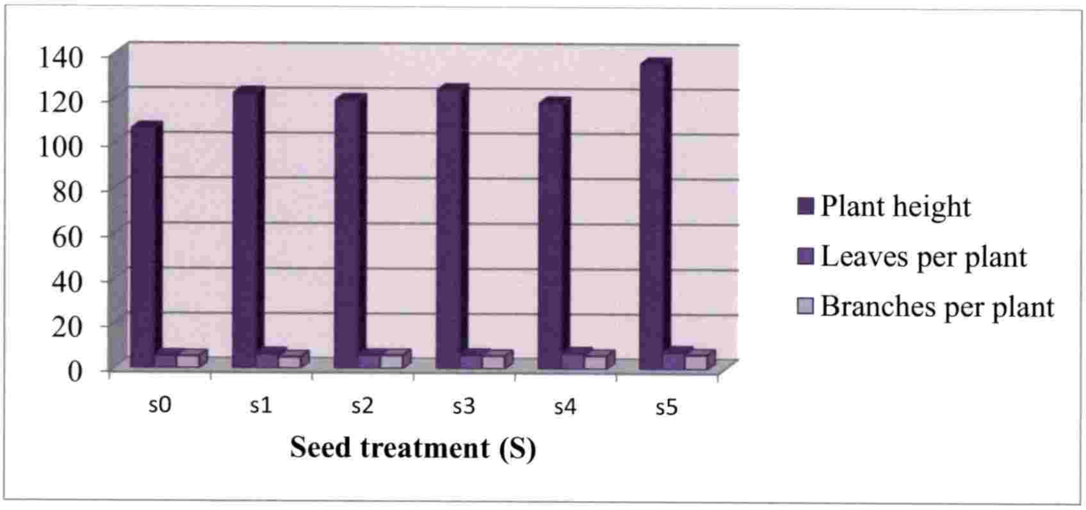

Fig.3. Effect of seed treatment on plant height, number of leaves and number of branches per plant at harvest

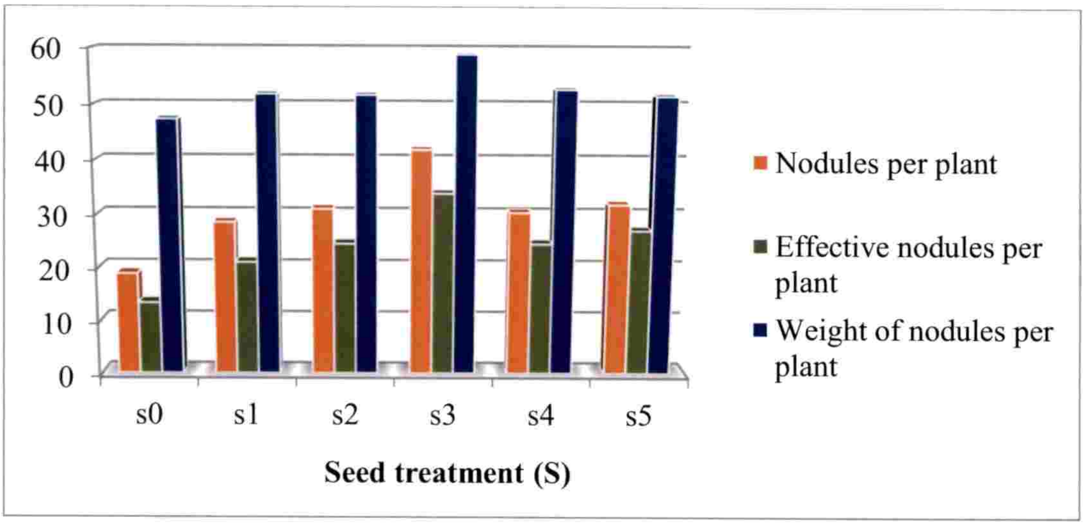

Fig. 4. Effect of seed treatment on nodule number, effective nodule number and weight of nodules per plant at flowering

Seed treatment with borax and sodium molybdate each @ 1 g kg^{-1} seed recorded significantly higher pods per plant (24.16), length of pod (5.23 cm), hundred seed weight (6.74 g) (Fig. 5), grain yield (1005 kg ha^{-1}) and harvest index (0.38) compared to the control. The combined application of micronutrients had significant influence on N fixation and thus growth and yield of blackgram. The main contributing factors for yield increase were increased DMP and efficient translocation of assimilates to developing reproductive parts thus leading to increased number of pods and higher grain yield. This might also be due to enhanced chlorophyll formation resulting in higher photosynthetic rates leading to an increase in growth attributes contributing to better seed yield. Dixit and Elamathi (2007), Manonmani and Srimathi (2009), Rahman *et al.* (2014) and Janaki *et al.* (2018) also reported similar findings.

The highest number of seeds per pod (7.33) was observed with borax seed treatment @ 1 g kg^{-1} seed. This might be due to the role of B in better sugar translocation. Similar conclusions were also reported by Masuthi *et al.* (2009) in cowpea, El-Dahsouri *et al.* (2017) in common bean and Mahadule *et al.* (2019) in Frenchbean.

The highest haulm yield (1854 kg ha^{-1}), and DMP (2657 kg ha^{-1}) were observed with sodium molybdate @ 1g kg^{-1} seed compared to control. This might be due to improved germination and balanced growth pattern of plants. These results were also in accordance with Tahir *et al.* (2014) in blackgram.

The quality parameters of blackgram in terms of grain protein content was found significantly higher (22.28 %) in seed treatment with borax and sodium molybdate each @ 1g kg^{-1} seed compared to control (Table 11). The combined application of micronutrients helped in increasing N fixation, sugar and assimilates translocation, sugar metabolism and regulation of nitrate reductase enzyme thus improved protein content, this was also reported by Rahman *et al.* (2014).

5.1.3 Effect of Seed Treatment on Nutrient Uptake

At harvest, plant samples were analyzed for N, P, K and B content and uptake of these nutrients were computed. Seed treatment had significant influence on N, P and B uptake but no profound influence on K uptake (Table 12a).

The highest N and P uptake (36.84 and 11.24 kg ha^{-1}) were observed when treated with borax and sodium molybdate each @ 1 g kg^{-1} seed (Fig. 6). Whereas maximum uptake of B (70.51 mg kg^{-1}) was registered with borax @ 2g kg^{-1} seed. The highest uptake might be due to the favourable effect of Mo for partial substitution of N fertilizers through accelerating rhizobial infection; B helped in the transport of sugars and thus combined application of B and Mo enhanced the nutrient uptake as reported by Jain *et al*. (2007) in mungbean.

5.1.4 Effect of Seed Treatment on Soil Available Nutrient Status

Soil organic carbon, available N, K, B and Mo status of soil after blackgram harvest were significantly influenced by seed treatment but soil available P had no significant influence due to seed treatment (Table 13a and 14a).

Soil organic carbon (1.31 %), B (0.764 mg kg^{-1}) and K (236.22 kg ha^{-1}) status of soil after the experiment were maximum when treated with borax @ 1 g and 2 g kg^{-1} seed respectively compared to control, whereas Mo status of soil after the experiment was increased by s_4. Similar results were also reported by Reddy *et al.* (2007) in pigeon pea.

Available N content in soil was the highest (265.51 kg ha^{-1}) with s_3. This increase in available N content in soil after harvest might be due to the fact that there is stimulation of nitrogenase and nitrate reductase activity by Mo application which enhanced soil N fixation. This is in accordance with the findings of Deo and Kathari (2002) in chickpea and Reddy *et al*. (2007) in pigeonpea.

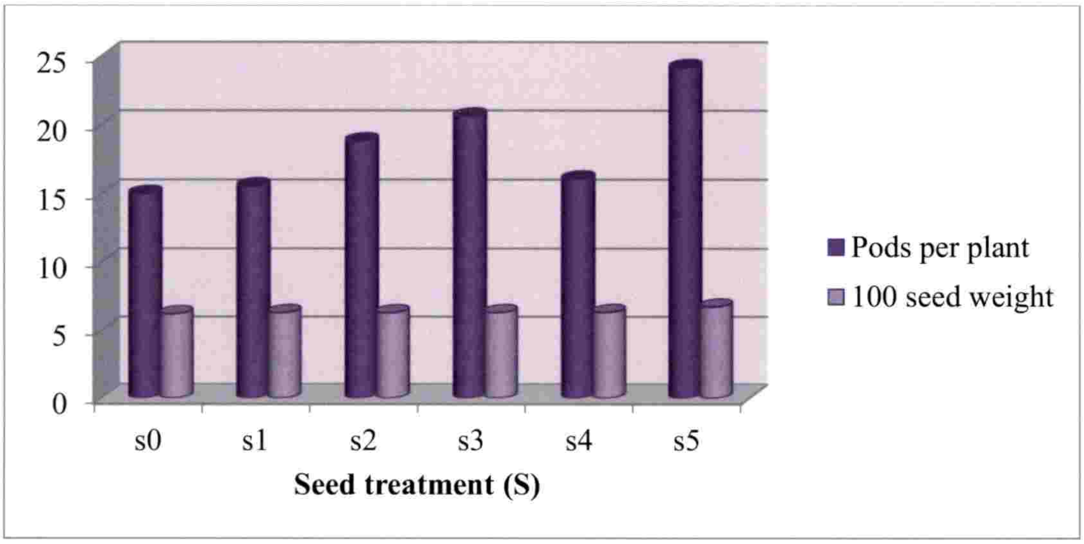

Fig. 5. Effect of seed treatment on pods per plant and 100 seed weight, g

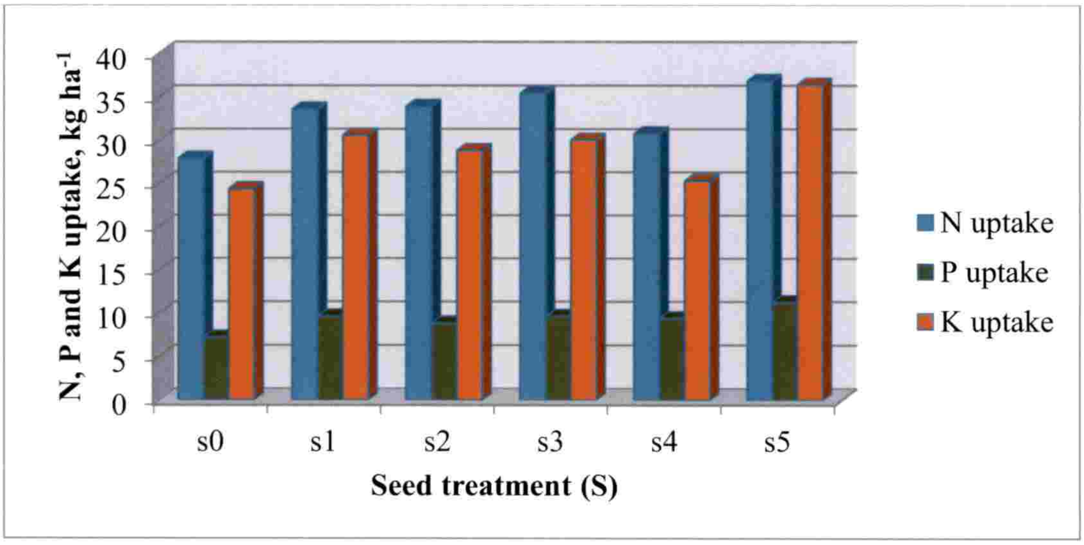

Fig. 6. Effect of seed treatment on N, P and K uptake of plant at harvest, kg ha^{-1}

5.2 EFFECT OF NUTRIENT SCHEDULE ON BLACKGRAM

Nutrient schedule also showed positive influence on different parameters of blackgram and effect on each parameter is discussed briefly.

5.2.1 Effect of Nutrient Schedule on Growth Characters

All growth attributing characters *viz.,* plant height, number of leaves per plant, number of branches per plant, leaf area index, nodule number, effective nodule number and weight of nodules per plant were significantly influenced by nutrient schedule.

Maximum plant height (99.69 cm), the highest number of branches per plant (5.86) at 60 DAS and maximum number of trifoliate leaves (6.68) at harvest were observed with ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS (Table 2a, 3a and 4a). Significant increase in growth characters could be due to the fact that K enhances plant vigor and strengthens the stalk. Also it had synergistic effect with N and P, thus resulting in better plant growth and more number of branches per plant (Das, 1999). These results are in accordance with the findings of Govindan and Thirumurugan (2000) in greengram, Bardhan *et al.* (2007) in chickpea, Goud *et al.* (2014) in chickpea, Zanje (2015) and Marksole (2016) in soyabean.

Nutrient schedule of ½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS had significant influence on number of leaves per plant (14.61) at 60 DAS and number of branches per plant (5.89) at harvest. The favourable effect might be due to improved photosynthetic efficiency by foliar application of fertilizers, thus increasing number of leaves and branches per plant. These results are also in accordance with findings of Venkatesh *et al.* (2012) in chickpea, Sarker and Rahim (2013), Das and Jana (2016) in lentil and Dey *et al.* (2017) in cowpea.

The data on number of nodules, effective nodules and weight of nodules per plant showed that nutrient schedule with ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS had significant influence (Table 5a). There was17.93, 11.48 and 4.90 per cent increase in the number of nodules, effective nodules and weight of nodules per plant respectively compared to control (Fig. 7). Spraying of K nutrients increased the number of nodules per plant which promoted the growth and development of leguminous plants. Development of root nodule is mainly dependent on P availability, where K has synergistic effect on P and N thus resulting in better nodule formation. Similar results were reported by Goud *et al.* (2014) and Sanjeev (2015).

Scheduling nutrients as ½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS registered maximum number, length, spread and weight of roots at flowering (Table 7a and Fig. 8). This might be due to fact that foliar spray of urea might have enhanced the growth hormone synthesis in roots and thus improved the root characters. These results are in accordance with Khalilzadeh *et al.* (2012) in mungbean.

5.2.2 Effect of Nutrient Schedule on Yield Parameters

Among various yield parameters, nutrient schedule had significant influence on 50 per cent flowering, 100 seed weight, grain yield, haulm yield and dry matter production.

Lesser number of days (41.28) for 50 per cent flowering was observed with nutrient schedule of ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS (Table 8a), same trend was also reported by Zanje (2015) in soyabean.

Hundred seed weight, grain yield, haulm yield and dry matter production increased to the tune of 4.99, 12.52, 8.16 and 9.52 per cent respectively compared to

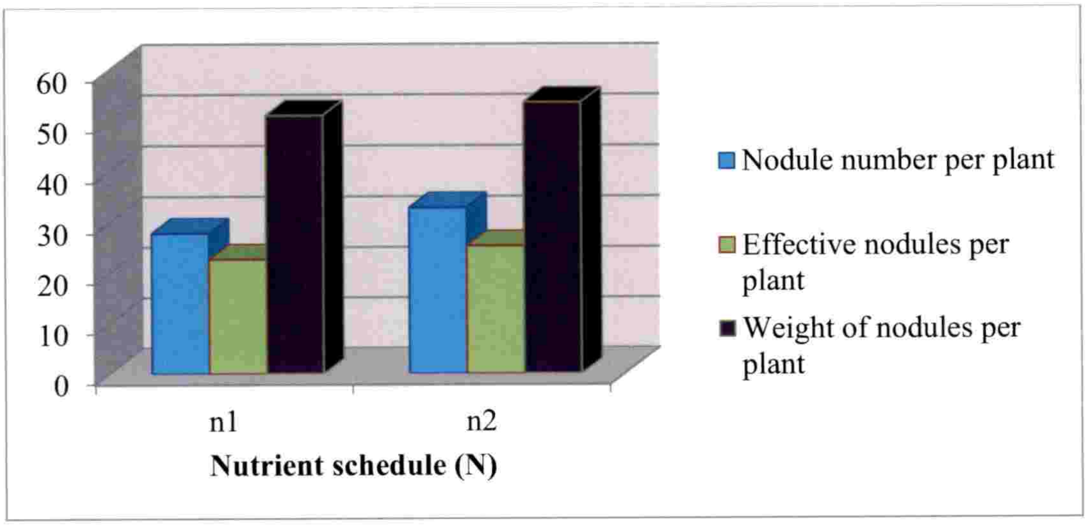

Fig. 7. Effect of nutrient schedule on nodule number, effective nodule number and weight of nodules per plant at flowering

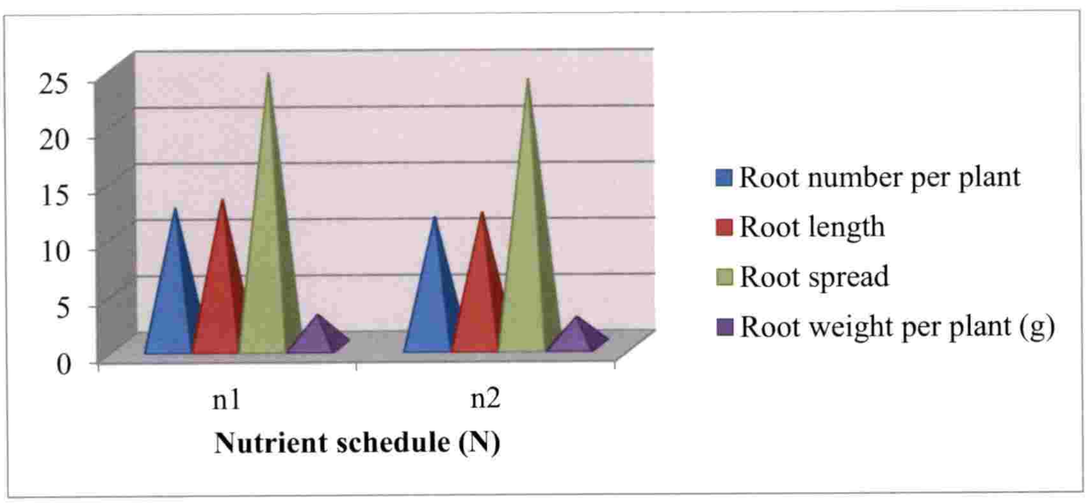

Fig. 8. Effect of nutrient schedule on number, length, spread and weight of roots per plant at flowering

control with nutrient schedule ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS (Table 8a, 9a, 10a and Fig. 9). Increase in hundred seed weight might be due to enhanced photosynthetic activity, efficient transfer and accumulation of metabolites in the seed with the resultant increase in the size and weight of individual seed. This increased hundred seed weight due to K application eventually contributed to higher seed yield; K foliar application also increased haulm yield. Increase in dry matter production might be due to application of K fertilizer which enhanced the soil microbial activity and N level which was reflected in total dry weight of plants. Spraying of 1 per cent KNO_3 facilitated nutrient availability to blackgram even during flowering period (Muhammad *et al.*, 2011). Positive response in terms of yield attributes due to application of K has also been reported by Vekaria *et al.* (2013) in greengram, Goud *et al.* (2014) in chickpea, Keerthy *et al.* (2015) in greengram, Sanjeev (2015) and Dilip (2017) in soyabean.

5.2.3 Effect of Nutrient Schedule on Uptake of Nutrients

At harvest, plant samples were analyzed for the uptake of N, P, K and B and the results showed that nutrient schedule had significant influence on N and K uptake (Table 12a).

Increase in N and K uptake to the tune of 10.26 and 25.30 per cent compared to control with nutrient schedule of ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS were observed (Fig. 10). Uptake of nutrients was the highest with increasing level of K due to its ready availability through foliage and higher K utilization efficiency (Tiwari and Pathak, 1985). The results are in conformity with findings of Somimol (2012), Goud *et al.* (2014) and Sanjeev (2015).

5.2.4 Effect of Nutrient Schedule on Soil Available Nutrients

The soil organic carbon and available B and Mo status of soil was not significantly influenced by nutrient schedule, however soil available N and K had been significantly influenced by nutrient schedule.

Soil available N and K were 6.68 and 6.12 per cent higher with application of ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS compared to control (Table 13a). The improvement in N and K status of soil might be due to more availability of foliar applied N and K resulting in lesser extraction from soil besides biological N fixation (Sahai, 2004). These results are in conformity with the findings of Goud *et al*. (2014) and Zanje (2015).

Soil available P had increased 5.95 per cent over control with the application of ½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS.

5.3 INTERACTION EFFECT OF SEED TREATMENT AND NUTRIENT SCHEDULE

There was positive interaction between seed treatment and nutrient schedule on the growth, yield, grain quality, nutrient status of soil and uptake of nutrients in blackgram, which is discussed below.

5.3.1 Interaction Effect on Growth Characters

Interaction effect had significant influence on all growth parameters *viz*., plant height (20, 40, 60 DAS and at harvest), leaves per plant (at harvest), branches per plant (20, 60 DAS and at harvest), LAI (20 and 60 DAS), number of nodules, effective nodules and weight of nodules and root parameters at flowering.

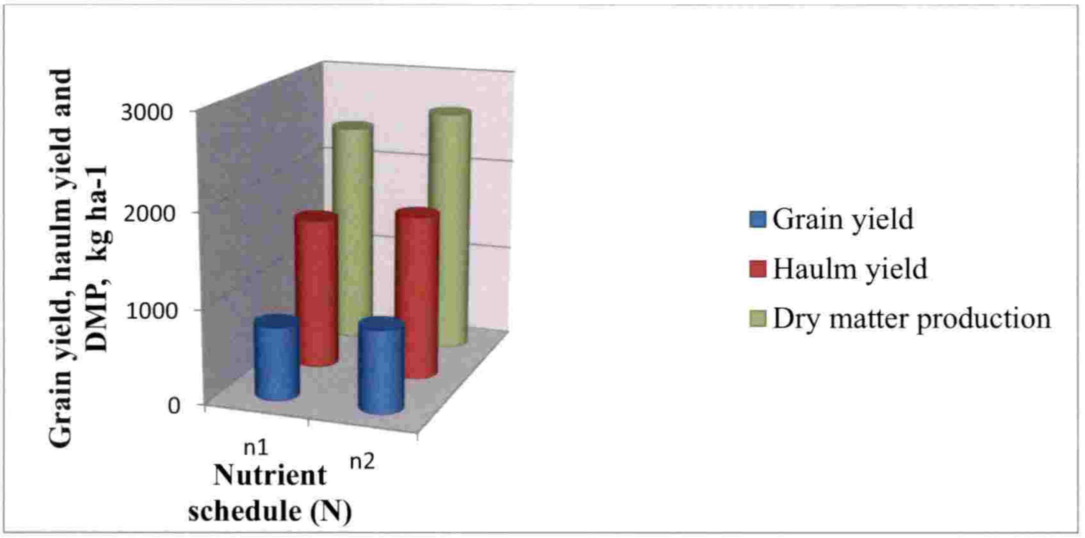

Fig. 9. Effect of nutrient schedule on grain yield, haulm yield and dry matter production at harvest, kg ha^{-1}

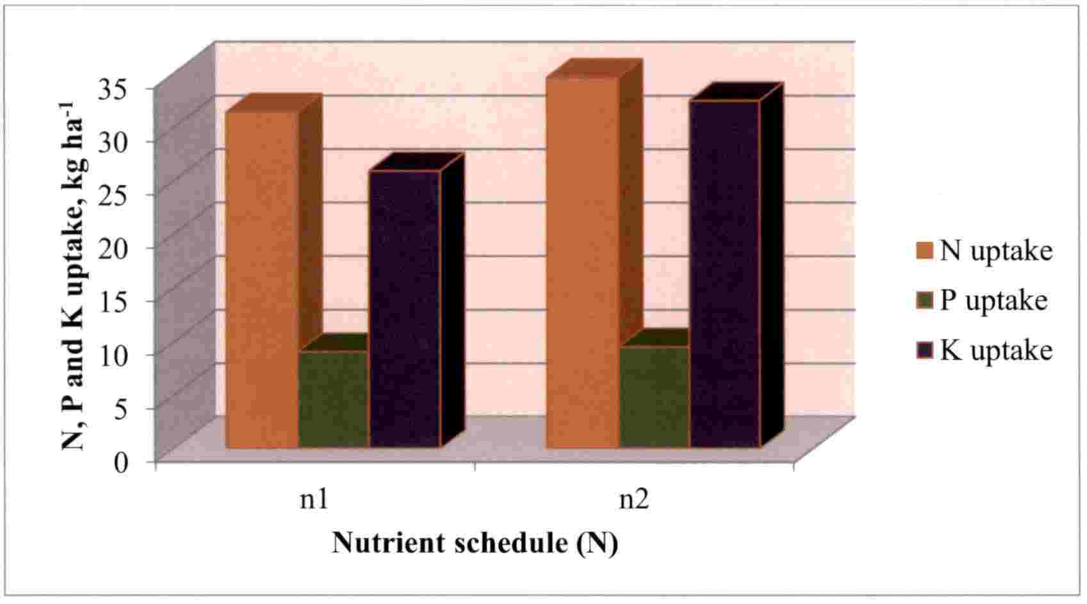

Fig. 10. Effect of nutrient schedule on N, P and K uptake by crop at harvest, kg ha^{-1}

Treatment combination s_0n_1 (without seed treatment and application of ½ N + full P + full K as basal soil application + ½ N as foliar spray of urea at 15 and 35 DAS) recorded the highest plant height (40.10 cm) at 20 DAS compared to all other treatments (Table 2b).

At 40 and 60 DAS and at harvest, the highest plant height of 110.62, 133.65 and 140.35 cm respectively and maximum number of leaves per plant (7.59) at harvest were recorded with treatment combination s_5n_2. Micronutrients played a significant role in cell enlargement and helped to develop a vigorous root system thus enhancing nutrient uptake. Foliar spraying of K also enhanced the vigour and resulted an increase in height and number of leaves per plant. These results are in conformity with the findings of Shil *et al.* (2007), Rao (2013), Marksole (2016) and Shinde *et al.* (2018).

The highest number of branches (2.33 and 6.78 per plant) at 20 DAS and at harvest (Table 4b) and leaf area index (0.37) at 20 DAS (Table 5b and Fig. 11) were recorded with the treatment combination s_5n_1. The increase might be due to application of micronutrients which enhanced cell division and translocation of nutrients in combination with urea as foliar spray which had positive effect on legume plants in enhancing growth of plants. These results are in agreement with Venkatesh *et al.* (2012), Das and Jana (2016) and Shinde *et al.* (2018).

The treatment combination s_3n_2 (seed treatment with sodium molybdate 1 g kg^{-1} seed along with ½ N + full P + ½ K as basal soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS) registered maximum number of nodules (50.33), effective nodules (42.33) and weight of nodules (64.67 mg) per plant at flowering (Table 6b and Fig. 12). The Mo seed treatment might have enhanced nodule formation and promoted N fixation by *Rhizobium* as it is an important component of enzyme nitrogenase and also foliar spray of KNO_3promoted better

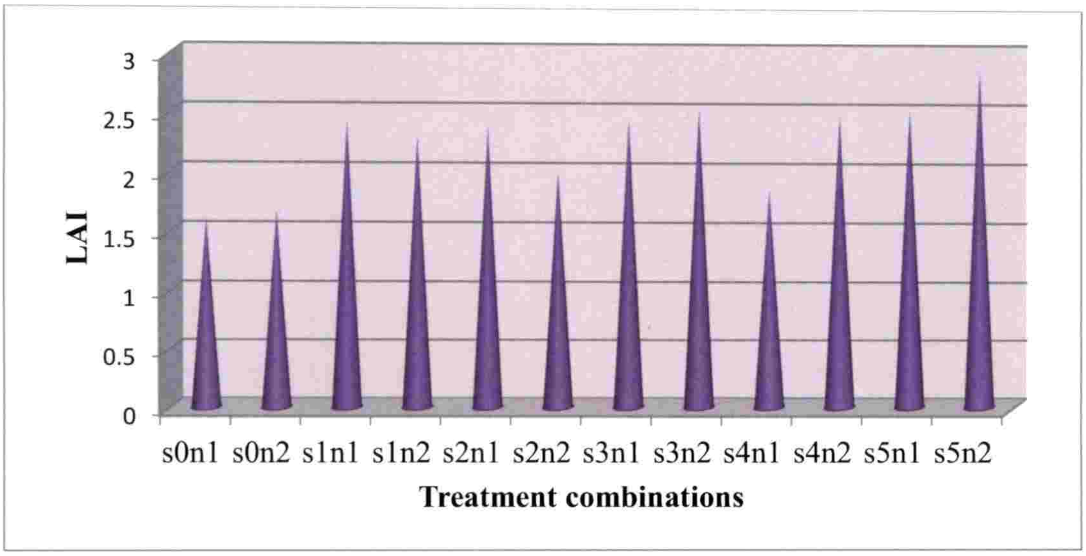

Fig. 11. Interaction effect of seed treatment and nutrient schedule on LAI at 60 DAS

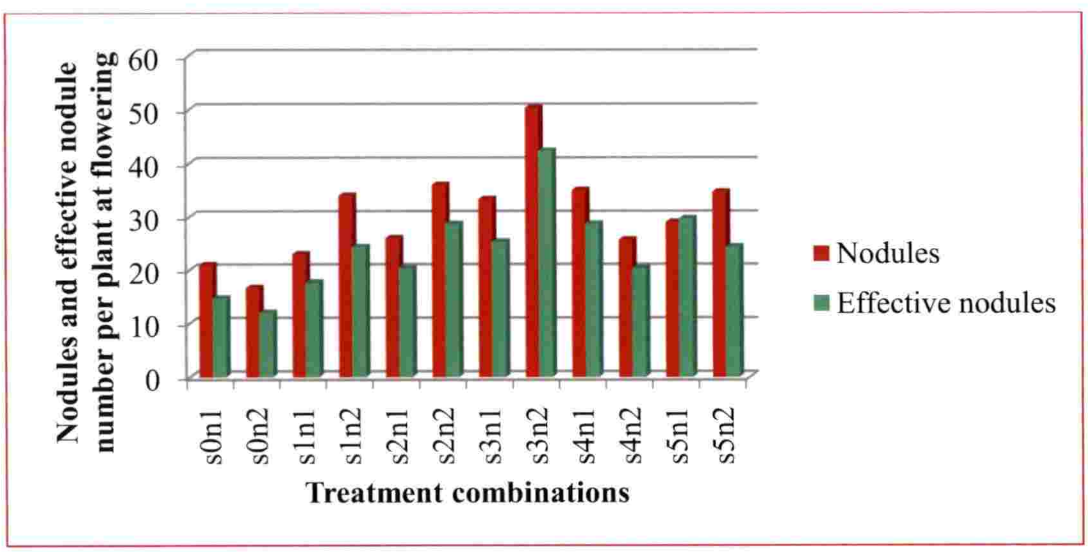

Fig. 12. Interaction effect of seed treatment and nutrient schedule on number of nodules and effective nodules per plant at flowering

translocation of nutrients and improved nodulation. Similar results are also supported by Tahir *et al.* (2014) and Sanjeev (2015) in soyabean.

5.3.2 Interaction Effect on Yield Parameters and Grain Quality

Treatment combination also had significant influence on almost all yield parameters except hundred seed weight and harvest index.

Treatment combination s_1n_1 (seed treatment with borax 1g kg^{-1} seed and ½ N + full P + full K as basal soil application + ½ N as foliar spray of urea at 15 and 35 DAS) took lesser number of days (39.33) for 50 per cent flowering whereas s_0n_2 (without seed treatment and application of ½ N + full P + ½ K as basal soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS) need more number of days (44.33) for 50 per cent flowering (Table 8b).

The highest number of pods per plant (24.99) was observed with treatment combination of s_5n_1. Whereas, treatment combination s_5n_2 documented the highest number of seeds per pod (7.45) (Table 9b and Fig. 13), length of pod (5.59 cm), grain yield (1130 kg ha^{-1}) (Fig. 14) and dry matter production (2933 kg ha^{-1}). Application of micronutrients as seed treatment and foliar spray of K resulted in better availability of nutrients and also enhanced translocation of nutrients which increased the number of seeds per pod and pod length resulting in increased grain yield and dry matter production.

The highest haulm yield (1899 kg ha^{-1}) was recorded with s_3n_2 (seed treatment with sodium molybdate @ 1 g kg^{-1} seed along with ½ N + full P + ½ K as basal soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS).

Treatment combination had significant influence on protein content (Table 11), the highest protein content (22.75 %) was recorded in treatment combination s_5n_2. The increase in protein content might be due to increased translocation of

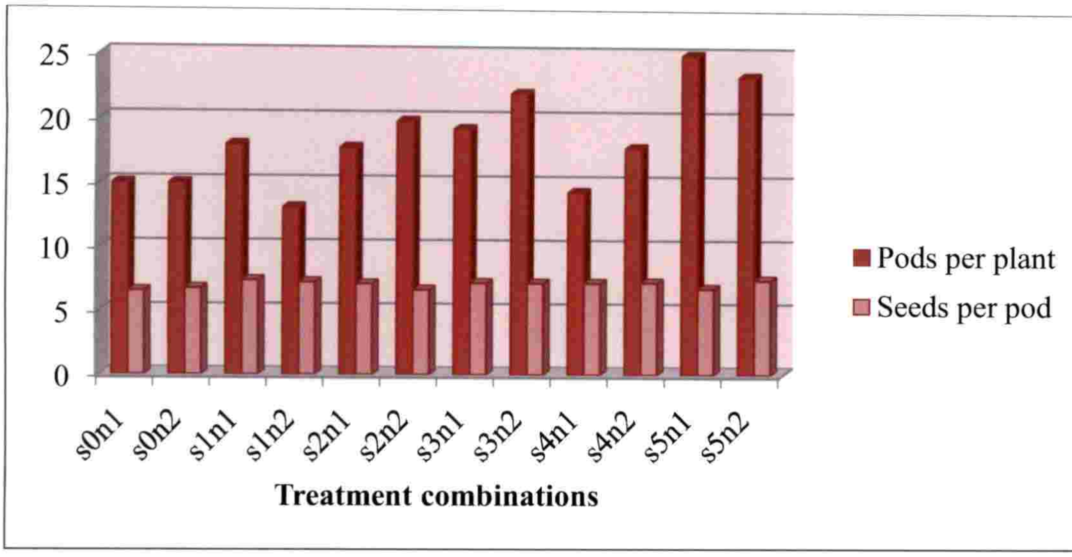

Fig. 13. Interaction effect of seed treatment and nutrient schedule on number of pods per plant and seeds per pod at harvest

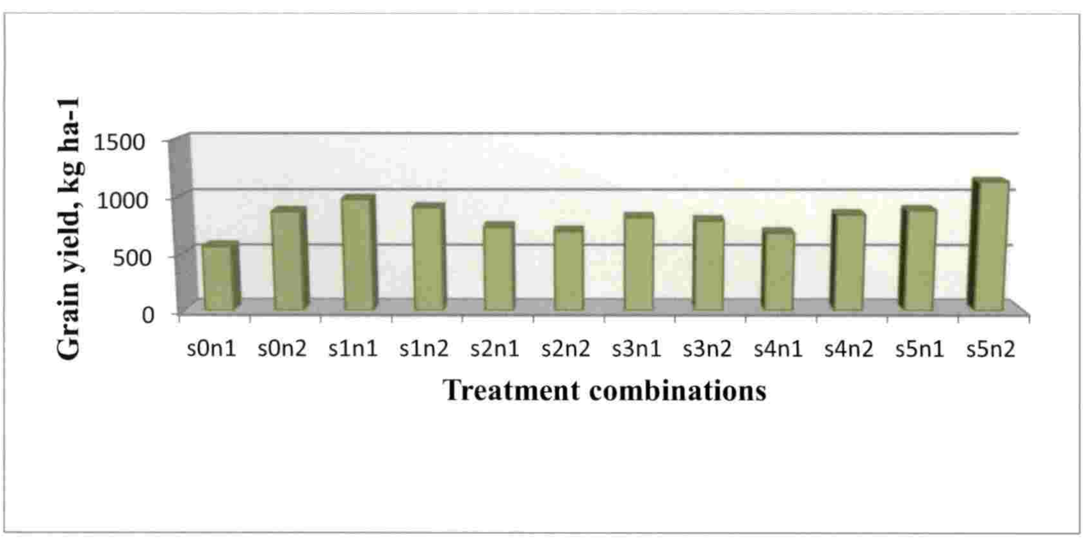

Fig. 14. Interaction effect of seed treatment and nutrient schedule on grain yield at harvest

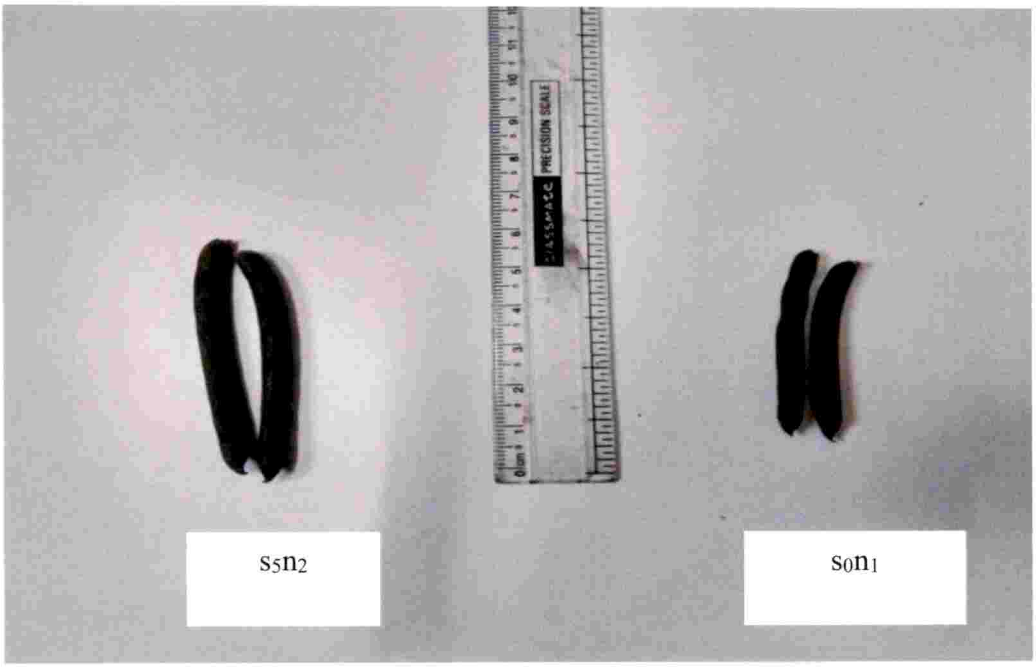

Plate 3.Comparision of pod length of different treatments

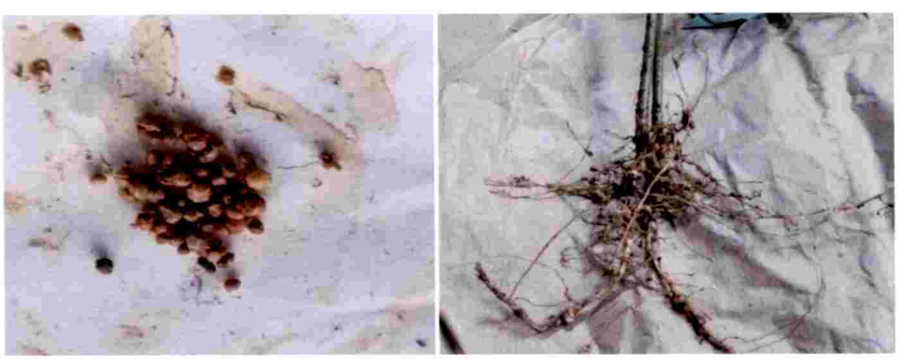

Plate 4. Nodules on plant

nutrients especially N to the grain by combination of seed treatment by micronutrients and K as foliar spray.

5.3.3 Interaction Effect on Nutrient Uptake

Treatment combination s_5n_2 had revealed the highest nutrient uptake of 40.65 and 12.89 kg ha^{-1} of N and P respectively (Table 12b). This was due to the positive effect of micronutrients and K on increased uptake and translocation of nutrients.

5.3.4 Interaction Effect on Soil Available Nutrients

Treatment combination had significant influence on soil organic carbon, available P and K status of soil but had no significant effect on soil available N (Table 13b).

Soil organic carbon was the highest with treatment combination s_1n_1 (seed treatment with borax @ 1g kg^{-1} seed and application of ½ N + full P + full K as basal soil application + ½ N as foliar spray of urea at 15 and 35 DAS). The increase in soil available organic carbon might be due to heavy leaf fall during the crop growth and also due to addition of organic manures at the time of sowing. Soil available P was highest(32.53 kg ha^{-1}) in control s_0n_1 (without seed treatment and application of ½ N + full P + full K as basal soil application + ½ N as foliar spray of urea at 15 and 35 DAS) and maximum soil available K (286.96 kg ha^{-1}) was observed in the treatment combination s_2n_1.

5.4 ECONOMICS

The acceptance of improved production technology involving costly scarce inputs like fertilizer nutrients for blackgram by the farmers depends largely on economic returns. Economic analysis of the system thus assures significance.

5.4.1 Effect of Seed Treatment

Economic analysis of data presented in Table 15a revealed that the highest net returns (₹ 16,907 ha^{-1}) and B: C ratio (1.38) were obtained with s_5 (Fig. 15). The increase in net returns and benefit cost ratio were due to increase in seed yield. These results are supported by the findings of Dixit and Elamathi (2007).

5.4.2 Effect of Nutrient Schedule

Similar to seed treatment, nutrient schedule also increased net income and B: C ratio (Table 15a). The highest net returns (₹ 6, 507 ha^{-1}) and B: C ratio (1.16) were noticed with the nutrient schedule of n_2 –(½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS). This was due to the highest grain and haulm yields recorded under same treatment (n_2) as compared to n_1. The results obtained are in accordance with the findings of Kundu and Sarkar (2009), Vekaria *et al.* (2013), Goud *et al.* (2014) and Keerthy *et al.* (2015) in greengram.

5.4.3 Effect of Treatment Combination

The treatment combination of s_5n_2 registered the highest net income (₹ 21,914 ha^{-1}) and B: C ratio (1.48) and the lowest net returns (₹ -7,154 ha^{-1}) and B: C ratio (0.83) with treatment combination s_0n_0 (Table 15b and Fig. 16). The highest net returns and B: C ratios were due to increase in grain yield in proportion to cost of production.

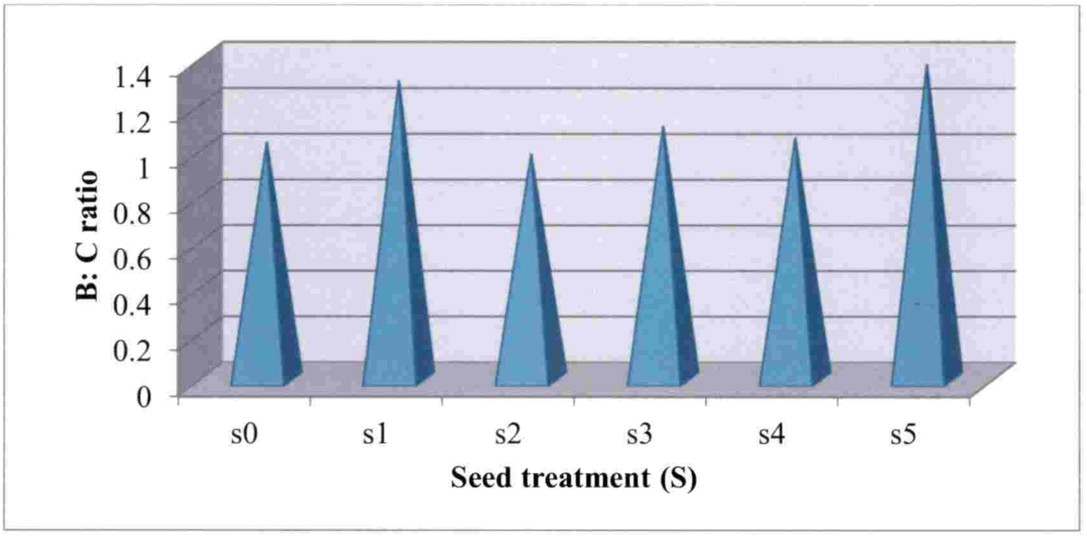

Fig. 15. Effect of seed treatment on benefit cost ratio

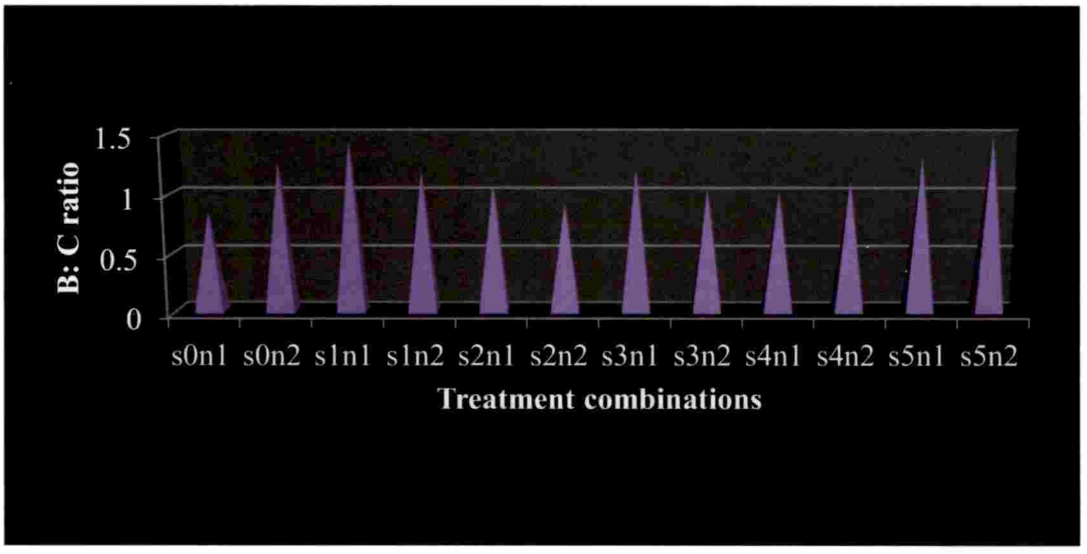

Fig. 16. Interaction effect of seed treatment and nutrient schedule on benefit cost ratio

Summary

6. SUMMARY

The present investigation was conducted at Instructional farm, attached to College of Agriculture, Vellayani, Thiruvananthapuram during *Rabi* 2018 to know the impact of seed treatment and foliar nutrition for enhanced productivity of blackgram (*Vigna mungo* L.). The soil texture was sandy clay loam high in organic carbon, available P and K, low in available N and medium in B. The layout of the exprimentwas in randomized block design with six seed treatments levels and two nutrient schedule levels in three replications. The levels of seed treatment were s_0 – without seed treatment, s_1 – seed treatment with borax @ 1g kg^{-1} seed, s_2 – seed treatment with borax @ 2 g kg^{-1} seed, s_3 – seed treatment with sodium molybdate @ 1 g kg^{-1} seed, s_4 – seed treatment with sodium molybdate @ 1.5 g kg^{-1} seed and s_5 – seed treatment with borax and sodium molybdate @ 1 g kg^{-1} seed each. Two levels of nutrient schedule were n_1- ½ N + full P + full K (basal) as soil application + ½ N as foliar spray of urea at 15 and 35 DAS and n_2- ½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS. The fertilizer recommendation of 20: 30: 30 kg NPK ha^{-1}has been adopted. day before sowing blackgram seeds of variety Co-6 were treated with borax and sodium molybdate at rates as per experimental schedule and shade dried, on the day of sowing the seeds were treated with *Rhizobium* and dibbled in the field at 25 kg ha^{-1}at a spacing of 25 cm x 15 cm. Manures and fertilizers were applied as per the technical programme.

The observations on growth characters *viz.*, height of plant, number of leaves per plant, number of branches per plant, leaf area index, nodule number per plant, effective nodule number per plant, nodule weight per plant and root parameters were registered at different growth stages. The data on yield parameters *viz.*, days to 50 per cent flowering, pod number per plant, seed number per pod, pod length, hundred seed weight, yield of pod, yield of grain, yield of haulm, harvest index and dry matter production were recorded at harvest. Chemical and quality analysis *viz.*, protein content, organic carbon content, uptake of N, P and K and B and N,P,K,B and Mo status of soil after experiment were also recorded. Economics of cultivation and B: C ratios were also tabulated. The results were statistically analyzed and interpretations drawn are briefly presented here.

Seed treatment had significant influence on growth characters. Maximum height of the plant, number of leaves per plant, number of branches per plant and LAI (135.84 cm, 7.61, 6.39 and 2.71 respectively) at harvest were recorded with s_5. Seed treatment with sodium molybdate @ 1g kg^{-1} seed had shown maximum number of nodules (41.83), effective nodules (33.83), weight of nodules (58.83 mg) and root number (13.33) per plant at flowering compared to control. There was significant increase in root spread and root weight when seeds were treated with borax @ 2g kg^{-1} seed and s_4 had recorded the highest root length (14.88 cm) at flowering.

Nutrient schedule also had significant influence on growth characters. Scheduling nutrients as ½ N + full P + full K as basal application and ½ N as foliar spray of urea at 15 and 35 DAS (n_1) had recorded the tallest plants (99.16 cm) at 40 DAS, maximum number of leaves (14.61 per plant) at 60 DAS, maximum number of branches per plant (5.89) at harvest and all root parameters while n_2 (½ N + full P + ½ K (basal) as soil application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45, 60 DAS) has registered the highest LAI (2.32) at 60 DAS, maximum number of nodules, effective nodules and weight of nodules per plant (32.89, 25.33, 53.56 respectively) at flowering.

The treatment combination s_5n_1 has recorded maximum plant height and branches per plant (140.35 and 6.78 respectively) at harvest. The highest LAI (2.88) and maximum number of leaves per plant (7.89) were recorded with $s_5n_2$whereas maximum number of nodules, effective nodules and weight of nodules per plant (50.33, 42.33 and 64.67 respectively) at flowering were recorded with treatment combination s_3n_2.

Yield parameters and yield were also significantly influenced by seed treatment, Among different yield parameters, maximum pod number per plant (24.16), pod length (5.23 cm) and weight of 100 seeds(6.74 g) were recorded with s_5, and maximum seeds number per pod (7.33) were recorded in s_1.

Basal application of ½ N + full P + ½ K and ½ N, ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS has taken lesser number of days (40.88) for 50 per cent flowering and also recorded maximum 100 seed weight (6.52 g).

Treatment combination s_5n_2 had recorded the highest seeds per pod (7.45) and length of pod (5.59 cm) whereas maximum numbers of pods per plant (24.99) were observed in s_5n_1 and was on par with s_5n_2 and s_3n_2.

The highest yield of grain (1005 kg ha^{-1}) and harvest index (0.38) were observed s_5. The maximum haulm yield and dry matter production of 1854 and 2657 kg ha^{-1} respectively were registered with s_3 whereas the highest yield of pod (1833 kg ha^{-1}) was observed with s_1 (seed treatment with borax @ 1g kg^{-1} seed).

Scheduling nutrients as ½ N + full P + ½ K as basal application and ½ N, ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS has registered the highest grain yield, haulm yield and dry matter production of 872, 1750 and 2622 kg ha^{-1} respectively at harvest.

The grain protein content was also influenced by seed treatment and interaction effects. Maximum protein content of 22.75 per cent was registered with s_5n_2. N, P, K and B uptake were significantly influenced by seed treatment, nutrient schedule and interaction effect. s_5 had recorded maximum uptake of N and P (36.84 and 11.24 kg ha^{-1} respectively) whereas, maximum uptake of B was registered with s_2 (70.51 mg kg^{-1}) and was statistically comparable with s_1. Scheduling nutrients as ½ N + full P + ½ K as basal application and ½ N, ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS recorded maximum N and K uptake (34.70 and 32.54 kg ha^{-1}

respectively). Treatment combination s_5n_2 had maximum uptake of N and P (40.65 and 12.89 kg ha^{-1} respectively).

Seed treatment had significantly influenced soil available N and K. Maximum soil available N and K (265.51 and 240.10 kg ha^{-1}) were recorded with s_3 and s_4 respectively. Nutrient schedule also had significant influence after the experiment on N, P and K status of soil. Maximum soil available N and K were observed with n_2, and maximum P status of soil (29.55 kg ha^{-1}) with n_1. Treatment combination s_0n_1 had registered maximum soil available P (32.53 kg ha^{-1}) whereas s_2n_1 recorded maximum K (286.96 kg ha^{-1}) status of soil after the experiment.

Seed treatment with borax @ 1 g kg^{-1} seed recorded maximum soil available B (0.764 mg kg^{-1}) and was statistically comparable with s_2. Mo status of soil after the experiment was maximum when treated with sodium molybdate @ 1.5 g kg^{-1} seed. Treatment combination s_2n_1 recorded maximum B status of soil (0.868 mg kg^{-1}) and was statistically comparable with s_1n_2. Soil available Mo was maximum (0.070 mg kg^{-1}) with s_4n_1 and was statistically comparable with s_5n_2.

Seed treatment with borax and sodium molydate @ 1 g kg^{-1} seed each had increased the net income and B: C ratio. The highest net income (₹ 21,914 ha^{-1}) and B: C ratio of 1.48 were recorded with the treatment combination s_5n_2.

Based on the study, it can be concluded that, in blackgram, seed treatment with borax and sodium molybdate @ 1g kg^{-1} seed each and scheduling nutrient application at 20: 30: 30 kg NPK ha^{-1} as ½ N + full P + ½ K as basal followed by ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS could be suggested for realizing higher yield and net income.

Future line of work

1. Since positive and significant response was obtained by B and Mo application for blackgram, investigations should be taken up for assessing the efficiency of

different sources of B and Mo and at different methods of application in different legumes.

2. To ascertain the interaction effect, different levels of B and Mo can be tested with foliar spray of KNO_3.
3. The same experiment may be conducted again to confirm the trend of results recorded in the present study.

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Appendix

APPENDIX 1

Weather data during the crop season (September 2018- December 2018)

Standard week	Temperature (^{0}C)		RH (%)		Rainfall (mm)	No. of rainy days
	Maximum	Minimum	Maximum	Minimum		
39	32.6	24.7	89	85	18.5	2
40	31.5	24.7	92	85	48.3	2
41	30.7	24.3	93	80	134.6	3
42	32	24.5	91	77	90.6	5
43	31.4	24.2	93	76	11.3	1
44	31.8	24.3	93	77	71.8	2
45	31.1	24.3	93	78	59.2	3
46	31.7	23.8	92	73	51.2	1
47	31.6	24.1	93	74	51.8	3
48	31.9	23.7	93	72	0	0
49	31.9	23.7	93	72	17.2	2
50	32.2	23.8	94	73	26.1	1
51	32.4	23	92.5	72	0	0

SEED TREATMENT AND FOLIAR NUTRITION FOR ENHANCED PRODUCTIVITY OF BLACKGRAM (*Vigna mungo* L.)

by

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ABSTRACT

SEED TREATMENT AND FOLIAR NUTRITION FOR ENHANCED PRODUCTIVITY OF BLACKGRAM (*Vigna mungo* L.)

A field experiment on "Seed treatment and foliar nutrition for enhanced productivity of blackgram (*Vigna mungo* L.)" was conducted during *Rabi* 2018 at the Instructional Farm, College of Agriculture, Vellayani with an objective to evaluate the effect of different seed treatments and foliar nutrition on the growth and yield of blackgram and also to work out the economics of production. The experiment was laid out in randomized block design with six levels of seed treatments and two levels of nutrient schedule in three replications. The levels of seed treatment were s_0 – without seed treatment, s_1 – seed treatment with borax @ 1g kg^{-1} seed, s_2 – seed treatment with borax @ 2 g kg^{-1} seed, s_3 – seed treatment with sodium molybdate @ 1 g kg^{-1} seed, s_4 – seed treatment with sodium molybdate @ 1.5 g kg^{-1} seed and s_5 – seed treatment with borax and sodium molybdate @ 1 g kg^{-1} seed each. Two levels of nutrient schedule were n_1- ½ N + full P + full K as basal application + ½ N as foliar spray of urea at 15 and 35 DAS and n_2- ½ N + full P + ½ K as basal application + ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS.

Among the seed treatments, s_5 produced the tallest plants, higher number of leaves and branches per plant at harvest and also registered maximum LAI at 60 DAS. Between the nutrient schedules n_1 recorded the tallest plants at 40 DAS and maximum branches number per plant at harvest, while n_2 registered maximum leaves number per plant at harvest and LAI at 60 DAS.

Maximum nodules number, effective nodules and nodules weight per plant was recorded with s_3 and n_2 15, 30, 45 and 60 DAS. Seed treatment and nutrient schedule also had significant influence on root parameters with the highest root spread and root weight observed with s_2 and n_1.

The yield characters *viz*., number of pods per plant, pod length, 100 seed weight, grain yield and harvest index were favorably influenced by s_5. However, the highest

number of seeds per pod and yield of pod were registered with s_1. The treatment s_5 registered the highest yield of grain of 1005 kg ha^{-1} and was statistically comparable with s_1, while s_3 registered the highest yield of haulm of 1854 kg ha^{-1}, which was statistically comparable with s_2. Between the nutrient schedules, n_2 recorded the highest 100 seed weight, yield of grain and yield of haulm (872 and 1750 kg ha^{-1}). Interaction effects also significantly influenced yield parameters and yield. The treatment combination s_5n_2 recorded the highest pods per plant, seeds per pod, 100 seed weight, pod yield and grain yield. With regard to haulm yield, s_3n_2 recorded highest value of 1899 kg ha^{-1}.

The results also showed favorable increase in dry matter production with seed treatment, nutrient schedule and interaction effect, and the highest DMP (2933 kg ha^{-1}) was obtained with s_5n_2. Seed treatment and interaction effects also significantly influenced protein content. The highest protein content of 22.28 per cent was recorded with s_5 and it was statistically comparable with s_2. Among the interaction effects, the treatment combination s_5n_2 recorded maximum protein content of 22.75 per cent.

Increased N and P uptake were recorded with s_5 and the treatment combination s_5n_2. The highest boron uptake was recorded with s_2 and it was at par with s_1. Net income and B: C ratio were maximum in plots treated with s_5 and n_2. The highest net returns of ₹ 21,914 ha^{-1} and B: C ratio of 1.48 were recorded with treatment combination s_5n_2.

The results revealed that, in blackgram, seed treatment with borax and sodium molybdate @ 1g kg^{-1} seed each and scheduling nutrient application at 20: 30: 30 kg NPK ha^{-1} as ½ N + full P + ½ K as basal followed by ½ N and ½ K as foliar spray of 13:0:45 at 15, 30, 45 and 60 DAS could be suggested for realizing higher yield and net returns.

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സംഗ്രഹം

വിത്ത് ഉപചാരവും പത്രപോഷണവും ഉഴുന്നിന്റെ ഉല്പാദനക്ഷമത വർദ്ധനവിന്

വിവിധ വിത്ത് ഉപചാരീതികളും പത്രപോഷണവും ഉഴുന്നിന്റെ കായിക വളർച്ചയെയും ഉല്പാദന ഘടകങ്ങളെയും ഉല്പാദനത്തെയും വരവ് ചിലവിനേയും എങ്ങനെ സ്വാധീനിക്കുന്നു എന്ന് അറിയുവാനായി **"വിത്ത് ഉപചാരവും പത്രപോഷണവും ഉഴുന്നിന്റെ ഉല്പാദനക്ഷമത വർദ്ധനവിന്"** എന്ന ഒരു ഗവേഷണ പദ്ധതി 2018 റാബി വിളക്കാലത്ത് വെള്ളായണി കാർഷിക കോളേജിനോടനുബന്ധിച്ച ഇൻസ്ട്രക്ഷണൽ ഫാമിൽ നടപ്പിലാക്കുകയുണ്ടായി. റാൻഡമൈസിഡ് ബ്ളോക്ക് ഡിസൈനിൽ ആറ് രീതിയിലുള്ള വിത്ത് ഉപചാര രീതികളും രണ്ടു രീതിയിലുള്ള വളപ്ര യോഗങ്ങളും മൂന്ന് റെപ്ളിക്കഷനിലും വിന്യസിക്കുകയുണ്ടായി. വിത്ത് ഉപചാര രീതികൾ താഴെ പറയുന്ന വിധമായിരുന്നു.

എസ് 0 – ഉപചാരമില്ലാതെ, എസ് 1 – ബോറോക്സിൻ 1 ഗ്രാം 1 കിലോ വിത്തിൽ, എസ് 2 – ബോറോക്സിൻ 2 ഗ്രാം 1 കിലോ വിത്തചന്റ്, എസ് 3 – സോഡിയം മോളിബഡേറ്റ് 1 ഗ്രാം 1 കിലോ വിത്തിൽ, എസ് 4 – ബോറോക്സിൻ 1.5 ഗ്രാം 1 കിലോ വിത്തിൽ, എസ് 5 – ബോറോണും സോഡിയവും മോളിബ്ഡേറ്റും 1 ഗ്രാം വീതം 1 കിലോ വിത്തിൽ

രണ്ട് രീതിയിലുള്ള വളപ്രയോഗങ്ങൾ താഴെ പറയുന്നവയായിരുന്നു

എൻ 1 – അടിവളമായി 1/2 എൻ + മുഴുവൻ ഫോസഫറസ് + മുഴുവൻ പൊട്ടാസ്യം + വിത്ത് വിതച്ചശേഷം 15, 35 ദിവസം കഴിഞ്ഞ് 1/2 എൻ പത്രപോഷണത്തിലൂടെ

എൻ 2 – അടിവളമായി 1/2 എൻ + മുഴുവൻ ഫോസഫറസ് + മുഴുവൻ പൊട്ടാസ്യം + വിത്ത് വിതച്ചശേഷം 15, 35,45,60 ദിവസത്തിന് ശേഷം 1/2 എൻ + 1/2 ഫോസഫറസ് 13:0:45 വളത്തിലൂടെ പത്രപോഷണം

ബോറോണും സോഡിയം മോളിബ്ടേറ്റും 1 കിലോ വിത്തിൽ1 ഗ്രാം നിരക്കിൽ ഉപചാരം ചെയ്യുപ്പോൾ കൂടുതൽ ഉയരവും ഇലകളും ശിഖരങ്ങളും ഇലപ്പരപ്പും ഉണ്ടായി.

എൻ 1 വള പ്രേയോഗരീതിയിൽ 40 ദിവസം കഴിയുമ്പോൾ ചെടികൾക്ക് കൂടുതൽ ഉയരം വച്ചതായും, വിളവെടുപ്പു സമയത്ത് ശിഖിരങ്ങൾ ഉണ്ടാകുകയും ചെയ്തു. എന്നാൽ എൻ 2 രീതി യിൽ വിളവെടുപ്പ് സമയത്ത് കൂടുതൽ ഇലകൾ കാണപ്പെടുകയുണ്ടായി.

വേരുപടലത്തിലെ മുഴകളുടെ എണ്ണം ഫലപ്രദമായ മുഴകൾ, മുഴകളുടെ തൂക്കം എസ് 3 യിൽ കൂടുതലായി കാണപ്പെട്ടു. എസ് 2 വും എൻ 1 ഉം വേരിന്റെ ത്വരിത വളർച്ചയെ സഹായിക്കു ന്നതായി കണ്ടു.

വിളവിനെ ബാധിക്കുന്ന ഘടകങ്ങളായ കായുടെ എണ്ണം നീളം 100 വിത്തിന്റെ തൂക്കം വിളവ് എന്നിവയുടെ വർദ്ധനവിന് എസ് 5 ഏറെ സഹായകരമായിരുന്നു. എന്നിരുന്നാലും ഏറ്റവും കൂടുതൽ വിളവ് (കായ്) ലഭിച്ചിരുന്നത് എസ് 1 നിന്നായിരുന്നു. എന്നാൽ എസ് 5 ആയിരുന്നു വിള (ധാന്യം) കൂടുതൽ. ചണ്ടി കൂടുതലുണ്ടായത് എസ് 3 യിലായിരുന്നു. വളപ്രയോഗത്തിന്റെ കാര്യമെടുക്കുമ്പോൾ 100 വിത്തിന് തൂക്കം ധാന്യ വിളവ് ചണ്ടി തൂക്കം തുടങ്ങിയവ കൂടുതലായി ലഭിച്ചത് എൻ 2 വിലായിരുന്നു. എസ് 5 എൻ 2 പരമാവധി കായുടെയും ധാന്യത്തിന്റെയും വിളവ് രേഖപ്പെടുത്തുകയുണ്ടായി. കൂടാതെ മൊത്തം ഉല്പാദനത്തിലും പ്രോട്ടിന്റെ അളവിലും കാര്യമായ വർദ്ധനവുണ്ടായി.

മണ്ണിൽ നിന്നും വലിച്ചെടുക്കുന്ന നൈട്രജൻ, ഫോസഫറസ് അളവിൽ എസ് 5 എൻ 2 കൂടുതൽ വിളവ് രേഖപ്പെടുത്തുകയുണ്ടായി. ബോറോൺ വലിച്ചെടുക്കുന്നതിൽ എസ് 2 നിർണ്ണായകമായ സ്വാധീനം ചെലുത്തുകയുണ്ടായി. അറ്റാദായം, വരവ് ചിലവ് അനുപാതം തുടങ്ങിയവ എസ് 5 എൻ 2 വിൽ കൂടുതൽ രേഖപ്പെടുത്തുകയുണ്ടായി.

ഉഴുന്ന് കൃഷിയിൽ 1 ഗ്രാം തോതിൽ ബോറോണും സോഡിയം മോളിബ്ടേറ്റും കൊണ്ട് വിത്ത് ഉപചാരം ചെയ്യുകയും ഹെകടറിന് 20:30:30 കിലോഗ്രാം നൈട്രജൻ, ഫോസഫറസ്, പൊട്ടാസ്യം രണ്ട് സമയങ്ങളിലായി അതായത് 1/2 എൻ + മുഴുവൻ ഫോസഫറസ് + മുഴുവൻ പൊട്ടാസ്യം അടിവളമായും, വിത്ത് വിതച്ചശേഷം 15, 30, 45, 60 ദിവസങ്ങൾ കഴിഞ്ഞ് 1/2 നൈട്രജൻ, 1/2 പൊട്ടാസ്യം പത്രപോഷണം വഴി 13:0:45 വളത്തിൽ കൂടി നൽകുകയും ചെയ്യുമ്പോൾ അധികരിച്ച വിളവും ലാഭവും ലഭ്യമാകുന്നു.