“Effect of sulphur and bio-fertilizers on growth and yield of coriander (*Coriandrum sativum* L.)”

THESIS

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PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS

by

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CERTIFICATE – I

This is to certify that the thesis entitled **"Effect of sulphur and bio-fertilizers on growth and yield of coriander (Coriandrum sativum L.)"** submitted in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE AGRICULTURE** in **HORTICULTURE (Plantation, Spice, Medicinal and Aromatic Crops)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, is a record of the bona-side research work carried out by **Mr. HIMALAY CHANDEL.** under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee and the Director of Instruction.

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

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This is to certify that the thesis **"Effect of sulphur and bio-fertilizers on growth and yield of coriander (Coriandrum sativum L.)"** *submitted by* **Mr. HIMALAY CHANDEL.** *to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, in partial fulfilment of the requirements for the degree of* **Master of Science AGRICULTURE** *in* **HORTICULTURE** *in the* **Department of (Plantation, Spice, Medicinal and Aromatic Crops)** *has been accepted after valuation by the external examiner and the Student's Advisory Committee after an oral examination on the same.*

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Date:

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List of Abbreviations

Symbol	Abbreviation	Stands for
/		Per
@		At the rate of
%		Percentage
^{0}C		Degree Celsius
&		And
,		Comma
.		Full stop
-		Dash
-	cm^2	Centimeter square
-	Cm	Centimeter
-	cv.	Cultivar
-	DAP	Days After planting
-	DF	Degrees of freedom
-	*et al.*	And others/ associates
-	Fig.	Figure
-	G	Gram
-	Kg	Kilogram
-	Max.	Maximum
-	Min	Minimum
-	MSS	Mean of sum square
-	m^2	Meter square
-	Mm	Millimeter
-	NS	Non-significant
-	T	Tonnes
-	Q	Quintal
-	Ha	Hectare
-	SPAD	Soil plant analysis development

-	ANOVA	Analysis of variance
-	CD	Critical difference
-	i,e	That is
-	Df	Degrees of freedom
-	*viz.*	Videlicet (Namely)
-	Temp.	Temperature
-	RVSKVV	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
-	q ha^{-1}	Quintal per hectare
-	*	Significant
-	“ “	Quotation mark

Chapter - I
INTRODUCTION

Coriander (*Coriandrum sativum* L.) is one of the major seed spices crop known to mankind. It is originated from the Mediterranean region and belong to the Apiaceae family, having diploid chromosome number 2n=22. It is an annual herbaceous plant which requires low temperature during vegetative growth and warm dry climate at flowering stage.

Stem leaves and coriander seeds are used in a number of culinary preparations (Jhankar *et al.,* 2017). It is mainly grown for its aroma and aromatic seeds, which are botanically a creamy carp fruit. The fresh green stems, leaves and fruits of coriander have a pleasant aromatic scent. Coriander plants are grown for both fresh green leaves and dried seeds. Dried seeds are mainly used whole or crushed as a spice to add flavor and aroma to various foods, while green leaves are sprinkled to garnish various dishes. Coriander leaves and seeds contain essential oils in varying amounts; add flavor, aroma and have medicinal properties (Mandal and Mandal, 2015).

The fresh green stems, leaves and fruits of coriander have a pleasant aromatic scent. The pleasant aroma of the plant is due to the essential oil called “corianderrol” which makes up 0.1 to 1.3 percent in dry seeds. Coriander seed oil is used in perfumery, beauty products, soups, candy, cocoa, chocolate, meat products, soft drinks and alcoholic beverages. Good quality oleoresin can be extracted from coriander seeds, which are used to flavor drinks, sweet pickles, sausages, shacks, etc. Coriander bark oil is highly bactericidal and can be used as fungicides (Krishna, 1999). The entire young plant is used to flavor all kinds of curries and chutneys. In medicine, its seeds are used as a carminative, cooling and diuretic. Dry coriander seeds contain 0.3% essential oil, 19.6% non-volatile oil, 24% carbohydrates, 5.3% minerals, and 175 IU / 100 vitamins A.

In India, coriander is cultivated in about 583 thousand hectare area with annual production about 784 thousand MT, (NHB 2018-19). The major coriander growing state are Rajasthan, Madhya Pradesh, Andhra Pradesh, Gujarat, Bihar, Uttar Pradesh and with scattered pockets in Tamil Nadu, Odisha, Karnataka and Haryana. The major growing districts in the Madhya Pradesh state are Guna, Shivpuri, Mandsaur, Neemuch, Ratlam, Shajapur, Rajgarh and Vidisha.

The present investigation was under taken to determine the influence of different biofertilizers like Azospirillum, Azotobacter, PSB (*Bacillus polymyxa and Pseudomonas striata*) and K-mobilizers in combination with organic and inorganic on the growth, flowering, fruit setting, maturity and yield of coriander and also to assess the amount of biofertilizers for beneficial exploitation on maximum response in coriander.

Sulphur is a secondary plant nutrient but now considered as the fourth major plant nutrients after nitrogen, phosphorus and potash and helps in photosynthesis and nitrogen fixation (Patel *et al.,* 2013). Sulphur levels increase the yield which in turn increases the net returns being the main component for the higher returns (Abdulrazaq *et al.,* 2020). Increasing level of sulphur recorded significant improved yield and yield attributing trails as compare to control in coriander (Meena *et al.,* 2014). Sulphur is essential for production of protein, fats and oils. It helps in the emergence of chlorophyll and is alsoconstitute of amino acids such as methionine, cysteine and cysteine. Sulfur is also overseen for the union of certain vitamins, protein, fat and carbohydrate assimilation (Tondon, 1991). Sulfur is necessary for the building of oils,proteins andfats, further enzyme pursuit and aids in chlorophyll origination, grain stuffing and boost root growth leads to vigorous plant growth and resistance to cold. Its lack causes optic chlorosis with a very sharp red tinge of the veins and petioles(Shanyn and Lucy, 1999).

Phosphate-solubilizing bacteria increases the availability of phosphorus in the soil through the secretion of the enzyme phosphatase, which leads to the conversion of organic phosphorus into the accessible form. Consequently, it increases the absorption and accumulation of phosphorus in plant tissues. An increase in nutrient uptake caused by combined inoculation of rhizobium and PSB has been reported (Rudresh *et al.,* 2005).

The use of biofertilizers such as PSB, Azotobacter, Azospirillum reduced the use of chemical fertilizers but provided a high quality organic product that does not contain harmful agrochemicals for the safety of public health. Free-living nitrogen-fixing bacteria have been found to have not only the ability to fix nitrogen, but also the ability to secrete phytohormones like gibberellic acid and indoleacetic acid, which can stimulate plant growth, nutrient uptake and photosynthesis (Mahfouz *et al.,* 2007). Plant-related bacteria that can colonize roots are called rhizobacteria and can be classified into beneficial, harmful and neutral groups based on their effect on plant growth. Beneficial rhizobacteria that stimulate plant growth are commonly referred to the plant growth promoting rhizobacteria (PGPR), a group that includes different species and strains of bacteria belonging to different genera such as acetobacter, azospirillum, azotobacter, bacillus, herbaspirillum, and pseudomonas (Glick, 1995). Plant growth promoting rhizobacteria directly promote growth, for example by fixing atmospheric nitrogen, solubilizing minerals (phosphorus and potassium), producing siderophores that solubilize and bind iron, or producing hormones that regulate plant growth (Grover *et al.,* 2009).

Organic farming is becoming more and more popular these days, which emphasizes the transition from a large-scale production system to a high value-added production system. These combinations are environmentally friendly and improved soil fertility by improving the biological,physical and chemical stuff of the soil. The consumption of organic food in India is very low compared to western markets. The organic food market in India is extremely disorganized and fragmented, offering tremendous growth opportunities for local and international players. India exports mainly processed organic food, organic rice, beverages and other grains and millet to the United States, Canada, Europe and Southeast Asia. India is ranked 10th in the world for organic certification.

Keeping view, the current examination is conducted to study the **"Effect of Sulphur andBio-fertilizers on Growth and Yield of Coriander (*Coriandrum sativum* L.)"** with following objectives.

Objectives:

1. To determine the effect of sulphur and bio-fertilizer on growth of coriander
2. To study the response of sulphur and bio- fertilizer on yield and yield attributingTraits
3. To find out the economics of the treatments

Chapter – II

REVIEW OF LITERATURE

A brief review of work carried out by various scientists in different parts of the India and abroad in relation to **“Effect of sulphur and bio-fertilizers on growth and yield of coriander (*Coriandrum sativum* L.)”** studies has been reviewed and presented in this chapter.

As the available information on nutrient management in coriander through sulphurand bio-fertilizers resources is meager, literature pertaining to the use of inorganicand bio-fertilizers on seed spices and other related crops and those which nearly resemble coriander (*Coriandrum sativum* L.)with respect to growth, development and yield have also been reviewed here under and presented in the following headings.

Singh and Rao (2005)recorded that the cultivar RZ-19 was superior to local cultivar with respect to seed yield and its attributes. The net returns and benefit:cost ratio obtained with RZ-19 was much higher compared to that of local variety. All the nutrient management practices recorded significantly higher yield and its attributes over control. However, the maximum seed yield was recorded with integrated nutrient management practices involving tumba cake (*Citrullus colocynthis*) with 50% recommended dose of fertilizers and application of bio-fertilizer (Azotobacter chroococcum + phosphate solubilizing bacteria), whose yield was at par with that of integrated nutrient management practices involving application of 5 t farm yard manure.

Choudhary *et al*. (2006) conducted an experiment to study the response of cumin (*Cuminum cyminum*) to inorganic nitrogen, farmyard manure and biofertilizer. Application of inorganic N (100 %) + Azotobacter + 5 tons FYM per hectare recorded more nitrogen, phosphorus and potassium content (17.05, 5.46 and 12.08 kg/ha) as compared to control (9.45, 3.25 and 7.69 kg/ha).

Sharma *et al*. (2006) reported that, application of 75 per cent recommended doseof phosphorus + 100 per cent nitrogen and potassium +

PSB + *rhizobium* significantly increased the plant height (79.40 cm), number of branches (7.07) and dry matter (11.74g/plant)infenugreek(*Trigonellafoenum-graecum*).

Garg(2007) studied **t**he response of non-symbiotic microbial inoculants on growth, yield and qualityof fennel (*Foeniculum vulgare*) grown in partially reclaimed sodic soils was studied atLucknow(UttarPradesh).Theresultsrevealedthatinoculationofphosphatesolubilizing bacteria or in combination with *azotobacter chroococcum* was superiorresultingin14 percent to 15 percentincreaseinseedyield.

Kalidasu *et al.* (2008) conducted an experiment with nine treatment combinations containing Azospirillum Sp., Azatobactor sp. and PSB and combination of Azospirillum and PSB, Azatobactor and PSB, Vermicompost, Trichoderma viride, 100 % inorganic Nitrogen and control in RBD with three replications. Inoculation of microorganisms and FYM @ 5 t ha^{-1} applied along with recommended dose of inorganic Nitrogen @ 100 % N had shown significant influence on growth parameters when compared with absolute control. However, the influence of microorganisms is significant only on number of secondary branches and number of umbels $plant^{-1}$ when compared to 100% N. Plant height, number of primary and secondary branches were significantly more in treatment with 100 % N in combination with Azospirillum, PSB and FYM @ 5 t ha^{-1} (66.4 cm, 6.2 and 15.4 respectively) than control (58.3 cm, 4.4 and 8.7 respectively).

Rahimi *et al.* (2009) conducted an experiment in 2007 at the experimental field of Gorgan University, Iran. Treatments were control T_1, biofertilizer (Azotobacter + Azospirillum) T_2, biofertilizer + 37.5 kg N T_3, and 75 kg N without inoculation T_4. Application of T_4 and T_3 significantly increased plant height, number of branches/plant, total dry weights, fruit yield, essential oil percentage, essential oil yield/plant, content of linalool in essential oil and linalool yield compared with control. The highest values were always obtained by T_3 for all traits, followed by T_4, but there were no significant differences in most cases. The lowest values were obtained in the control.

Akhani *et al.* (2012) studied the effect of bio-fertilizer and plant density on yield components and seed yield of coriander (*Coriandrum sativum*). The factors were biofertilizer (Nitrogen fixing bacteria), mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum* in four levels (noninoculated, inoculated seeds, spray on the plant base at stem elongation stage and inoculated seeds+spray on the plant base at stem elongation stage) and plant density in three levels (12.5, 16.6 and 25 plants m^{-2}). Results showed that the highest plant height, umbel number $plant^{-1}$, weight of 1000 seeds, dry weight of plant and seed yield were obtained by using the biofertilizer twice. Plant density, also showed significant effects on mentioned traits. The maximum umbel number $plant^{-1}$, weight of 1000 seeds and dry weight of plant were obtained with 12.5 plants m^{-2} and the highest plant height and seed yield were obtained with 25 plants m^{-2}.

Aishwath *et al.* (2012) studied the effect of PSB, azotobacter and their combination on growth characters and yield attributes of coriander. Results revealed that plant height at various stages and number of primary and secondary branches was higher with combine inoculation of PSB and azotobacter. However, DAS to germination and DAS to 50% and complete flowering and number of umbels $plant^{-1}$ were not influence with these inoculants. Numbers of umbellate $umbel^{-1}$, seed, straw and biological yields were highest with the combine use of bio-fertilizers, which was at par with individual inoculation. Per cent seed yield increased with the use of azotobacter, PSB and their combinations of both was 8.8, 11.6 and 18.5, respectively, as compared to control.

Lal *et al.* (2012) reported that cultivation of Acr-1 with the application of organic Module-1 comprising of soil application of vermicompost, *Trichoderma* and neem cake as well as seed treatment of *Azotobacter* , PSB and *Trichoderma* with the foliar spray of garlic extract and neem oil exhibited maximum values for all the yield attributing characters and quality parameters like days to 50 percent flowering, number of umbels per plant, number of umbellate per umbel, number of seed per umbellate, seed yield per hectare, test weight, chlorophyll content in leaves at 60 and 90 DAS, grain colour, aroma and essential oil and Net returns (Rs 105518.25) with, B:C ratio (3.92:1) over Acr-1 and RCr-41 grown under Module-2 and Module-3.

Patel *et al.* (2013) studied the application of different levels of nitrogen (20, 40, 60 and 80 kg N ha^{-1}) and sulphur (0, 10, 20 and 30 kg S ha^{-1}) Among the levels of sulphur @ 30 kg ha^{-1} recorded significantly higher seed yield (1184 kg ha^{-1}) and straw yield (1577 kg ha^{-1}). Sulphur application @ 30 kg ha^{-1} significant improvement in growth and yield parameters *viz.,* number of branches $plant^{-1}$, number of umbels $plant^{-1}$, test weight (g) and seed weight $plant^{-1}$ (g).

Hnamte *et al.* (2013) reported that combined inoculation of biofertilizers along with vermicompost and NPK (T6) showed superiority with respect to plant height both at 45 DAS (40.80cm) and at maturity (63.96 cm), number of primary (7.42) and secondary branches (13.07), stem girth (3.37cm), root length (14.39cm) followed by T3 treatment (Azospirillum + Vermicompost + NPK) where the plant height, number of primary and secondary branches, stem girth and root length were 63.09cm, 7.35, 12.22, 3.27cm and 14.05cm respectively. Treatment T6 also exhibited earliness for 50% flowering (61.66) and seed setting (79.49), days for fruit setting (96.79) and maturity (103.96). Seed yield was also obtained higher with T6 (13.34 tha-1) followed by T3 (13.06 tha-1), and was obtained lowest (6.19 tha-1) when plants were raised with cow dung manure.

Singh (2013) observed that the combination of bio-fertilizer *Azospirrilum* + inorganic Nitrogen + FYM gave better performance as compared to alone application of bio-fertilizer *Azospirrilum*, organic FYM, inorganic nitrogen and other combinations. The combination treatment as soil application of inorganic Nitrogen (100%)of RDF+ *Azospirrilum* @ 15 kg ha^{-1} + FYM @ 5 t ha^{-1} (T_1) gave the maximum plant height, number of branches $plant^{-1}$, number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$, number of grains $umbel^{-1}$ and yield $plot^{-1}$ or yield $hectare^{-1}$ and increased the yield 71.65 % over control followed by combination treatment (T_2) as soil application of inorganic Nitrogen (75%) of RDF + *Azospirrilum* @ 15kg ha^{-1} + FYM @ 5 t ha^{-1} Plant height, number of branches $plant^{-1}$, number of umbels plant^{-1}, number of umbellets umbel^{-1}, number of grains umbel^{-1} and yield plot^{-1} or per hectare and increase the yield 55.90% over control.

Lal *et al.* (2014) studied the growth and yield of coriander as influenced by varying levels of sulphur and zinc. Treatments comprising of three sulphur levels and three zinc levels. Reduction in days to germination initiation and enhanced days of flowering were observed due to higher dosage of sulphur. Plant height was not significantly influenced with varying sulphur levels except at 60 days after sowing. Higher number of primary and secondary branches plant^{-1}, number of umbellates umbel^{-1} and seed yield was obtained with soil application of 40 kg sulphur hectare^{-1}. Varying levels of foliar application of zinc did not significantly influence plant height except at 60 DAS. The highest number of primary branches plant^{-1}, number of umblets umbel^{-1} and seed yield were obtained with foliar application of 0.6% zinc. Basal application of sulphur @ 40 kg ha^{-1} along with foliar application of 0.6 percent zinc is better for realizing higher yield of coriander

Meena *et al.* (2014)showed that significantly higher plant height, dry matter accumulation plant^{-1}, chlorophyll content, number of branches plant^{-1}, number of umbels plant^{-1}, umbellets umbel^{-1}, seeds umbellet$^{-`1}$, seed, straw and biological yields were obtained with 500ppm thiourea spray as compared to water spray and brassinolide but remained at par with 1000 ppm triacontanol. Application of sulphur up to 40 kg ha^{-1} significantly increased all above mentioned growth, yield attributes and yield of coriander over control and 20 kg S ha^{-1}. In terms of net returns and B:C ratio, the treatment 500ppm thiourea and 40kg S ha^{-1} fetched significantly higher net returns and B:C ratio over rest of the treatment.

Yousuf *et al.* (2014) determined the requirement of N, P, K, and S of coriander (BARI Corinader-1) for achieving satisfactory seed yield of this crop. Different levels of nitrogen, phosphorus, potassium and sulphur were distributed in the plot. The experiment was tested in randomized complete block design with three replications. There was positive impact of application of those nutrients on the yield and yield contributing characters of coriander up to a moderate level of N-70 P-50 K-30 S-20 kg ha^{-1}. The highest seed yield was obtained with this moderate application of N, P, K, and S (70, 50, 30, and

20 kg/ha, respectively) and yield was declined with higher doses of these elements.

Darzi *et al*. (2015*)* studied on vermicompost in four level (0, 3, 6 and 9 ton ha^{-1}) and nitrogen fixing bacteria (Nitroxin), mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum* were applied on coriander. Results showed that the highest umbel number $plant^{-1}$, seed yield and essential oil content were obtained after applying 6 ton ha^{-1} vermicompost. Nitrogen fixing bacteria also showed significant effect on biomass yield and seed yield. The maximum biomass yield and seed yield were obtained by using the biofertilizer.

Hussein *et al.* (2015)studied the effect of Nitrogen or bio-fertilizers and reported significantly increased plant height, number of branches, herb fresh and dry weights. The highest values of branches number, fresh and dry weights were recorded by using 60 kg N/feddan. In the same time, the combined treatment between bio-fertilizer and 80 kg N/feddan gave the largest values of plant height. Using nitrogen or bio-fertilizers increased chlorophyll a, b and total carotenoids compared unfertilized plant. Using bio-fertilizer or nitrogen fertilizer up to 60 kg N/fed., in fertilizing dill plants increased total carbohydrate content. The results of the used 60 kg N/fed., alone or 40 kg N/fed., combined with bio-fertilizer were the best affected. Using bio-fertilizer or nitrogen fertilizer increased the percentage values of N compared to control ones.

Bastami and Majidian (2016) conducted an experiment as factorial based on a randomized complete blocks design with 18 treatments and three replications. The factors were mycorrhizal inoculation in two levels, phosphatic biofertilizer and manure in three levels. The highest concentration of P in seed, leaf total carotenoid Biomass yield, seed yield and harvest index was obtained in inoculation with Mycorrhiza, consumption of 70 kg ha^{-1} phosphate biofertilizer and 20 ton ha^{-1}manure and they accounted for 51,168, 80 and 27 percent more than chemical control. Positive and synergistic interactions were obtained between Mycorrhizal inoculation × phosphate biofertilizer on leaf total carotenoid, seed yield and harvest index.

Patidar *et al.* (2016)recorded the application of biofertilizers in combinations with different doses of chemical fertilizers. The treatment included various combinations of Azotobacter, Arbuscular Mycorrhizal Fungi (AMF), phospahte solublizing bacteria (PSB) in combination with 80 and 100% Recommended Dose of Fertilizer (RDF). The effects of these treatments were evaluated for various growth, yield and quality traits. Plant height, number of primary and secondary branches, number of umbel plant^{-1}, number of umbellet umbel^{-1}, number of seeds umbellet^{-1}, total seed yield per plot, chlorophyll 'a', 'b' and total chlorophyll were found maximum in treatment Azotobacter+AM+PSB+100% RDF which was at par with Azotobacter+AM+PSB+80% RDF while it was found minimum in treatment having only biofertilizer .

Meena *et al.* (2017) recorded that the different levels of zinc and sulphur significantly increased umbels plant^{-1}, umbellets umbel^{-1}, seeds umbel^{-1} and test weight, seed (1406 kg ha^{-1}), stover and biological yields, and net returns (39175 ha^{-1}) over control. The sulphur at 40 kg ha^{-1} register 20.8 and 7.5 % higher seed yield, 39.0 and 12.7% more net return over control.

Jhankar *et al.* (2017) reported that, thecombination of bio-fertilizer gave better performance as compared to alone bio-fertilizers, organic manure, inorganic fertilizers and other combinations in coriander. The results showed that a soil application of inorganic fertilizer**s** (100% of RDF) with bio-fertilizers (*Azotobacter* + *Azospirillum* + PSB) @ 2.5 kg ha^{-1} and FYM @ 5 t ha^{-1} which resulted the maximum plant height (26.93 cm), number of primary branches per plant (6.93), number of compound leaves per plant (38.74), yield (8.0 t ha^{-1}). Regarding economics of the experiment, the maximum net profit Rs. 10769 ha^{-1} and benefit: cost (2.09) were computed in the treatment having a soil application of inorganic fertilizer (100% of RDF**)** + Biofertilizers (*Azotobacter*+ *Azospirillum*+ PSB) @ 2.5 kg ha^{-1} + FYM @ 5 t ha^{-1}.

Monika *et al.* (2017) conducted an experiment in a factorial randomized block design with bio-fertilizers and micronutrients. The biofertilizer treatments were seed inoculation with Azospirillum, Phosphate Solubilising Bacteria (PSB), Azospirillum + Phosphate Solubilising Bacteria (PSB) and control (without any biofertilizer), while the micronutrient treatments comprised of foliar sprays of Zinc sulphate, Copper sulphate, Ferrous sulphate each at @ 0.5% and control (without any micronutrient). The sixteen treatment combinations were replicated thrice. Among the treatments, seed inoculation with Azospirillum + PSB+ foliar spray of zinc sulphate @ 0.5% recorded maximum plant height, number of primary branches, leaf area, fresh leaf yield plant^{-1}, leaf yield plot^{-1}, leaf yield hectare^{-1}, dry matter production, protein content, ascorbic acid content and moisture content.

Mishra *et al.* (2017)evaluatedrhizobacterial isolates for their ability to promote growth and yield of coriander under open field conditions. Highest seedling vigour index was recorded for *B. aerophilus Cor-15* followed by *B. megaterium* and minimum was observed with control. The maximum total chlorophyll content was assayed with *B. subtilis NRCSS-I.* The highest Pox activity was recorded with *B. megaterium ISB28* in coriander shoot tissues followed by *B. aerophilus cor-15.* At harvest stage, maximum plant height was recorded with *B. aerophilus cor-15* which was at par with *B. megaterium.* Coriander seed yield ranged from 1128.80 to 1650.94 kg ha^{-1} and the maximum seed yield of 1650.94 kg ha^{-1} was recorded with *B. aerophilus Cor-15* being at par with *B. subtilis* strains and the minimum in control.

Kucha *et al.* (2019)reported that theapplication of 120 kg nitrogen ha^{-1} was observed superior over rest of the levels of N in increasing plant height, number of branches plant^{-1}, number of umbels plant^{-1}, number of umbellate umbel^{-1}, number of seeds umbellate^{-1}, weight of 1000 seed, protein content, seed yield and stover yield. Application of 40 kg sulphur ha^{-1} significantly increased plant height, number of branches plant^{-1}, number of umbels plant^{-1}, number of umbellates umbel^{-1}, number of seeds umbellate^{-1}, weight of 1000 seed, seed yield and stover yield.

Elsayed *et al.* (2020) demonstrated that dill cv. Dukat gave the highest plants, maximum leaf number plant^{-1}, pigment content, total carbohydrates, nitrogen, and phosphorus percentages in the vegetative growth stage. Meanwhile, dill cv. Balady recorded the maximum potassium percentage and low content of nitrate accumulation in the vegetative growth stage. Both dill cultivars contained antioxidants without significant differences between them.

The best fertilization treatments were 100% organic fertilization with biofertilizer and 100% chemical fertilizer for plant height, leaf number plant^{-1}, pigment content, antioxidant percentage, total carbohydrate percentage, and N and P percentages of two dill genotypes. On the other hand, 50% organic fertilization with biofertilizers was recorded as the best treatment for nitrate accumulation and K percentage with two dill cultivars.

Ibrahim *et al.* (2020)showed that, the increase in the nitrogen level added was accompanied by a significant increase in plant growth and yield of seeds and oil. The treatment of the 100 % nitrogen of the recommended dose gave the highest seed yield and volatile oil. Biofertilizers increased the growth measurements and the yield of seeds (2.1kg ha^{-1}) and oil (35.2 l ha^{-1}). Also the short irrigation interval produced the maximum growth characteristics and the yield of seeds (1.36 kg ha^{-1}) and volatile oil (8.32l ha^{-1}) comparing to the long irrigation interval.

Adib *et al.* (2020) showed that total phenol content and flavonoids were enhanced with the increase of drought intensity and the maximum amount was recorded under I3, while I3 caused a substantial reduction in grain yield. Flavonoid and grain yield significantly increased in F4. Total phenol content was the highest in F2 and F3 treatments. Application of sulfur fertilizer resulted in a significant increase in peroxidase, phenol and flavonoids. The highest amount of peroxidase was obtained in I3F4 and I3F3. The present study suggests that foliar application of Fe and Zn and sulfur fertilizer can improve the injurious effects of water deficiency on cumin plant through alteration in yield and biochemical characteristics.

Bepari *et al.* (2020) laid out experiment in factorial RBD with three replications including four levels of sulphur and four levels of zinc. Results showed that sulphur application at 45 kg ha^{-1} and 6 kg Zn ha^{-1} recorded significantly increased Umbels plant^{-1}, biology yield, seed yield, gross return, net returns and B:C ratio over control and treatment T5. It was concluded that independent application of 45kg sulphur as soil application during sowing and soil application of zinc at 6kg ha^{-1} is recommended as these treatments fetched significantly higher economic net return and higher yield from coriander.

Chapter- III

MATERIALS AND METHODS

A field experiment was conducted on **"Effect of Sulphur and Bio-Fertilizers on Growth and Yield of Coriander (*Coriandrum sativum* L.)"**at the Horticulture Research Farm, department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, Mandsaurunder Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) from November 2020 to March 2021. The details of the materials used and methods followed during the course of investigation are presented in this chapter.

3.1 Experimental site:

The field experiment was carried out at the Horticulture Research Farm, under department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture Mandsaur, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) during 2020-21. The College of Horticulture, Mandsaur is situated in Malwa plateau in Western part of Madhya Pradesh at 23.45° to 24.13° North latitude, 74.44° to 75.18° East longitudes and at an altitude of 435.02 meters above mean sea level. This region falls under agro climatic zone no.10 of the state.

3.2 Climatic conditions of the experimental site:

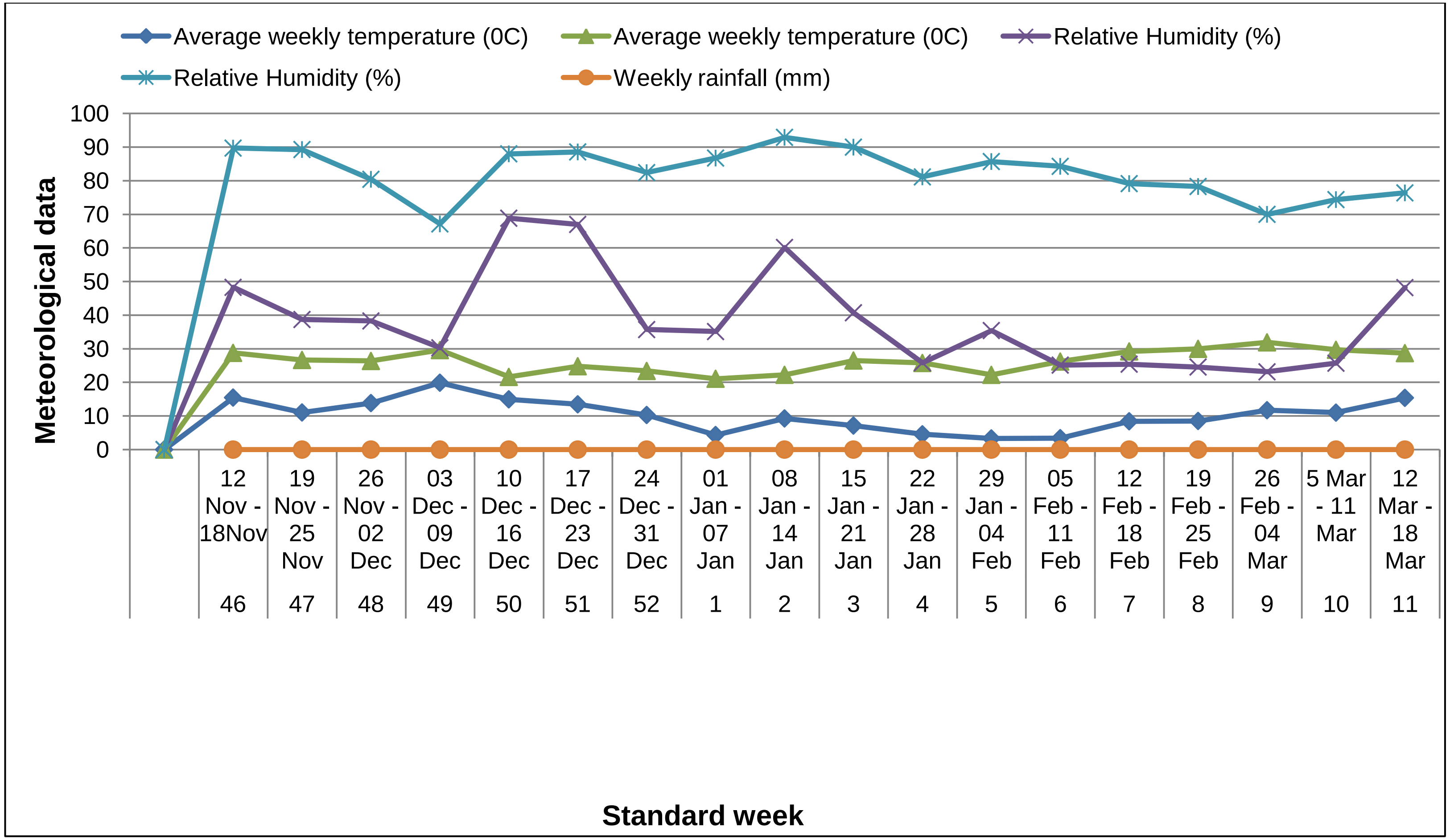
Mandsaur belongs to sub-tropical and semi-arid climatic conditions having a mean maximum temperature of 44°C and mean minimum temperature of 5° C in summer and winter respectively. It receives an annual average rainfall of 544.05 mm during mid-June to September. South-West monsoon is responsible for major part of annual precipitation. Meteorological data recorded during the period of investigation are presented in (Table 1) and are graphically shown in (Fig. 1)

Table 1: Meteorological variables during the period of investigation (12 November 2020 to 21February 2021)

Source: Meteorological observatory of the College of Horticulture, Mandsaur (M.P.)

Standard Metrological Week	Duration	Average weekly temperature (^{0}C) Min.	Average weekly temperature (^{0}C) Max.	Relative Humidity (%) Min.	Relative Humidity (%) Max.	Weekly rainfall (mm)
46	12 Nov - 18Nov	15.48	28.78	48.28	89.71	0
47	19 Nov - 25 Nov	11.05	26.67	38.71	89.28	0
48	26 Nov - 02 Dec	13.84	26.37	38.28	80.42	0
49	03 Dec - 09 Dec	19.9	29.60	30.28	67.14	0
50	10 Dec - 16 Dec	14.95	21.62	68.85	88.00	0
51	17 Dec - 23 Dec	13.47	24.80	67.00	88.57	0
52	24 Dec - 31 Dec	10.30	23.40	35.71	82.42	0
1	01 Jan - 07 Jan	4.33	21.08	35.12	86.75	0
2	08 Jan - 14 Jan	9.27	22.25	60.14	92.91	0
3	15 Jan - 21 Jan	7.15	26.51	40.71	90.00	0
4	22 Jan - 28 Jan	4.55	25.77	25.85	81.14	0
5	29 Jan - 04 Feb	3.32	22.24	35.42	85.71	0
6	05 Feb - 11 Feb	3.40	26.20	25.14	84.28	0
7	12 Feb - 18 Feb	8.42	29.21	25.42	79.14	0
8	19 Feb - 25 Feb	8.52	29.98	24.57	78.28	0
9	26 Feb - 04 Mar	11.72	31.91	23.14	70.00	0
10	5 Mar - 11 Mar	11.00	29.70	25.70	74.38	0
11	12 Mar - 18 Mar	15.4	28.70	48.20	76.38	0

Fig. 1: Weekly meteorological data recorded during the period of experiment (Nov. 2020 – March 2021)



3.3 Soil characteristics of the experimental site:

To ascertain physico-chemical characteristics of the soil during the year of study, soil samples from 0-15 cm depth were taken from different spots of the experimental field before application of fertilizer. A representative composite sample was prepared by processing and mixing them together and analysis presented, showed that the soil of experimental site is light black loamy texture, with low in availability of nitrogen, low in phosphorus and high in potassium status.

Table 3.2: Physical and chemical composition of the soil sample of experimental site

Particular	Value obtain	Method
Physical characters		
Sand%	35%	By international Pipette method (Piper,1950)
Silt%	42%	
Clay%	28%	
Chemical characters		
Soil pH	8.08	Method No. 4 USDA Handbook No.60 (Richards, 1954)
Electrical conductivity(ds/m)	0.23	EC Meter
Availabile nitrogen(kg/ha)	192	Alkaline KMnO4 (Subbiah&Asija, 1956)
Available phosphorus(kg/ha)	7.9	Olsen extraction method (Olsen*et. al.,*1954)
Available potash (Kg/ha)	141	Flame photometer method Metson, 1956)

3.4 Experimental details:

3.4.1 Design and layout of experiment:

The experiment was laid out in open field with simple randomized block design. There were three replications in the experiment. The plan of layout of the experiment is given in Fig. 2.

The details are as follows:

1. Location	: Horticulture Research Farm, College of Horticulture,Mandsaur (M.P.)
2. Crop	: Coriander (*Coriandrum sativum* L.)
3. Season	: *Rabi,* 2020-21
4. Variety	: Acr -1
5. Spacing	: 20 x 10 cm
6. Design	: Randomized Block Design
7. Number of treatments	: 10
8. Number of replications	: 03
9. Total Number of plots	: 30
10. Plot area	: 2 m × 1.5 m = 3 m^2
11. Total Experimental area	: 8 m × 19.5 m = 156 m^2

Treatment combinations:

T_1 Control

T_2S (30 kg ha^{-1})

T_3S (30 kg ha^{-1})+ PSB (5 kg ha^{-1})

T_4S (30 kg ha^{-1})+ *Azotobacter* (2.5 kg ha^{-1})

T_5 S (30 kg ha^{-1})+ *Azospirillum* (10 kg ha^{-1})

T_6 S (30 kg ha^{-1})+ *Azospirillum* (15 kg ha^{-1})

T_7 S (30 kg ha^{-1})+ PSB (5 kg ha^{-1})+ *Azotobacter* 2.5 kg ha^{-1})

T_8 S (30 kg ha^{-1})+ PSB (5 kg ha^{-1})+ *Azospirillum* (10 kg ha^{-1})

T_9 S (30 kg ha^{-1})+ PSB (5 kg ha^{-1})+ *Azospirillum* (15 kg ha^{-1})

T_{10}S (30kg ha^{-1})+ PSB 3 kg ha^{-1}) +*Azotobacter*(2.5 kg ha^{-1})+*Azospirillum* (15kg ha^{1})

Fig. 2: Layout of field experiment:

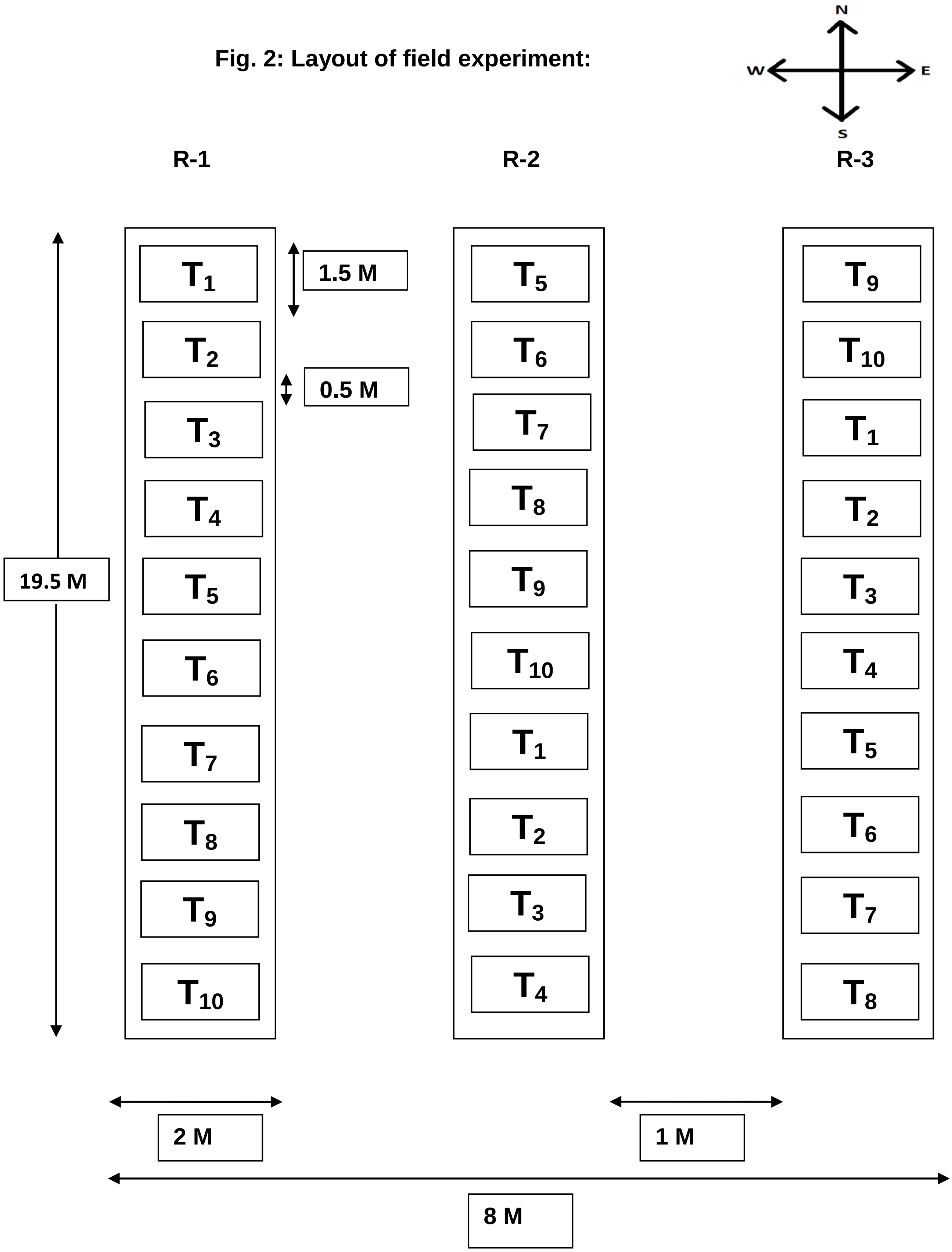


Fig 2.Panoramic view of experimental field coriander.

3.5 Cultural practices:

3.5.1 Planting material:

Seed of coriander *var.* Acr-1 was collected from NRC- Ajmer, Rajasthan, medium seed size is major morphologic character of *var.* Acr-1.

3.5.2 Preparation of the experimental plot:

The experimental plot was ploughed twice by tractor drawn cultivator and leveled. The clods were crushed & weeds removed and field brought to fine tilth. The land was divided into (2.0 m x 1.5 m) plots and provision made for bunds and irrigation channels.

3.5.3 Manures and fertilizers:

Bio-fertilizers were applied to soil before seed sowing and well in soil as per treatment details and schedule. Sulphur to applied before sowing with a constant close @ 30kg ha^{-1}.

3.5.4 Sowing of seeds:

The seeds were treated with carbendazim @ 2g/kg seeds. The pure, healthy, disease and insect free, vigorous and good quality seed was used for sowing. The seeds were sown at a depth of 1.5 cm in row 10 kg/ha.

3.5.5 Thinning of seedlings:

Thinning was done manually at 20 days after sowing to maintain 10 cm plant-to-plant spacing and obtain healthy & vigorous seedling.

3.6 After care:

3.6.1 Weeding and hoeing:

After sowing, weeding and hoeing were done to control seasonal weeds. The plots were kept free from weeds by hand weeding at 25, 40 and 60 days after sowing. Hoeing was done to loosen the soil and encourage the growth of coriander plants.

3.6.2 Irrigation:

For the establishment of the crop, first light irrigation was given just after sowing and thereafter as per requirement i.e. 25, 40, 60 and 75 days after sowing. Irrigations were given manually by check basin method through a slow stream of irrigation water.

3.6.3 Plant protection:

Imidachloprid @ 5.5 to 6.5 ml per 15 liter of water was sprayed to control aphid infestation.

3.6.4 Harvesting:

The plants took about 110-120 days from the date of sowing to harvesting. Harvesting of seeds was done when the lower leaves started shedding and pods became yellowish. Plants were uprooted and tied in bundles and allowed to dry for 4 - 6 days.

3.6.5 Threshing and winnowing:

After sun drying, the threshing of the individual plot was done with the help of wooden sticks and winnowed traditionally to separate seed and straw. Seed were weighed and plot wise samples taken. Seed and straw were separated for further analysis.

3.7 Observation Recoded during course of investigation:

3.7.1 Phenological parameters:

1. Days to 50% germination
2. Days to 50% flowering
3. Days to maturity

3.7.2 Morphological parameters: (at 30, 60, 90 DAS and at harvest)

1. Plant height (cm)
2. Number of branches (plant^{-1})
3. Fresh weight (g plant^{-1})
4. Dry weight (g plant^{-1})

3.7.3 Growth parameters: (at 30, 60, 90 DAS and at harvest)

1. Leaf Area (cm^2 plant^{-1})
2. Leaf Area Index
3. Leaf Area Duration (cm^2 days^{-1})
4. Relative Growth Rate (g g^{-1}days^{-1})
5. Crop Growth Rate (g cm^2 of ground area days^{-1})

3.7.4 Yield parameters:

1. Number of umbels (plant^{-1})
2. Number of umbellate (umbel^{-1})
3. Number of seeds (umbel^{-1})
4. Seed yield (g plant^{-1})
5. Seed yield (kg plot^{-1})
6. Seed yield (q ha^{-1})
7. Biological yield (q ha^{-1})
8. Harvest index (%)
9. Dry matter content in seed (%)

3.7.1 Growth attributes of coriander:

3.7.1.1 Plant height (cm)

Five plants were randomly selected from each plot for measuring plant height at 30, 60, 90 DAS and at harvest. The plant height was measured from the ground level to the tip of the last leaf/flower. The average was worked out and expressed in centimeter (cm).

3.7.1.2 Numbers of Leaves (plant^{-1})

In each plot, the number of leaves of five randomly plant was counted separately at 30, 60, 90 DAS and at harvest.

3.7.1.3 Number of branches (plant^{-1})

The branches from five randomly selected plants from each plot were counted at 30, 60, 90 DAS and at harvest. The average was computed and expressed as number of branches / plant.

3.7.1.4 Fresh weight (g plant^{-1})

A representative sample (5 plants) were collected from the border rows of each plot at 30, 60, 90 DAS and at harvest to record fresh weight and later on their mean was calculated and was expressed in grams.

3.7.1.5 Dry weight (g plant^{-1})

After taking fresh weight, the plants were kept in hot air oven at 60 ^{0}C temperature for about 3 hours for 2 days till plant become fully dried. Final weight was noted and average was worked out at each stage. Mean values were expressed in grams.

3.7.2. Growth parameters: (at 30, 60, 90 DAS and at harvest)

3.7.2.1 Leaf area (cm^2 $plant^{-1}$)

The leaves were detached from the plant and then detached leaf were subjected for area analyzed using leaf area meter (Li-COR model LI 3000) and expressed as cm^2 $plant^{-1}$ at 60, 90, 120, 150 DAS and at harvest.

3.7.2.2 Leaf area index

Leaf area index expresses the ratio of the total leaf area of the plant to the ground area occupied by the crop. Both were measured in square meter.

$$LAI = \frac{(LA_2 + LA_1)}{2\,P}$$

Where, the LA_1 and LA_2 represent the leaf area during of two successive intervals and 'P' unit ground area (Watson, 1974).

3.7.2Leaf area duration (cm^2 $days^{-1}$)

Leaf area duration states that ability of the plant to maintain the green leaves per unit area of the land over a period of time.

$$LAD = \frac{(L_2 + L_1)}{2} \times (t_2 - t_1)\ (cm^2\ day^{-1})$$

Where, L_1 an\d L_2 denote the leaf area index at first stage and leaf area at second stage, $(t_2 - t_1)$ time intervals in days (Watson, 1952).

3.7.2.4 Relative growth rate (mg g^{-1} day^{-1})

RGR is the rate of increase in dry weight per unit of dry weight present per unit time.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}\ (mg\ g^{-1}\ day^{-1})$$

Where, $\log_e W_1$ and $\log_e W_2$ are whole plant dry weight at t is time intervals.

3.7.2.3 Crop growth rate ($mgcm^{-2}\ day^{-1}$)

Crop growth rate indicates the dry matter production. It is used to estimate the production efficiency of a crop (Watson, 1952). It is influenced by leaf area index (LAI), leaf photosynthetic rate and leaf angle.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P} \text{ (mg cm}^{-2}\text{ of ground area day}^{-1}\text{)}$$

W_2 and W_1 are total plant dry weight at t_2 and t_1 time and P is land area.

3.7.3 Yield attributes and yield:

3.7.3.1 Number of racemes (plant-1)

The racemes of five randomly selected plants from each plot at the time of harvesting were counted and average number of racemes/plant was recorded.

3.7.3.2 Racemes length (cm)

The racemes of five randomly selected plants from each plot at the time of harvesting were measuring and average length of racemes/plant was recorded.

3.7.3.3 Weight of 1000 seed (g)

Coriander seed samples were drawn from the winnowed and cleaned produce

of each plot after weighing the net plot yield. From this, 1000 seeds were counted and

its weight (mg) was recorded on digital balance.

3.7.3.4 Seed yield (g $plant^{-1}$)

After threshing and winnowing, the seed yield from five randomly selected plants from each plot was recorded and expressed as seed yield per plant (g).

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

The crop was harvested and seeds of each plot were weighted and expressed as fresh yield per plot in kilograms.

3.7.3.6 Seed yield (q ha-1)

After threshing and winnowing clean grains obtained from individual plot were weighed and the weight was recorded in g/plot. This was then converted in q ha-1 by using the formula given below.

$$\text{Seed yield (q/ha)} = \frac{\text{Seed yield (g)/plot size (sq. m)} \times 10000}{\text{Size of plot (sq. m)} \times 1000 \times 100}$$

3.7.3.7 Biological yield (q ha-1)

The harvested and sun dried crop of each plot was weighed and the weight was recorded in g/plot and then converted into q/ha by using the formula given below.

$$\text{Biological yield (q/ha)} = \frac{\text{Biological yield (g) / plot (sq. m)} \times 10000}{\text{Size of plot (sq. m)} \times 1000 \times 100}$$

3.7.3.8 Harvest index (%)

The ratio of economic yield (seed yield) to the biological yield was worked out and expressed in percentage (Donald and Hamblin, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Seed yield (kg ha-1)} \times 100}{\text{Biological yield (kg ha-1)}}$$

3.7.4 Analysis of variance

The data obtained on various observations for each treatment were subject to “Analysis of variances” as recommended by Panse and Sukhatme (1984). The skeleton of ANOVA as per design is as follows:

Table 3. Template for Analysis of variances (ANOVA)

Source of variation	D.F.	S.S.	M.S.S.	"F" value calculated	"F" table value at 5%
Replications	(r-1)	SSR	MSR	MSR/ EMS	
Treatments	(t-1)	SST	MST	MST/ EMS	
Error	(r-1) (t-1)	SSE	MSE		
Total	(rt-1)	TSS			

The critical difference (C.D.) was calculated to assess the significance of difference between treatments, whenever the results were found significant through 'F' test, CD at 5 % level of significance was determined. S.Em. (±) and CD are calculated using the following formula.

Where,

r = number of replications

t = number of treatments

SSR = sum of squares due to replication

SST = sum of squares due to treatment

SSE = sum of squares due to error

TSS = total sum of squares

MSR = mean sum of squares due to replication

MST = mean sum of squares due to treatment

MSE = mean sum of squares due to error

$\sigma^2 e$ =MSE (mean sum of squares due to error)

SE.m.(±): Standard Error of difference between two treatments means calculated by using formula:

$$S.E. (d) = \sqrt{\frac{2MSE}{r}}$$

Where,

S.E. (d) = Standard error of difference between two treatments means.

MSE = mean sum of squares due to error.

r = number of replications.

Critical difference:

CD = S.E. (d) × t Value at \5% at error degree of freedom.

Chapter - IV

EXPERIMENTAL RESULTS

The results of the field experiment entitled **"Effect of Sulphur and Bio-fertilizers on Growth and Yield of Coriander (*Coriandrum sativum* L.)"** was conducted at department of Plantation, Spices, Medicinal and Aromatic crops, Research Farm College of Horticulture, underRajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya ,Mandsaur, (M.P.) during the *Rabi* season 2020-21, are being presented and described in this chapter. The experiment was conducted in simple Randomized Block Design in triplicate. In the present study nine constant dose of sulphur and different doses of bio-fertilizers were taken as treatments along with one untreated control plot. All the data were statistically analyzed and their variance has been furnished in appendices. Interpretation of data has been made on the mean basis. The results are presented under the following section.

4.1 Phenological parameter

The phenology of plants significantly varied with the application of sulphur and different doses of bio-fertilizer except for days to 50% germination and data are presented in Table 4.1 and diagrammatically illustrated in Fig. 4.1.

4.1.1 Days to 50% germination

The present study showed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had early germination (6.33) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(7) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (7). The late germination (8.67) was seen in T_1-control.

4.1.2 Days to 50% flowering

The experiment data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed early days to 50% flowering(66.33), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(66.67),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (67.00), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(67.67), T_5-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(68.33),T_6-S @ 30kg+ *Azosp* @ 10kg ha^{-1} (70.33) and T_4- S @

30kg + *Azoto* @ 2.5 kg ha^{-1} (69) but significantly early with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp*@ 15 kg ha^{-1} (66.67) lagged behind the former which was found significantly differed with T_2- S @ 30kg ha^{-1} (72.00) and T_1 - control (74.33) but at par over rest of the treatments. The late days to 50% flowering (74.33) was recorded in T_1-control.

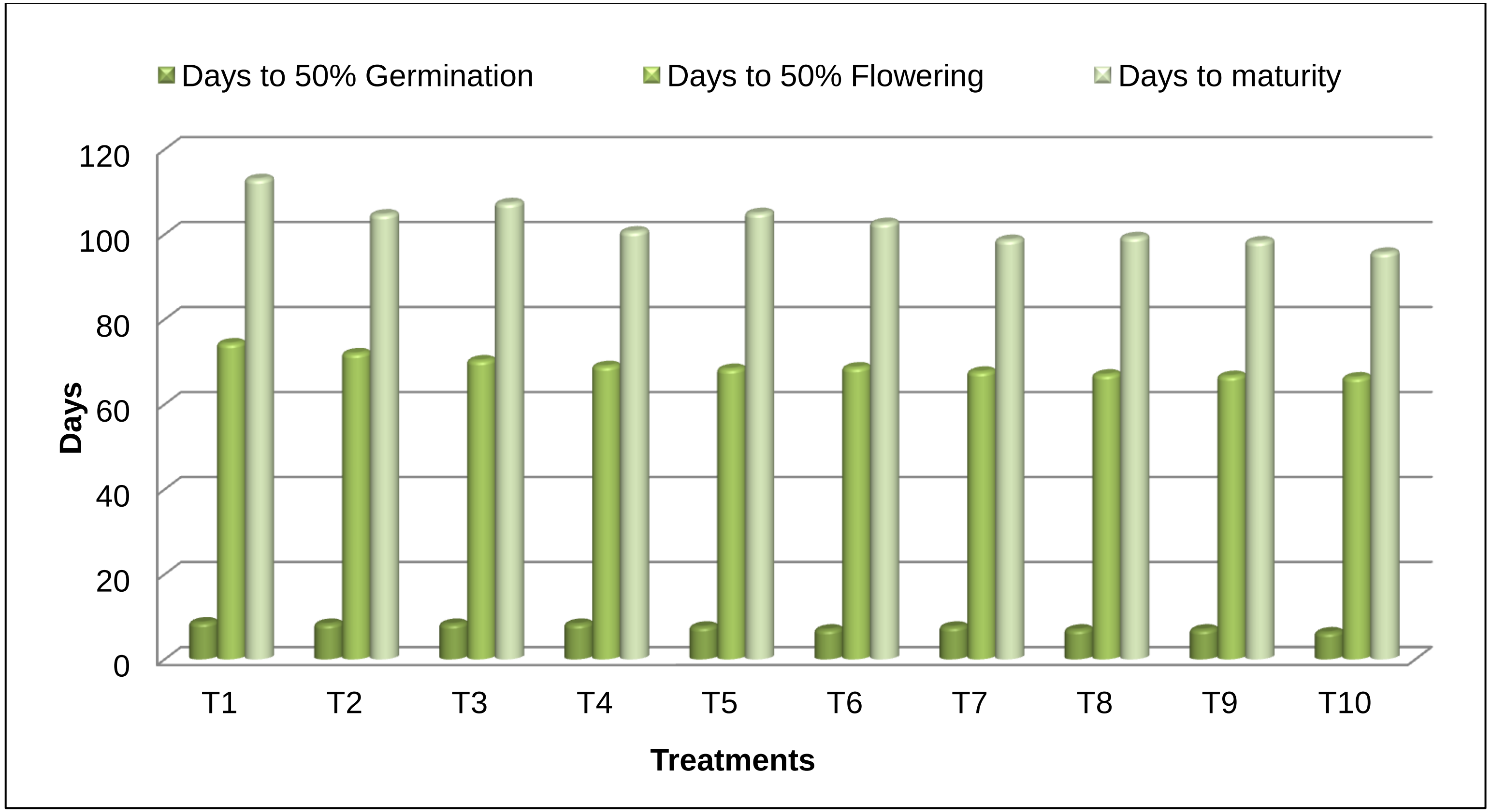
4.1.3 Days to maturity

The analysis of variance revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} was found early maturity(95.67) which was at par with T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(98.33),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (98.67), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(99.33) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(100.67)but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(98.33) lagged behind the former which significantly early over all the treatments except T_2- S (30kg ha^{-1}) (107.33) and T_1-control (113.00). The late early days to maturity(113.00) was recorded in T_1-control.

Table 4.1 Effect of sulphur and bio-fertilizers on phonological parameter of coriander.

Treatments	Days to 50% germination	Days to 50% flowering	Days to maturity
T_1-Control	8.67	74.33	113.00
T_2 -S @30kg ha-^{1}	8.33	72.00	104.67
T_3-S @30kg + PSB @5kg ha-^{1}	8.33	70.33	107.33
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	8.33	69.00	100.67
T_5-S @30kg + Azosp @10kg ha-^{1}	7.67	68.33	105.00
T_6-S @30kg + Azosp @15 kg ha-^{1}	7.00	68.67	102.67
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	7.67	67.67	98.67
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	7.00	67.00	99.33
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	7.00	66.67	98.33
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	6.33	66.33	95.67
S.Em.(±)	**0.58**	**1.32**	**2.31**
C.D. @ 5 %	**NS**	**3.92**	**6.86**

Fig 4.1 Effect of sulphur and bio-fertilizers onphenology parameter of coriander.



4.2 Morphological parameters

4.2.1 Plant height (cm plant^{-1})

Significant differences were exhibited with the application ofsulphur and combination of bio-fertilizers for plant height during the different intervals of plant growth and data are presented in Table 4.2 and diagrammatically illustrated in Fig. 4.2.

At 30 DAS

Result revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} recorded maximum plant height (9.87) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(9.73) which were at parwith treatment T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (9.37), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (9.07) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (8.87) but they were significantly higher over rest of the treatments. The minimum plant height (7.93) was registered in T_1-control.

At 60 DAS

The experiment data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} displayed maximum plant height (49.6)which was at parwithT_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (48.93),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (47.87), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (47.33), T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (46.23) and T_5-S @ 30kg ha^{-1}+ *Azosp* @ 10kg ha^{-1}(45.2) significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(48.93) lagged behind the former which was found significantly differed with T_3- S @ 30kg + PSB @ 5kg ha^{-1} (43.13),T_2- S @ 30kg ha^{-1}(42.73) and T_1 - control (41.93) but at par over rest of the treatments. The minimum plant height (41.93) was recorded in T_1-control.

At 90 DAS

On perusal of the data, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} displayed maximum plant height (106.67), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(104.2), T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (102.53) and T_7- S @ 30kg

+ PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (99.77)but significantly higher with the remaining treatments. Though, T_9-S @ 30kg +PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(104.2) lagged behind the former which was found significantly differed with T_3- S @ 30kg + PSB @ 5kg ha^{-1} (96.47),T_2- S @ 30kg ha^{-1} (95.6) and T_1 - control (94.03) but at par over rest of the treatments. The minimum plant height (94.03) was recorded in T_1-control.

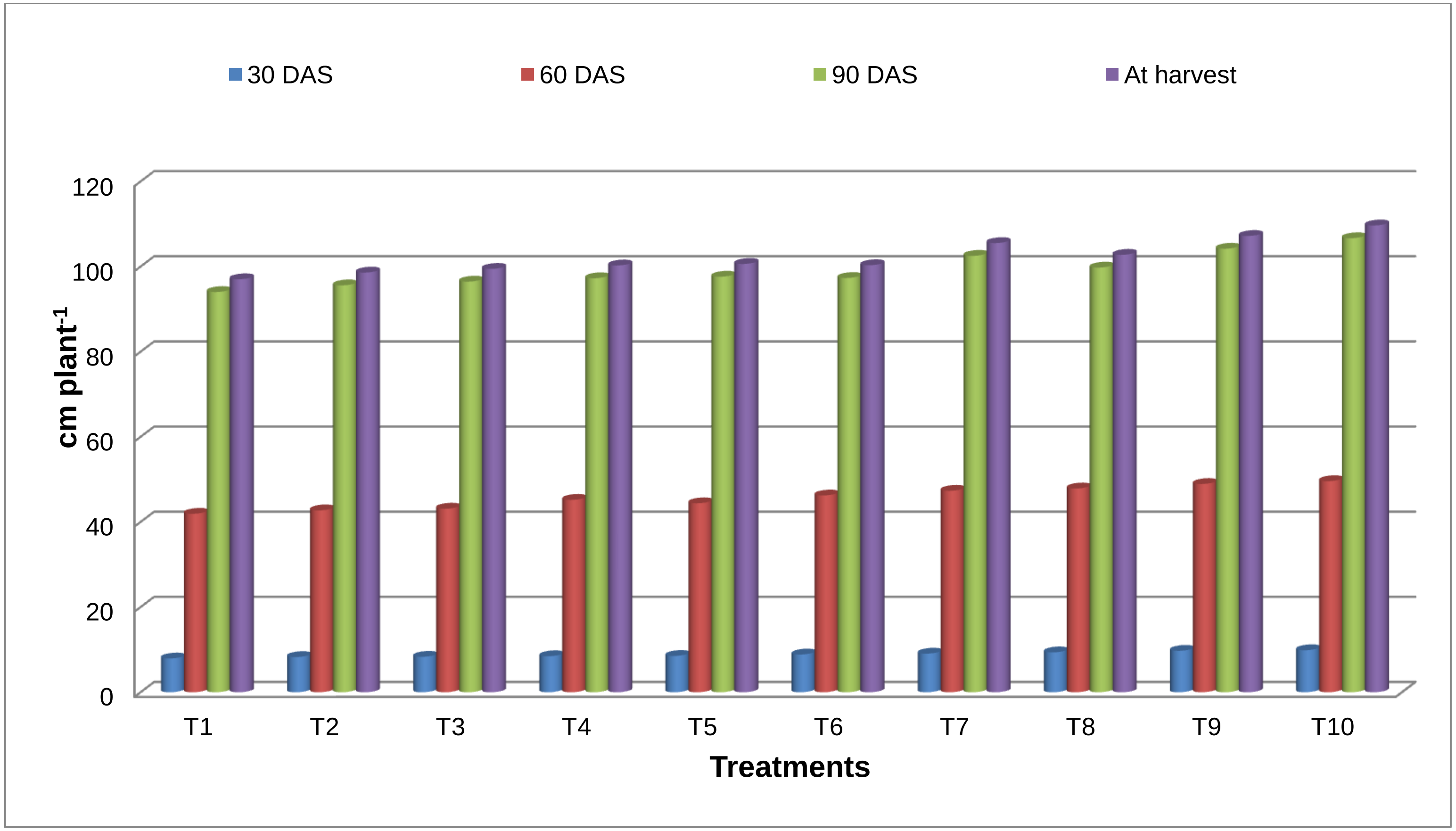
At harvest

The statistical analysis of data shown that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was found maximum plant height (109.67), which was at parwith T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (107.2),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (105.53) and T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (102.77)but significantly higher with the remaining treatments. Though, T_9-S(30kg ha^{-1})+PSB (5kg ha^{-1})+ *Azospirillum* (15 kg ha^{-1})*(*107.2) lagged behind the former which was found significantly differed with T_3- S @ 30kg + PSB @ 5kg ha^{-1} (99.47), T_2- S @ 30kg ha^{-1} (98.6) and T_1- control (97.03) but at par over rest of the treatments. The minimum plant height (97.03) was perceived in T_1-control.

Table 4.2 Effect of sulphur and bio-fertilizers on plant height of coriander.

Treatments	Plant height (cm plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1-Control	7.93	41.93	94.03	97.03
T_2 -S @30kg ha-^{1}	8.27	42.73	95.60	98.60
T_3-S @30kg + PSB @5kg ha-^{1}	8.33	43.13	96.47	99.47
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	8.47	45.20	97.27	100.27
T_5-S @30kg + Azosp @10kg ha-^{1}	8.53	44.40	97.63	100.63
T_6-S @30kg + Azosp @15 kg ha-^{1}	8.87	46.23	97.33	100.33
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	9.07	47.33	102.53	105.53
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	9.37	47.87	99.77	102.77
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	9.73	48.93	104.20	107.20
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	9.87	49.6	106.67	109.67
S.Em.(±)	**7.93**	**41.93**	**94.03**	**97.03**
C.D. @ 5 %	**8.27**	**42.73**	**95.60**	**98.60**

Fig 4.2 Effect of sulphur and bio-fertilizers on plant height of coriander.



4.2.2 Number of branches (plant^{-1})

The number of branches per plant at harvest of coriander was significantly influenced by of sulphur and different doses of bio-fertilizers at various growth stages. The data are presented in Table no. 4.3 and graphically illustrated in Fig. 4.3.

At 30 DAS

Result showed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had attained maximum number of branches (2.27) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(2.13) which were at parwith treatment T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (1.80), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (1.67), and T_5-S @ 30kg + *Azosp* @ 10 kg ha^{-1}(1.60) but they were significantly higher over rest of the treatments. The minimum number of branches (0.87) was registered in T_1-control.

At 60 DAS

The statistical analysis of data manifested that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} accumulated more number of branches (5.27) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(5.13) which were at parwith treatment T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (4.80), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (4.67) and T_5-S @ 30kg + *Azosp* @ 10 kg ha^{-1} (4.60) but they were significantly higher over rest of the treatments. The minimum number of branches (3.87) was observed in T_1-control.

At 90 DAS

The analysis of variances expressed that,T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}resulted in maximum number of branches(8.73) which was at par with T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(8.40),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (8.00), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(7.87) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(7.60)but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(8.40) lagged behind the former which was at par over all the treatments except T_1-control

(6.60). The minimum number of branches(6.60) was recorded in the treatment T_1 - control.

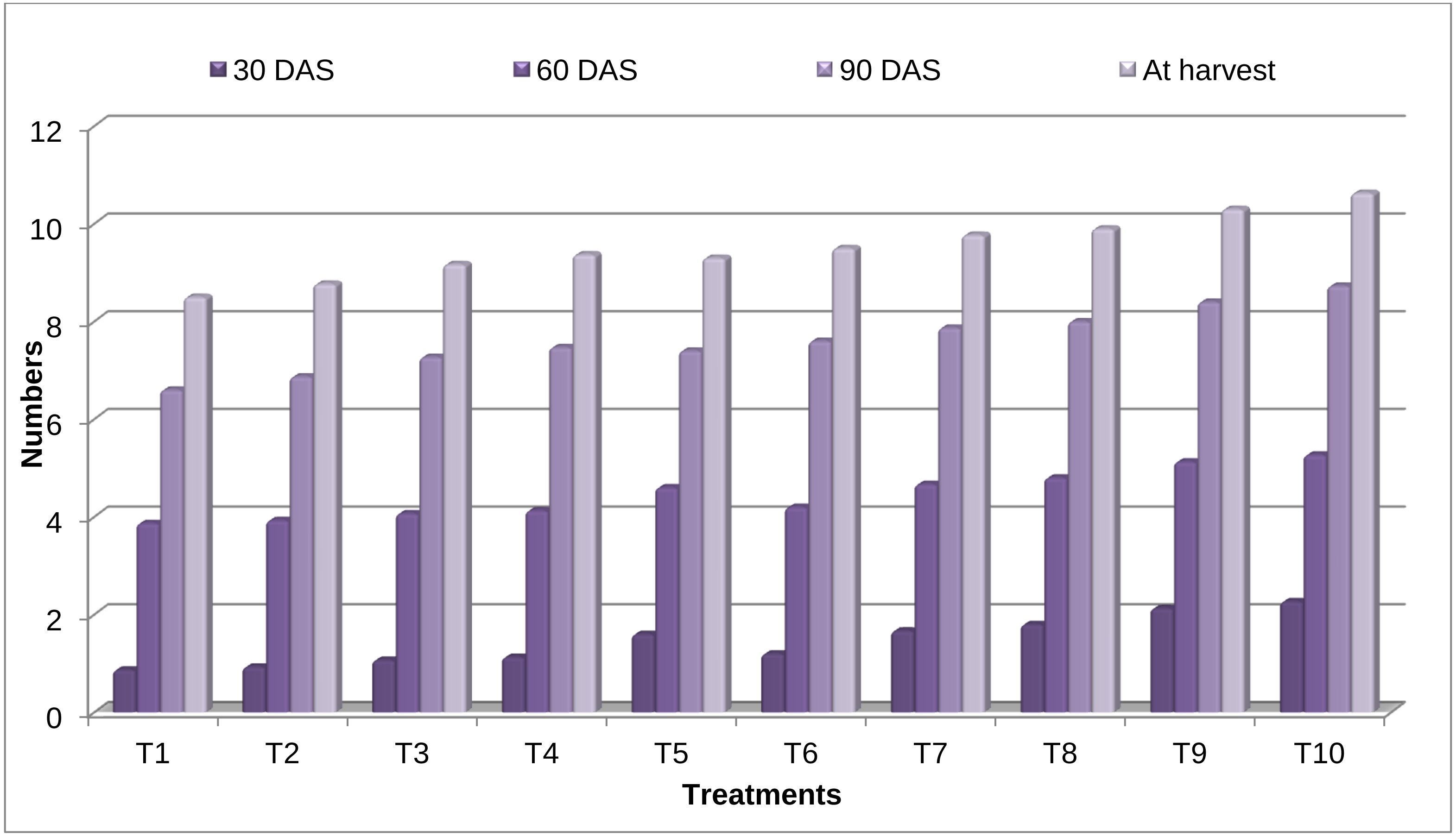
At harvest

The results presented that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was seen maximum number of branches(10.63) which was at par with T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(10.30), T_8-S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (4.80), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (4.67) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (4.60) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(10.30)were next highest which was at par over all the treatments except T_1-control (8.50). The minimum number of branches (8.50) was noted in T_1-control.

Table 4.3 Effect of sulphur and bio-fertilizers on number of branches of coriander.

Treatments	Number of branches (plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1-Control	0.87	3.87	6.60	8.50
T_2 -S @30kg ha-^{1}	0.93	3.93	6.87	8.77
T_3-S @30kg + PSB @5kg ha-^{1}	1.07	4.07	7.27	9.17
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	1.13	4.13	7.47	9.37
T_5-S @30kg + Azosp @10kg ha-^{1}	1.60	4.60	7.40	9.30
T_6-S @30kg + Azosp @15 kg ha-^{1}	1.20	4.20	7.60	9.50
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	1.67	4.67	7.87	9.77
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	1.80	4.80	8.00	9.90
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	2.13	5.13	8.40	10.30
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	2.27	5.27	8.73	10.63
S.Em.(±)	**7.93**	**41.93**	**94.03**	**97.03**
C.D. @ 5 %	**8.27**	**42.73**	**95.60**	**98.60**

Fig 4.3 Effect of sulphur and bio-fertilizers on number of branches of coriander.



4.2.3 Fresh weight (g $plant^{-1}$)

The sulphur and different doses bio-fertilizers were significantly influenced by the fresh weight during the different intervals of plant growth except 60 DAS. Data pertaining to fresh weight are depicted in Table 4.4 and graphically illustrated in Fig. 4.4.

At 30 DAS

The result revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was observed to have highest fresh weight (5.67) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (5.13) which were at parwith each other andT_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (5.07) but they were significantly higher over rest of the treatments. The lowest fresh weight (3.20) was registered in T_1-control.

At 60 DAS

The treatments were found to have no significant effect at 60DAS. The present study showed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} recorded maximum fresh weight (69.67) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(67.60) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (65.67). The minimum fresh weight (58.33) was perceived in T_1-control.

At 90 DAS

The analysis of variance revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} registered maximum fresh weight (92.33) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(90.67) which were at parwith each other andT_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(88.93) but they were significantly higher over rest of the treatments. The minimum fresh weight (79.33) was noted in T_1-control.

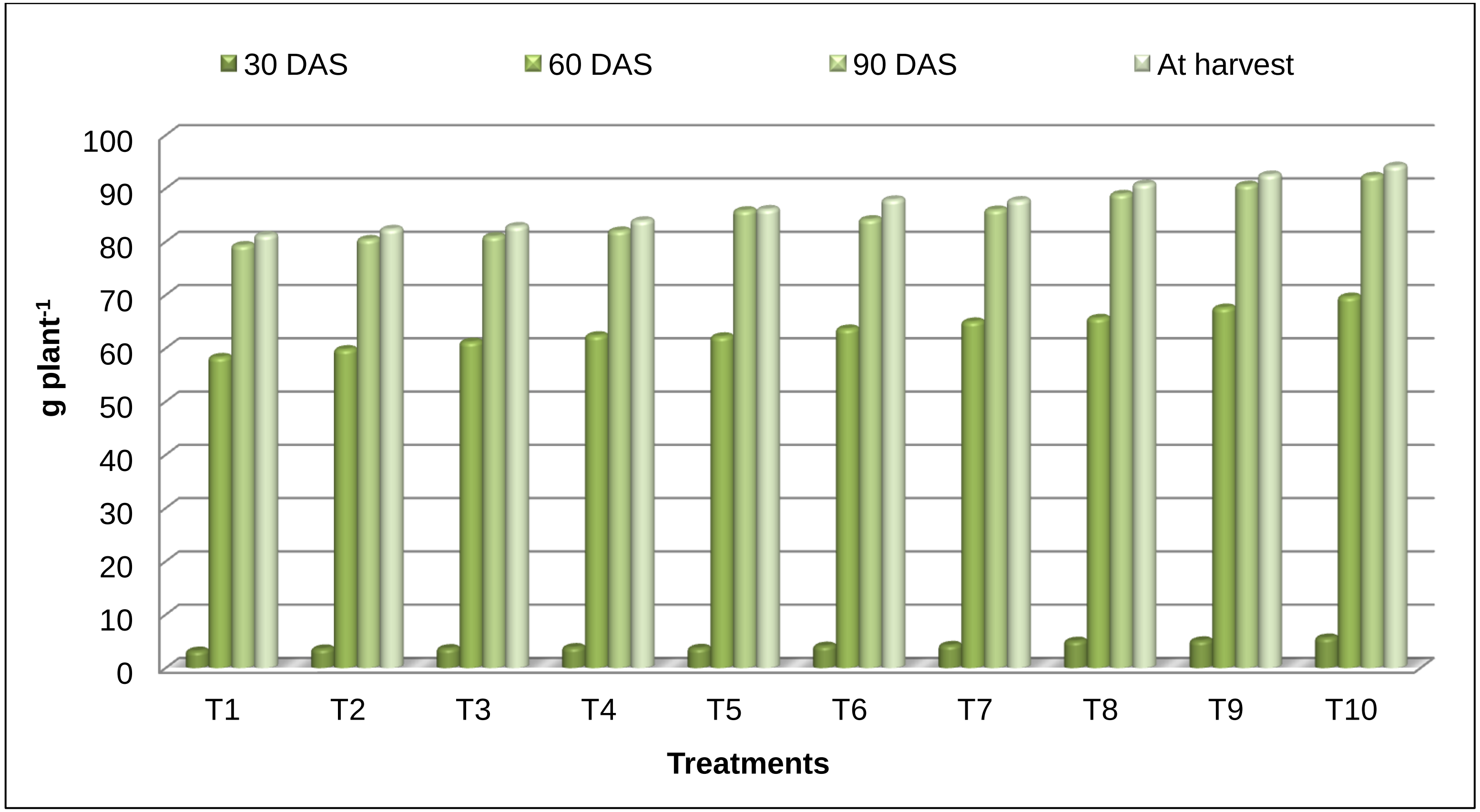
At harvest

The experiment data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} recorded maximum fresh weight (94.23) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(92.57) which were at parwith each other andT_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (90.83) but they were significantly higher over rest of the treatments. The minimum fresh weight (81.23) was distinguished in T_1-control.

Table 4.4 Effect of sulphur and bio-fertilizers on fresh weight of coriander.

Treatments	Fresh weight (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1-Control	3.20	58.33	79.33	81.23
T_2 -S @30kg ha-^{1}	3.60	59.80	80.47	82.37
T_3-S @30kg + PSB @5kg ha-^{1}	3.67	61.20	81.00	82.90
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	3.87	62.40	82.07	83.97
T_5-S @30kg + Azosp @10kg ha-^{1}	3.73	62.20	85.87	86.10
T_6-S @30kg + Azosp @15 kg ha-^{1}	4.13	63.67	84.20	87.90
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	4.27	65.00	86.00	87.77
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	5.07	65.67	88.93	90.83
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	5.13	67.6	90.67	92.57
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	5.67	69.67	92.33	94.23
S.Em.(±)	**0.24**	**2.5**	**0.72**	**0.72**
C.D. @ 5 %	**0.71**	**NS**	**2.14**	**2.14**

Fig 4.4 Effect of sulphur and bio-fertilizers on fresh weight of coriander.



4.2.4 Dry weight (g plant^{-1})

Significant differences were exhibited among the application of sulphur and different doses of bio-fertilizers in dry weight during the life span of plant growth and data are presented in Table 4.5 and diagrammatically illustrated in Fig. 4.5.

At 30 DAS

The data exhibited that,T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp*@ 15kg ha^{-1}was found to give maximum dry weight (1.39) which was at par with T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(1.29),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(1.22), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(1.18), T_5-S @ 30kg+ *Azosp* @ 10kg ha^{-1} (1.10),T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(1.09) and T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (1.01) but significantly higher with the remaining treatments. Though,T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (1.29)come after the highest which was significantly higher over all the treatments except T_1-control (0.62).The lowest dry weight (0.62) was registered in the treatment T_1-control.

At 60 DAS

The analysis of variance revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} displayed maximum dry weight (19.90) which was at par with T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (19.31),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(18.76), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(18.57) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(18.19) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(19.90)lagged behind the former which significantly higher over all the treatments except T_2- S @ 30kg ha^{-1} (17.09) and T_1-control (16.67). The lowest dry weight (16.67) was recorded in T_1-control.

At 90 DAS

The experiment data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} accumulated maximum dry weight(26.38) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (25.9) which were at parwith each otherT_8- S @ 30kg + PSB @ 5kg + *Azosp*@ 10kg ha^{-1} (25.41) but they were significantly higher over rest of the treatments. The lowest dry weight (22.67) was noted in T_1-control.

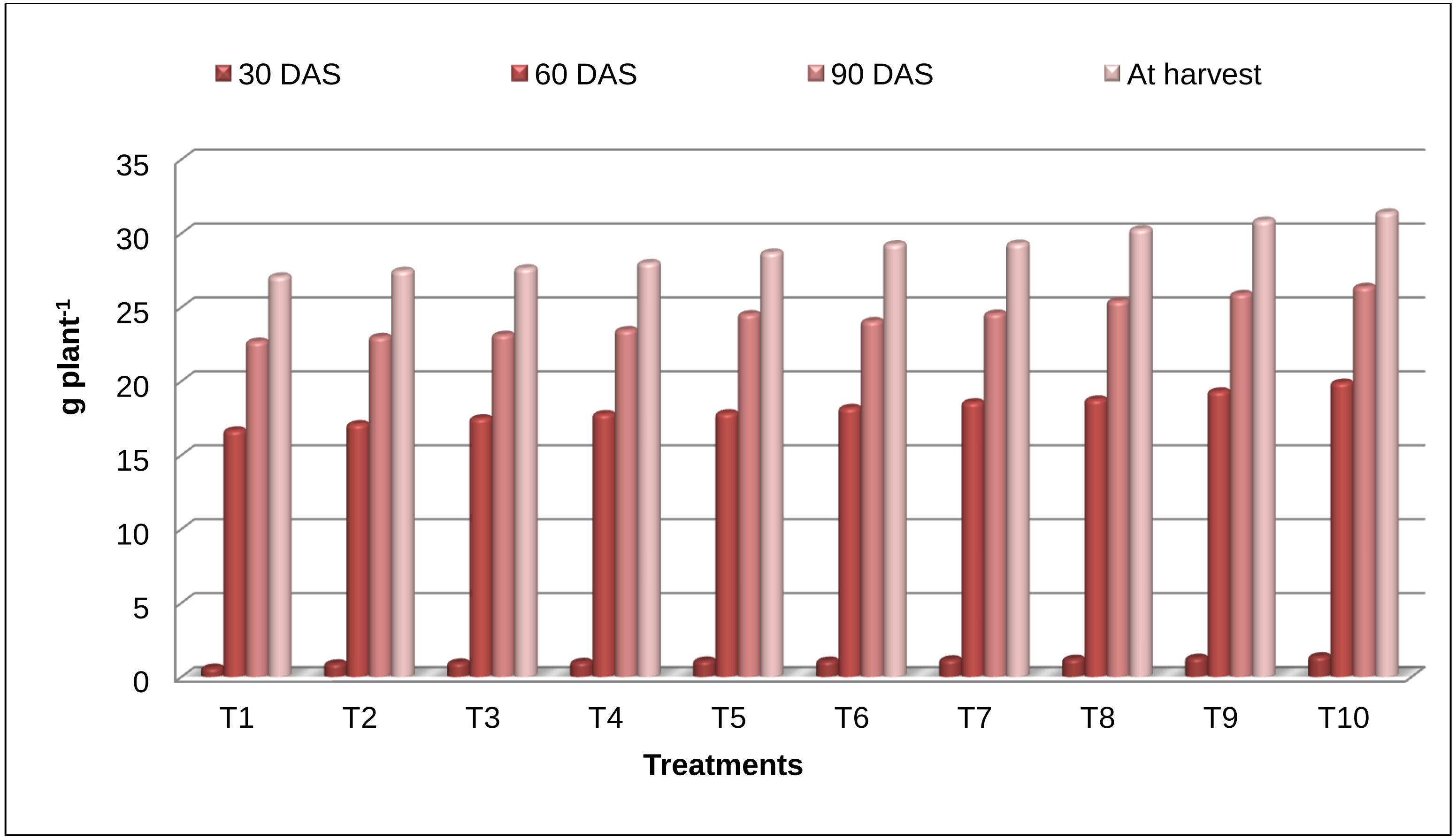
At harvest

The statistical analysis of data shown that,T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} recorded maximum dry weight(31.41) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(30.86) which were at parwith each other andT_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (30.28) but they were significantly higher over rest of the treatments. The lowest dry weight (27.08) was seen in the treatment T_1-control.

Table 4.5 Effect of sulphur and bio-fertilizers on dry weight of coriander.

Treatments	Dry weight (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
T_1-Control	0.62	16.67	22.67	27.08
T_2 -S @30kg ha-^{1}	0.91	17.09	22.99	27.46
T_3-S @30kg + PSB @5kg ha-^{1}	0.97	17.49	23.14	27.63
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	1.01	17.77	23.45	27.99
T_5-S @30kg + Azosp @10kg ha-^{1}	1.10	17.83	24.53	28.70
T_6-S @30kg + Azosp @15 kg ha-^{1}	1.09	18.19	24.06	29.26
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	1.18	18.57	24.57	29.30
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	1.22	18.76	25.41	30.28
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	1.29	19.31	25.90	30.86
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	1.39	19.9	26.38	31.41
S.Em.(±)	**0.13**	**0.63**	**0.21**	**0.24**
C.D. @ 5 %	**0.4**	**1.87**	**0.61**	**0.71**

Fig 4.5 Effect of sulphur and bio-fertilizers on dry weight of coriander.



4.3 Growth parameters

4.3.1 Leaf area (cm^2 $plant^{-1}$)

The significant variances were exhibited among the sulphur and different doses of bio-fertilizers in leaf area during the different intervals of plant growth except 90DAS and data are presented in Table 4.6 and diagrammatically illustrated in Fig 4.6.

At 30DAS

The experiment data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum leaf area(30.83), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*29.47),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (29.07) and T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(28.90)but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}*(*29.47) lagged behind the former which was found significantly differed with T_2- S @ 30kg ha^{-1} (26.67) and T_1 - control (26.59) but at par over rest of the treatments. The minimum leaf area (26.59) was recorded in T_1-control.

At 60 DAS

The analysis of variance revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} was registered maximum leaf area (84.27) which was at par with T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(80.27),T_8-S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (80.27), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(79.87) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(79.60) but significantly higher with the remaining treatments. Though T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(80.27) after the highest which significantly higher over all the treatments except T_1-control (71.07). The minimum leaf area (71.07) was perceived in T_1-control.

At 90 DAS

The treatments were found to have no significant effect on leaf area at 90DAS. The present investigation revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had took higher leaf area

(182.87)followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(180.93) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(180.33). The lower leaf area (175.47) was distinguished in T_1-contr

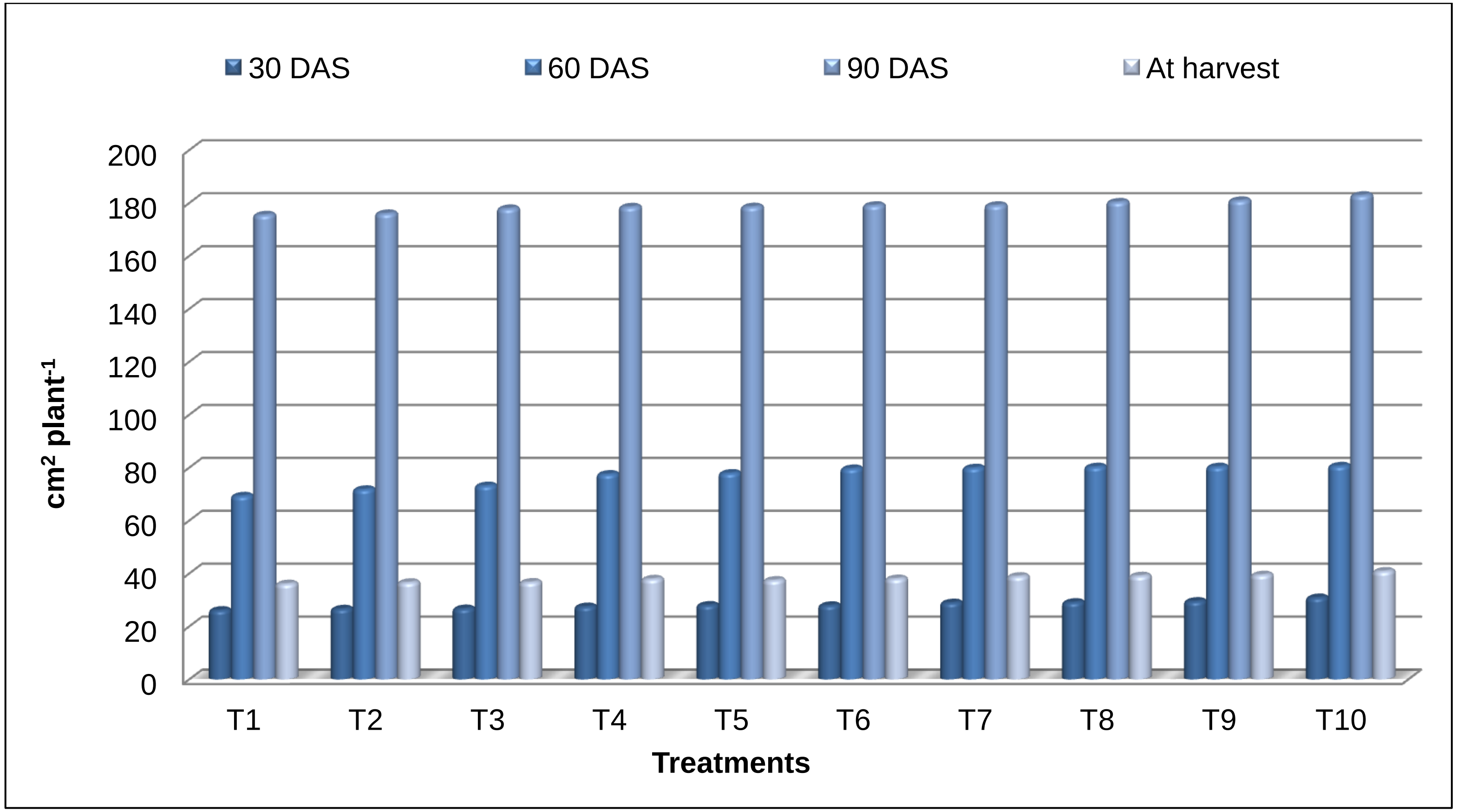
At harvest

The experimental data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} recorded highest leaf area(40.83), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*29.47),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (29.07) and T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(28.90)but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*39.47) lagged behind the former which was found significantly differed with T_2- S (30kg ha^{-1}) (36.67) and T_1 - control (36.59) but at par over rest of the treatments. The lowest leaf area (36.59) was recorded in T_1-control.

Table 4.6 Effect of sulphur and bio-fertilizers on leaf area of coriander.

Treatments	Leaf area (cm^2 $plant^{-1}$)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1-Control	26.07	69.27	175.47	36.07
T_2 -S @30kg ha^{-1}	26.59	71.73	176.00	36.59
T_3-S @30kg + PSB @5kg ha^{-1}	26.67	73.13	177.87	36.67
T_4-S @30kg + Azoto @2.5 kg ha^{-1}	27.43	77.47	178.47	37.90
T_5-S @30kg + Azosp @10kg ha^{-1}	28.00	77.87	178.53	37.43
T_6-S @30kg + Azosp @15 kg ha^{-1}	27.90	79.60	179.07	38.00
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha^{-1}	28.90	79.87	179.07	38.90
T_8-S @30kg + PSB @5kg + Azosp @10kg ha^{-1}	29.07	80.27	180.33	39.07
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha^{-1}	29.47	80.27	180.93	39.47
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1}	30.83	80.60	182.87	40.83
S.Em.(±)	**2.31**	**7.22**	**11.03**	**2.31**
C.D. @ 5 %	**0.78**	**2.43**	**NS**	**0.78**

Fig 4.6 Effect of sulphur and bio-fertilizers on leaf area of coriander.



4.3.2 Leaf area index

The leaf area index significantly varied with the application of sulphur and different doses of bio-fertilizers during life span of plants except 60-9DAS. Data are presented in Table 4.7 and diagrammatically illustrated in Fig 4.7.

At 30-60 DAS

The experiment data exhibited that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum leaf area index (0.182), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(0.181),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (0.179), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(0.178), T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(0.178) and T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1}(0.178) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.182) lagged behind the former which was found significantly differed with T_5- S @ 30kg + *Azosp* @ 10kg ha^{-1} (0.176), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (0.171), T_2- S @ 30kg ha^{-1} (0.166) and T_1 - control (0.160) but at par over rest of the treatments. The minimum leaf area index (0.160) was recorded in T_1-control.

At 60-90 DAS

No statistical difference between treatments was found at 60-90DAS with regard to leaf area index. The recorded of the data presented that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had noted maximum leaf area index(0.434) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(0.432) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(0.430). The minimum leaf area index (0.416) was seen in T_1-control.

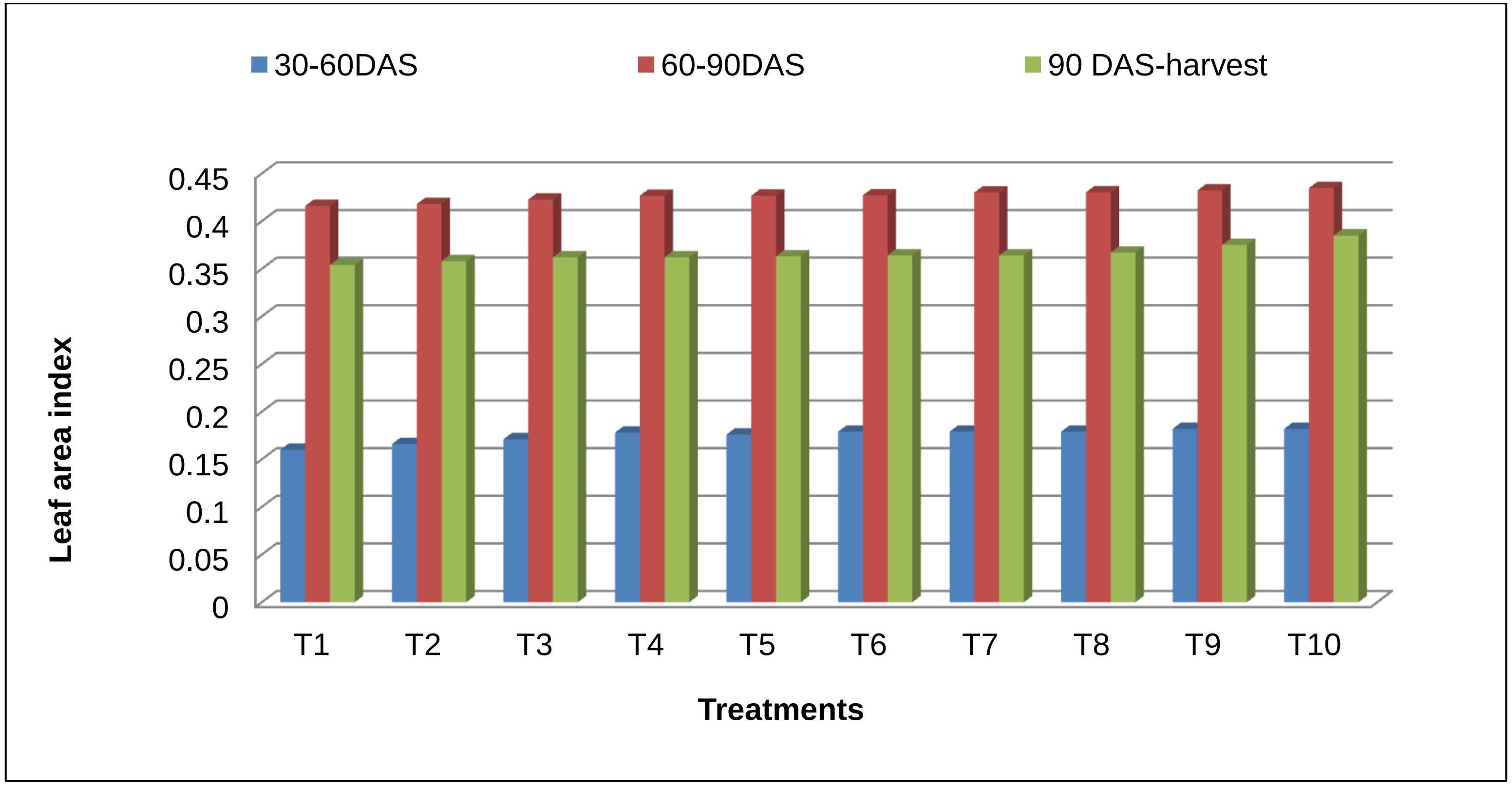
At 90 DAS – harvest:

The results exhibited that,T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}accumulated highest leaf area index (0.385), followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(0.375) were at par with each other. Both the treatments were significantly higher withT_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(0.367), T_7- S @ 30kg +PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (0.364), T_6-S @ 30kg ha^{-1}+ *Azosp* @ 15 kg ha^{-1}(0.364) and T_1-control (0.354) but at par with rest of the treatments. The lowest leaf area index (0.354) was registered in the treatment T_1-control.

Table 4.7 Effect of sulphur and bio-fertilizers on leaf area index of coriander.

Treatments	Leaf Area Index		
	30-60 DAS	60-90 DAS	90 DAS-harvest
T_1-Control	0.160	0.416	0.354
T_2 -S @30kg ha^{-1}	0.166	0.418	0.358
T_3-S @30kg + PSB @5kg ha^{-1}	0.171	0.422	0.362
T_4-S @30kg + Azoto @2.5 kg ha^{-1}	0.178	0.426	0.362
T_5-S @30kg + Azosp @10kg ha^{-1}	0.176	0.426	0.363
T_6-S @30kg + Azosp @15 kg ha^{-1}	0.179	0.427	0.364
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha^{-1}	0.179	0.430	0.364
T_8-S @30kg + PSB @5kg + Azosp @10kg ha^{-1}	0.179	0.430	0.367
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha^{-1}	0.182	0.432	0.375
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1}	0.182	0.434	0.385
S.Em. (±)	**0.013**	**0.021**	**0.017**
C.D. (5%)	**0.004**	**NS**	**0.006**

Fig 4.7 Effect of sulphur and bio-fertilizers on leaf area index of coriander.



4.3.3 Leaf area duration (cm^2 $days^{-1}$)

Significant variances were exhibited among the sulphur and different doses of bio-fertilizers for leaf area duration during the different intervals of plant growth except 60-90DAS and data are presented in Table 4.8 and graphically illustrated in Fig 4.8.

At 30-60 DAS

The present experiment manifested that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum leaf area duration (16.40), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(16.37),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (16.12), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1}(16.09), T_5- S @ 30kg + *Azosp* @ 10kg ha^{-1} (16.09) and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (16.04) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}*(*16.37) lagged behind the former which was found significantly differed with T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (15.80), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (15.38), T_2- S @ 30kg ha^{-1}(14.96) and T_1 - control (14.37) but at par over rest of the treatments. The minimum leaf area duration (14.37) was recorded in T_1-control.

At 60-90 DAS

The leaf area duration was found to be non-significant at 60-90DAS. Result revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had took maximum leaf area duration (39.12) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(38.90) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(38.72). The minimum leaf area duration (37.44) was noted in T_1-control.

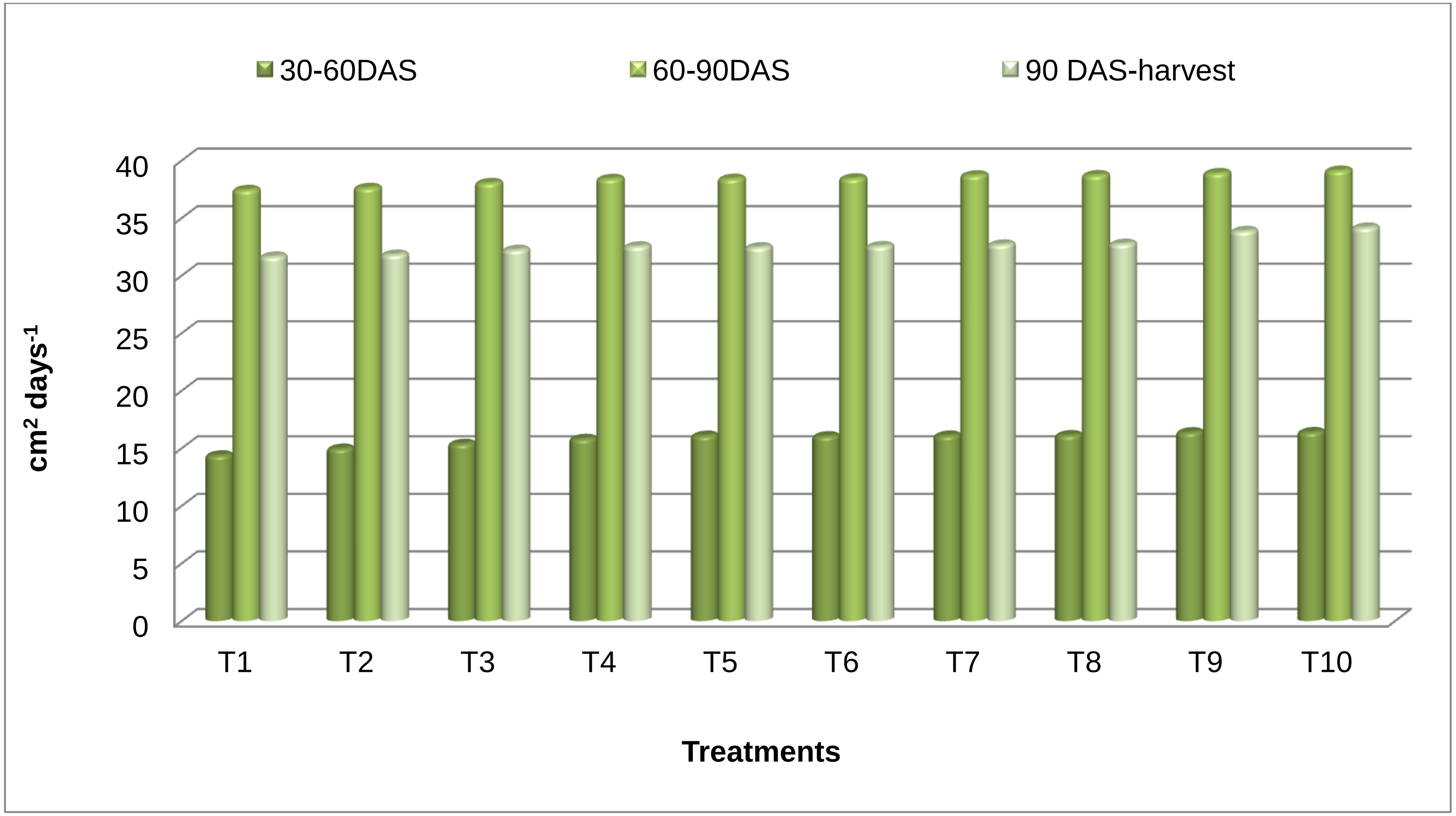
At 90-harvest DAS

On perusal of the data pertaining that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was accumulated highest leaf area duration(34.17), followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (33.87) were at par with each other. Both the treatments were significantly higher withT_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (32.75), T_7- S @ 30kg +PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (32.70), T_6-S @ 30kg ha^{-1}+ *Azosp* @ 15 kg ha^{-1}(32.56) and T_1-control (31.65) but at par with rest of the treatments. The minimum leaf area duration(31.65) was perceived in T_1-control.

Table 4.8 Effect of sulphur and bio-fertilizers on leaf area duration of coriander.

Treatments	Leaf area duration (cm^2 $days^{-1}$)		
	30-60 DAS	60-90 DAS	90 DAS-harvest
T_1-Control	14.38	37.44	31.65
T_2 -S @30kg ha^{-1}	14.96	37.62	31.82
T_3-S @30kg + PSB @5kg ha^{-1}	15.38	38.04	32.24
T_4-S @30kg + Azoto @2.5 kg ha^{-1}	15.81	38.40	32.54
T_5-S @30kg + Azosp @10kg ha^{-1}	16.09	38.41	32.46
T_6-S @30kg + Azosp @15 kg ha^{-1}	16.04	38.44	32.56
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha^{-1}	16.10	38.71	32.70
T_8-S @30kg + PSB @5kg + Azosp @10kg ha^{-1}	16.13	38.72	32.76
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha^{-1}	16.38	38.90	33.87
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1}	16.40	39.12	34.17
S.Em. (±)	**1.20**	**1.94**	**1.47**
C.D. (5%)	**0.40**	**NS**	**0.49**

Fig 4.8 Effect of sulphur and bio-fertilizers on leaf area duration of coriander.



4.3.4 Relative growth rate (g g^{-1} day^{-1})

This growth parameter varied significantly with the application of sulphur and different doses of bio-fertilizers for relative growth rate during the different plant growth stages except 90-harvest DAS and data are presented in Table 4.9 and graphically illustrated in Fig 4.9.

At 30-60 DAS

The present experiment manifested that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum relative growth rate (0.098)which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.096),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (0.095) and T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (0.095) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.096) lagged behind the former which was found significantly differed with T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (0.094), T_5-S @ 30kg ha^{-1}+ *Azosp* @ 10kg ha^{-1} (0.093), T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (0.093), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (0.093), T_2- S @ 30kg ha^{-1} (0.092) and T_1 - control (0.087) but at par over rest of the treatments. The minimum relative growth rate (0.087) was recorded in T_1-control.

At 60-90 DAS

The present investigation showed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum relative growth rate (0.077)which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.072),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (0.071), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (0.071), T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (0.070) and T_5-S @ 30kg ha^{-1}+ *Azosp* @ 10kg ha^{-1} (0.069) but significantly higher with the remaining treatments. Though,T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.072) lagged behind the former which was found significantly differed with T_4T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (0.068), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (0.067), T_2- S @ 30kg ha^{-1} (0.066) and T_1 - control (0.057) but at par over rest of the treatments. The minimum relative growth rate (0.057) was distinguished in T_1-control.

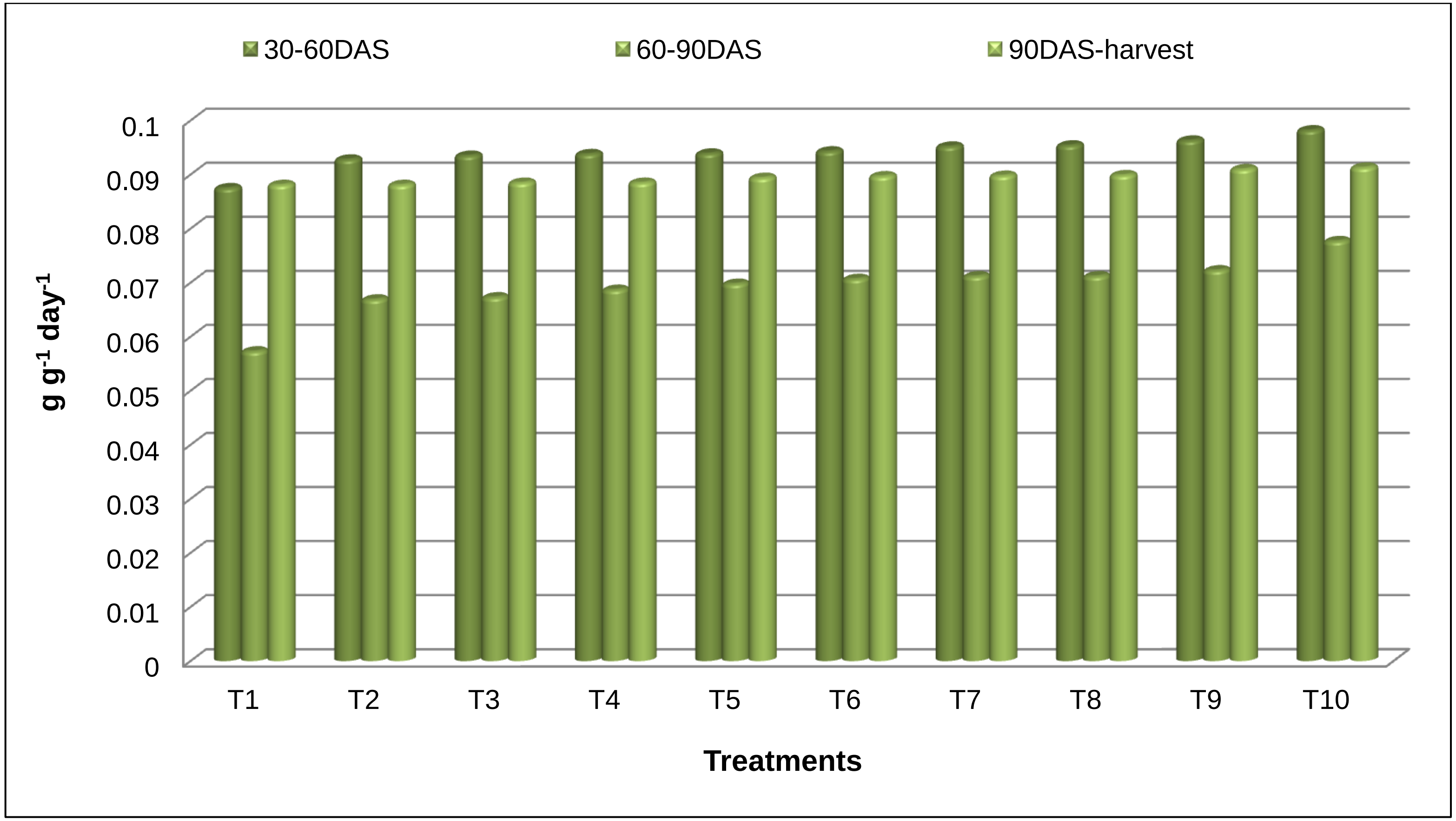
At 90 DAS- harvest

No significant effect of treatments was observed for relative growth rate at 90DAS-harvest. The analysis of variances revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had took maximum relative growth rate (0.091) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(0.091) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (0.089). The minimum relative growth rate (0.088) was recorded in T_1-control.

Table 4.9 Effect of sulphur and bio-fertilizers on relative growth rate of coriander.

Treatments	Relative growth rate (g g^{-1} day^{-1})		
	30-60 DAS	60-90 DAS	90DAS-harvest
T_1-Control	0.087	0.057	0.088
T_2 -S @30kg ha^{-1}	0.092	0.066	0.088
T_3-S @30kg + PSB @5kg ha^{-1}	0.093	0.067	0.088
T_4-S @30kg + Azoto @2.5 kg ha^{-1}	0.093	0.068	0.088
T_5-S @30kg + Azosp @10kg ha^{-1}	0.093	0.069	0.089
T_6-S @30kg + Azosp @15 kg ha^{-1}	0.094	0.070	0.089
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha^{-1}	0.095	0.071	0.089
T_8-S @30kg + PSB @5kg + Azosp @10kg ha^{-1}	0.095	0.071	0.089
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha^{-1}	0.096	0.072	0.091
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1}	0.098	0.077	0.091
S.Em. (±)	**0.005**	**0.010**	**0.008**
C.D. (5%)	**0.002**	**0.003**	**NS**

Fig 4.9 Effect of sulphur and bio-fertilizers on relative growth rate of coriander.



4.3.5 Crop growth rate (g cm^{-2} of ground area day^{-1})

The significant variances were exhibited among the sulphur and different doses of bio-fertilizers for crop growth rate during the different intervals of plant growth except 30-60 DAS and data are presented in Table 4.10 and graphically illustrated in Fig 4.10.

At 30-60 DAS

No significant difference was recorded between the treatments for crop growth rate at 30-60DAS. The present experiment revealed that**,** T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had took maximum crop growth rate(0.207) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(0.200) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1}(0.195). The minimum crop growth rate (0.194) was noted in the treatment T_1 - control.

At 60-90 DAS

The analysis of variances revealed that,T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum crop growth rate(0.140), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.102),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (0.098), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (0.097) and T_5-S @ 30kg ha^{-1}+ *Azosp* @ 10kg ha^{-1} (0.096)but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.102) lagged behind the former which was found significantly differed with T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1}(0.094), T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (0.094), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (0.094), T_2- S @ 30kg ha^{-1} (0.087) and T_1 - control (0.078) but at par over rest of the treatments. The minimum crop growth rate (0.078) was recorded in the treatment T_1 - control.

At 90 DAS - harvest

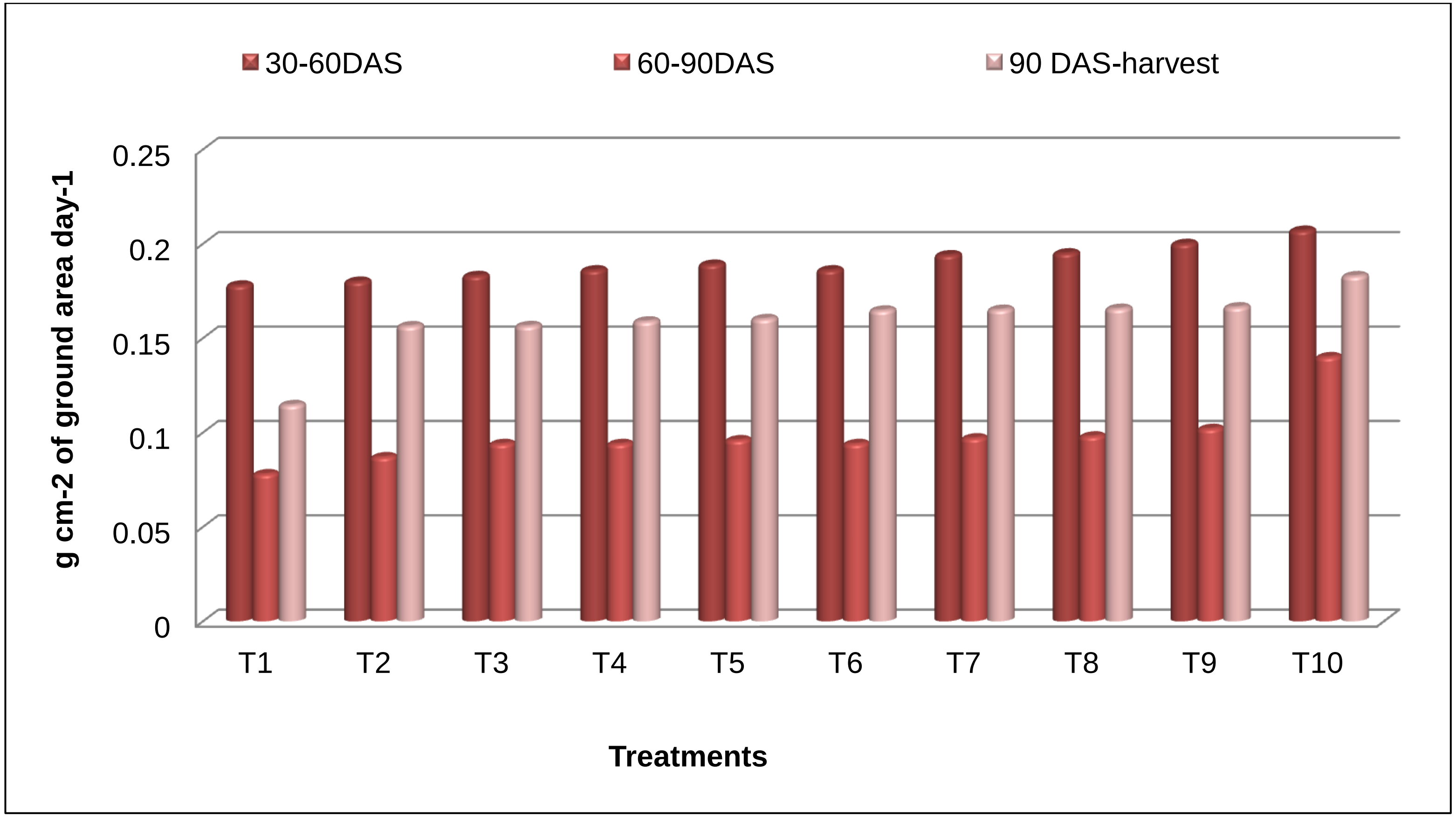
The present study showed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum crop growth rate(0.182), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*0.166),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (0.165), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (0.165), T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (0.164) T_5-S @ 30kg ha^{-1}+ *Azosp* @ 10kg ha^{-1} (0.160), T_4- S @

30kg + *Azoto* @ 2.5 kg ha^{-1} (0.158), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (0.156) and T_2- S @ 30kg ha^{-1} (0.156) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}*(*0.166)lagged behind the former which was found significantly differed with and T_1 - control (0.1146) but at par over rest of the treatments. The minimum crop growth rate (0.114) was recorded in the treatment T_1 - control.

Table 4.10 Effect of sulphur and bio-fertilizers on crop growth rate of coriander.

Treatments	Crop growth rate (g cm^{-2} of ground area day^{-1})		
	30-60 DAS	60-90 DAS	90 DAS-harvest
T_1-Control	0.178	0.078	0.114
T_2 -S @30kg ha^{-1}	0.180	0.087	0.156
T_3-S @30kg + PSB @5kg ha^{-1}	0.183	0.094	0.156
T_4-S @30kg + Azoto @2.5 kg ha^{-1}	0.186	0.094	0.158
T_5-S @30kg + Azosp @10kg ha^{-1}	0.189	0.096	0.160
T_6-S @30kg + Azosp @15 kg ha^{-1}	0.186	0.094	0.164
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha^{-1}	0.194	0.097	0.165
T_8-S @30kg + PSB @5kg + Azosp @10kg ha^{-1}	0.195	0.098	0.165
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha^{-1}	0.200	0.102	0.166
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1}	0.207	0.140	0.182
S.Em. (±)	**0.024**	**0.023**	**0.032**
C.D. (5%)	**NS**	**0.008**	**0.011**

Fig 4.10 Effect of sulphur and bio-fertilizers on crop growth rate of coriander.



4.4 Yield and yield components

The significant variances were exhibited among the different doses of sulphur and bio-fertilizers for racemes no. plant, length of racemes, seed yield (g plant $^{-1}$), seed yield (kg plot $^{-1}$), seed yield (q ha $^{-1}$), biological yield (q ha^{-1}) during the different intervals of plant growth except weight of 1000 seed (g) and harvesting index (%).

4.4.1 Number of umbles (plant^{-1})

Result revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}was manifested maximum number of umbles (27.53) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(26.83) which were at parwith treatment T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (25.67), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (24.83), and T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (23.63) but they were significantly higher over rest of the treatments. The minimum number of umbles (18.13) was registered in T_1-control.

4.4.2 Number of umbellates (umbel^{-1})

The present experiment revealed that there was no significant difference with respect to number of umbellate(umbel^{-1})**,** T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had attended maximum umbellates (6.47) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (6.40) and T_8-S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (6.33). The minimum umbellates (5.40) was noted in the treatment T_1 - control.

4.4.3 Number of seeds (umbel^{-1})

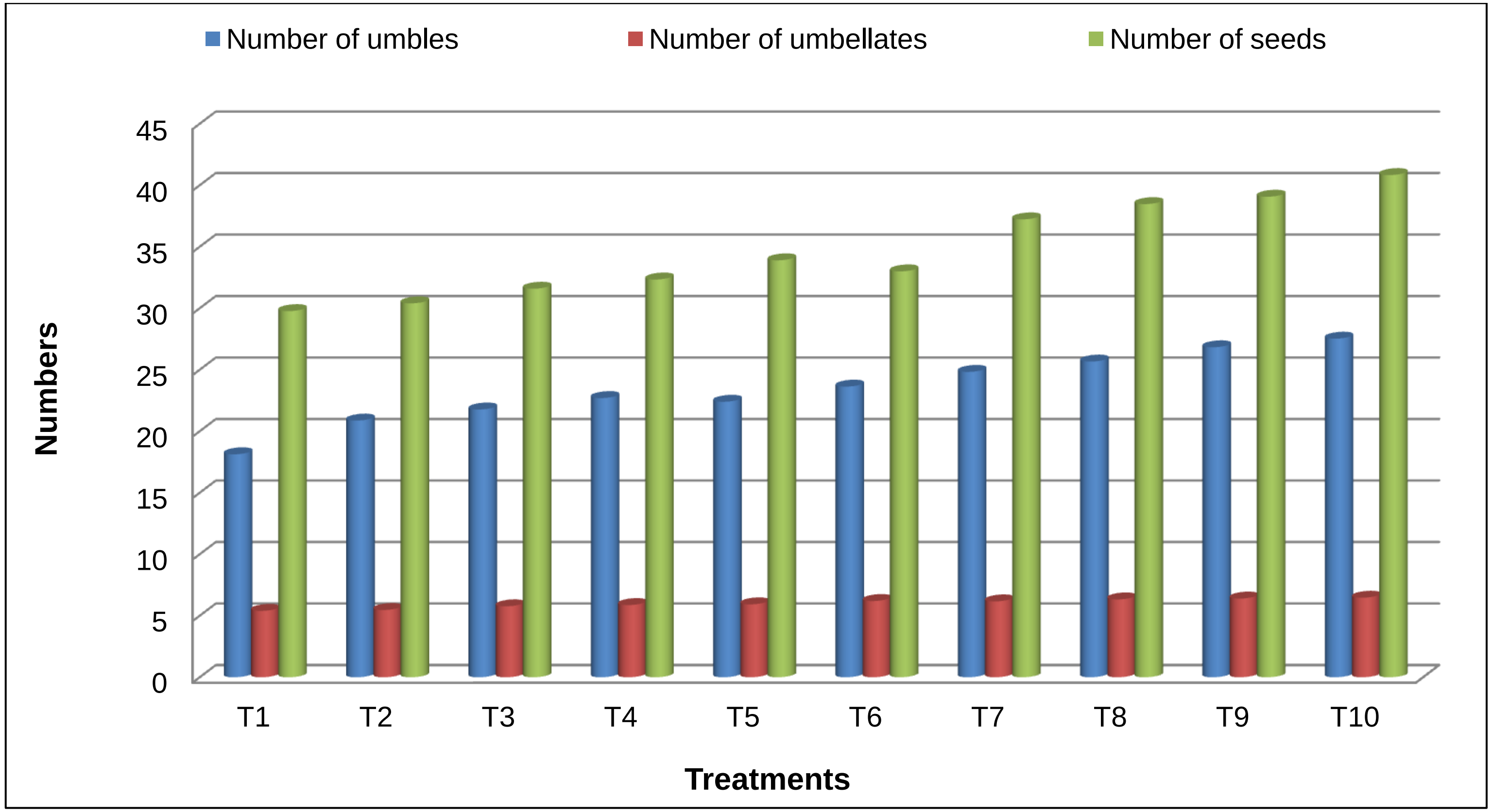
Test weight was shown statistically non significant variation on number of seeds (umbel^{-1}).The present investigation revealed from table no. 4.11 and fig no. 4.11 that,T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}was displayed maximum number of seeds (umbel^{-1}) (40.83), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*39.07),T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (38.47), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (37.23) and T_5-S @ 30kg + *Azosp* @ 10 kg ha^{-1} (33.90) but significantly higher with the remaining treatments. Though, T_9-S (30kg ha^{-1}) + PSB (5kg ha^{-1}) + *Azospirillum* (15 kg

ha^{-1}) (39.07) lagged behind the former which was at par with over all the treatments except T_3- S @ 30kg + PSB @ 5kg ha^{-1} (31.59), T_2- S @ 30kg ha^{-1}(30.40) and T_1 - control (29.77). The minimum number of seeds ($umbel^{-1}$) (29.77) was recorded in the treatment T_1 - control.

Table 4.11 Effect of sulphur and bio-fertilizers on number of umbles (plant^{-1}),number of umbellates (umbel^{-1}) andnumber of seeds (umbel^{-1})of coriander.

Treatments	**Number of umbles (plant^{-1})**	**Number of umbellates (umbel^{-1})**	**Number of seeds (umbel^{-1})**
T_1-Control	18.13	5.40	29.77
T_2 -S @30kg ha-^{1}	20.87	5.47	30.40
T_3-S @30kg + PSB @5kg ha-^{1}	21.77	5.77	31.59
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	22.70	5.87	32.34
T_5-S @30kg + Azosp @10kg ha-^{1}	22.40	5.93	33.90
T_6-S @30kg + Azosp @15 kg ha-^{1}	23.63	6.20	33.00
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	24.83	6.17	37.23
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	25.67	6.33	38.47
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	26.83	6.40	39.07
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	27.53	6.47	40.83
S.Em.(±)	**1.39**	**0.44**	**2.5**
C.D. @ 5 %	**4.12**	**NS**	**7.43**

Fig 4.11 Effect of sulphur and bio-fertilizers on number of umbels (plant^{-1}),number of umbellates (umbel^{-1})andnumber of seeds (umbel^{-1})of coriander.



4.4.4 Seed yield (g $plant^{-1}$)

Significant variances were exhibited among the different doses of sulphur and bio-fertilizers for seed yield (g $plant^{-1}$) and data are presented in table 4.12 and graphically illustrated in Fig 4.12.The statistical analysis of data presented that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was displayed maximum seed yield (2.13 g $plant^{-1}$)which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} *(*1.87 g $plant^{-1}$) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(1.87g $plant^{-1}$) lagged behind the former which was at par with over all treatments except T_2- S @ 30kg ha^{-1} (1.57g $plant^{-1}$) and T_1 - control (1.44g $plant^{-1}$) but at par over rest of the treatments. The minimum seed yield (1.44 g $plant^{-1}$) was recorded in T_1-control.

4.4.5 Seed yield (kg $plot^{-1}$)`

Result revealed from table no. 4.12 and fig no. 4.12 that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} displayed maximum seed yield (0.319 kg $plant^{-1}$), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (0.281 kg $plant^{-1}$) but significantly higher with the remaining treatments. Though, T_9-S (30kg ha^{-1}) + PSB (5kg ha^{-1}) + *Azospirillum* (15 kg ha^{-1}) *(*0.281kg $plant^{-1}$) lagged behind the former which was found significantly differed with T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (0.241 kg $plant^{-1}$), T_3- S @ 30kg + PSB @ 5kg ha^{-1} (0.237kg $plant^{-1}$), T_2- S @ 30kg ha^{-1} (0.235kg $plant^{-1}$) and T_1 - control (0.216kg $plant^{-1}$) but at par over rest of the treatments. The minimum seed yield (0.216kg $plant^{-1}$) was recorded in T_1-control.

4.4.6 Seed yield (q ha^{-1})

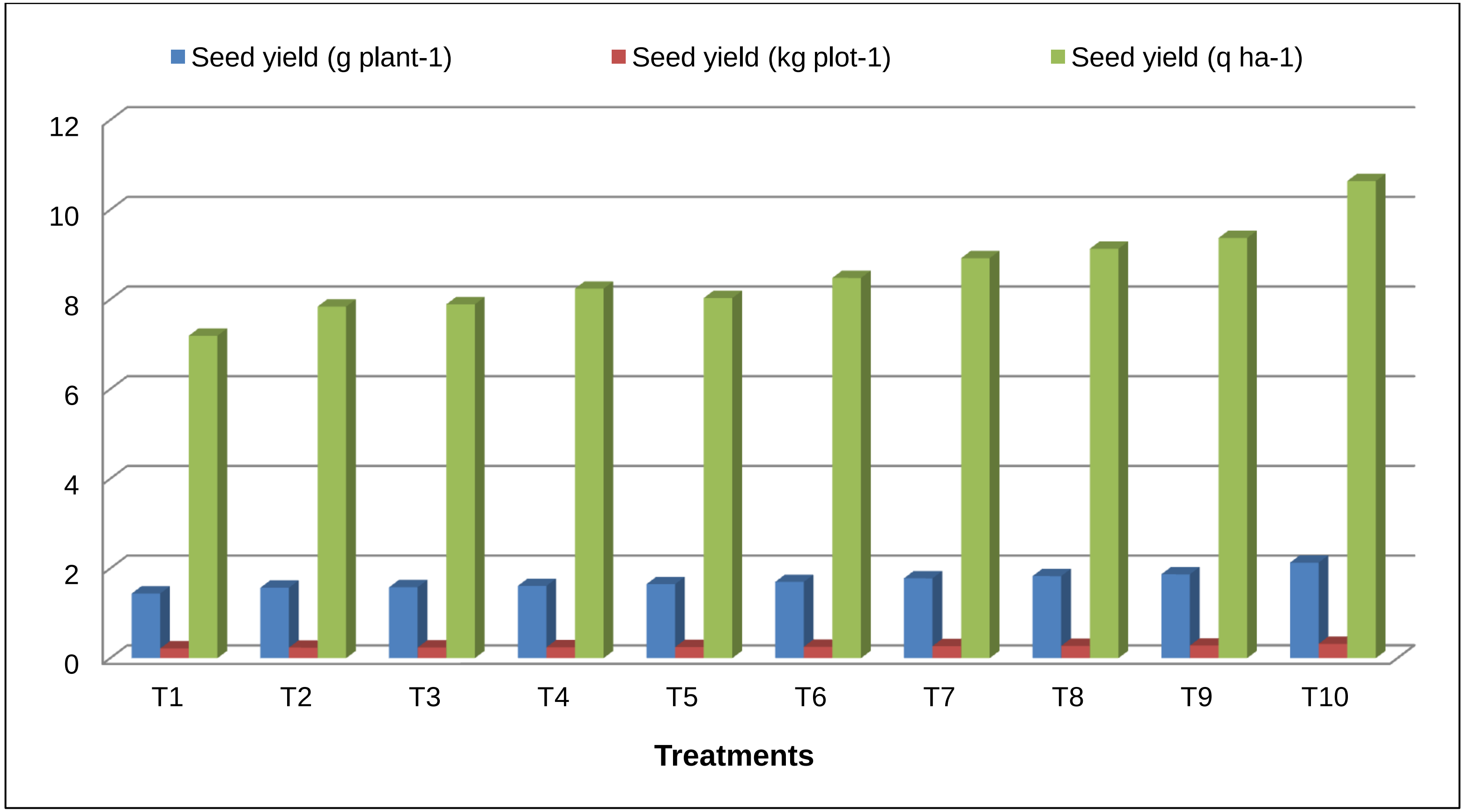
The results exhibited from table no. 4.12 and fig no. 4.12 that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} displayed maximum seed yield (10.64 q$plant^{-1}$), which was at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(9.37 q$plant^{-1}$) but significantly higher with the remaining treatments. Though, T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(9.37 q$plant^{-1}$) lagged behind the former which was found significantly differed with T_3- S @ 30kg + PSB @ 5kg ha^{-1} (7.89 q$plant^{-1}$), T_2- S (30kg ha⁻

^{1}) (7.84qplant^{-1}) and T_1 - control (7.19qplant^{-1}) but at par over rest of the treatments. The lowest seed yield (7.19qha^{-1}) was registered in T_1-control.

Table 4.11 Effect of sulphur and bio-fertilizers on Seed yield (g plant^{-1}, kg plot^{-1} and q ha^{-1}) of coriander.

Treatments	Seed yield (g plant^{-1})	Seed yield (kg plot^{-1})	Seed yield (q ha^{-1})
T_1-Control	1.44	0.216	7.19
T_2 -S @30kg ha-^{1}	1.57	0.235	7.84
T_3-S @30kg + PSB @5kg ha-^{1}	1.58	0.237	7.89
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	1.61	0.241	8.24
T_5-S @30kg + Azosp @10kg ha-^{1}	1.65	0.247	8.03
T_6-S @30kg + Azosp @15 kg ha-^{1}	1.70	0.254	8.48
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	1.78	0.268	8.92
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	1.83	0.274	9.13
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	1.87	0.281	9.37
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	2.13	0.319	10.64
S.Em. (±)	**0.1**	**0.015**	**0.49**
C.D. @ 5 %	**0.29**	**0.044**	**1.45**

Fig 4.11 Effect of sulphur and bio-fertilizers on Seed yield (g plant^{-1}, kg plot^{-1} and q ha^{-1}) of coriander.



4.4.7 Biological yield (q ha^{-1})

Significant variances were exhibited among the different doses of sulphur and bio-fertilizers for biological yield (q ha^{-1}) and data are presented in Table 4.13 and graphically illustrated in Fig 4.13.The results showed that Result revealed that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg $ha^{-1}$was manifested maximum biological yield(40.72 q ha^{-1}) followed by T_9-S(30kg ha^{-1})+PSB (5kg ha^{-1})+ *Azospirillum* (15 kg ha^{-1})(40.53 q ha^{-1}) which were at parwith treatment T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (38.38 q ha^{-1}), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (35.80 q ha^{-1}), T_5-S @ 30kg + *Azosp* @ 10 kg ha^{-1} (34.61 q ha^{-1}) and T_6-S @ 30kg ha^{-1}+ *Azosp* @ 15kg ha^{-1} (34.25 qha^{-1}) but they were significantly higher over rest of the treatments. The lowest biological yield(25.96 q ha^{-1}) was registered in T_1-control.

4.4.8 Harvesting index (%)

It is evident that different treatments had shown statistically non significant variation on percentage of harvesting index (%).The result showed from table no. 4.12 and fig no. 4.12 that, T_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1}had took maximum harvesting index(30.20%) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1}(26.45%) and T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (26.24%). The minimum harvesting index (23.01%) was noted in the treatment T_1 - control.

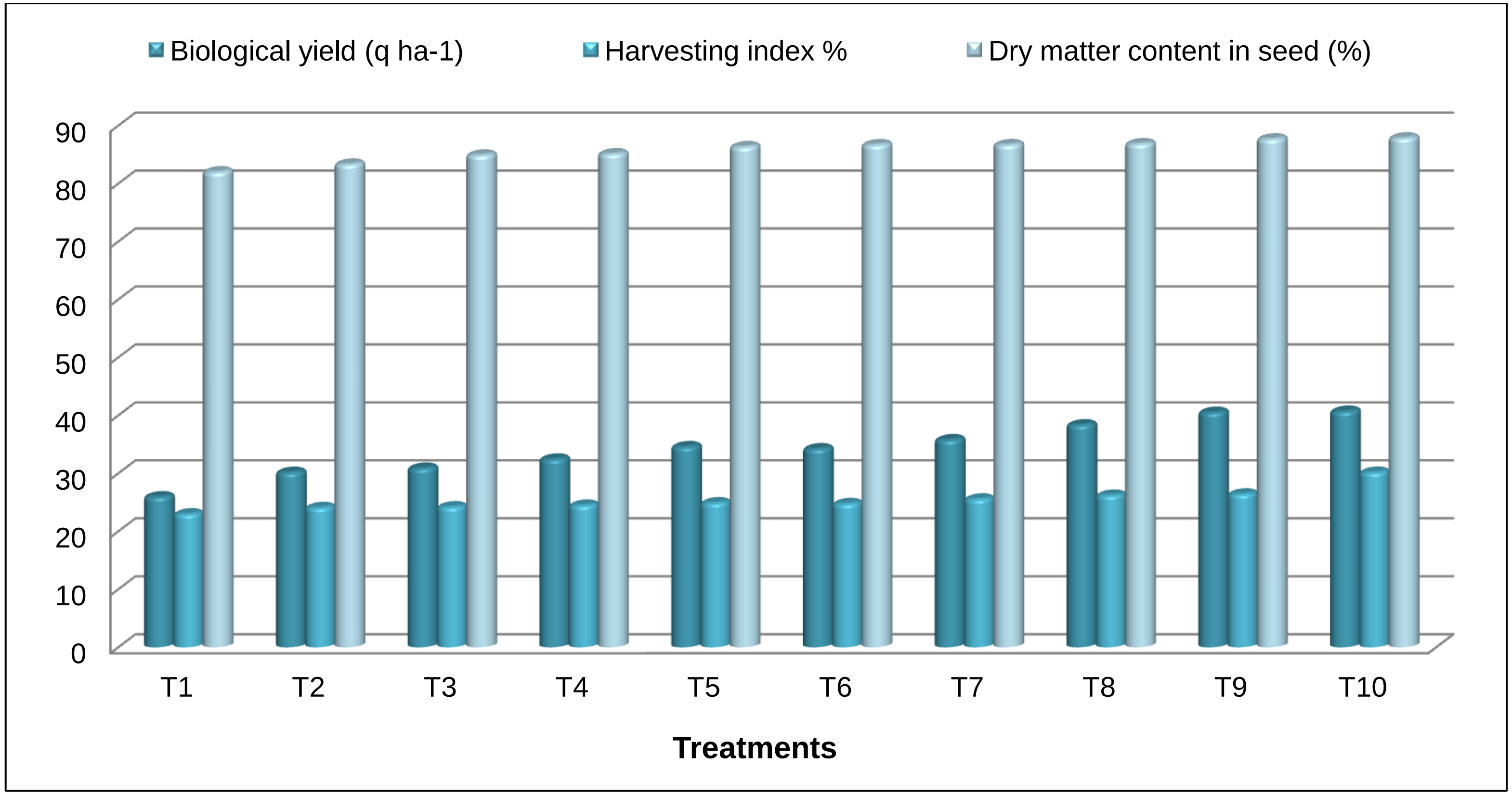
4.4.9 Dry matter content in seed (%)

The results showed thatT_{10}-S @ 30kg + PSB @ 5kg+*Azoto* @ 2.5kg +*Azosp* @ 15kg ha^{-1} manifested maximum dry matter content in seed (87.88%) followed by T_9-S @ 30kg + PSB @ 5kg + *Azosp* @ 15 kg ha^{-1} (87.71%) which were at parwith treatment T_8- S @ 30kg + PSB @ 5kg + *Azosp* @ 10kg ha^{-1} (86.88%), T_7- S @ 30kg + PSB @ 5kg ha^{-1}+ *Azoto* @ 2.5kg ha^{-1} (86.72%), T_6-S @ 30kg + *Azosp* @ 15 kg ha^{-1} (86.71%), T_5-S @ 30kg ha^{-1}+ *Azosp* @ 10kg ha^{-1} (86.37%), T_4- S @ 30kg + *Azoto* @ 2.5 kg ha^{-1} (85.15%) and T_3- S @ 30kg + PSB @ 5kg ha^{-1} (84.15%) but they were significantly higher over rest of the treatments. The lowest matter content in seed(82.03%) was registered in T_1-control.

Table 4.11 Effect of sulphur and bio-fertilizers on biological yield (q ha^{-1}), harvesting index % and dry matter content in seed (%)of coriander.

Treatments	Biological yield (q ha^{-1})	Harvesting index (%)	Dry matter content in seed (%)
T_1-Control	25.96	23.01	82.03
T_2 -S @30kg ha^{-1}	30.18	24.12	83.36
T_3-S @30kg + PSB @5kg ha^{-1}	30.9	24.23	84.93
T_4-S @30kg + Azoto @2.5 kg ha^{-1}	32.47	24.51	85.15
T_5-S @30kg + Azosp @10kg ha^{-1}	34.61	24.93	86.37
T_6-S @30kg + Azosp @15 kg ha^{-1}	34.25	24.78	86.71
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha^{-1}	35.8	25.58	86.72
T_8-S @30kg + PSB @5kg + Azosp @10kg ha^{-1}	38.38	26.24	86.88
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha^{-1}	40.53	26.45	87.71
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1}	40.72	30.2	87.88
S.Em. (±)	**2.64**	**2.67**	**1.02**
C.D. @ 5 %	**7.85**	**NS**	**3.04**

Fig 4.11 Effect of sulphur and bio-fertilizers on biological yield (q ha^{-1}), harvesting index % and dry matter content in seed (%)of coriander.



4.5 Economics of the treatment for coriander production

In the present investigation economics of various treatments with benefit cost ratio were affected with the application of sulphur and different doses of bio-fertilizers. The net profit from the cultivation of coriander was calculated after subtracting the cost of cultivation from gross returns.

Economic analysis indicated that the best treatment in term of net return was obtained in T_{10}-(30kgha^{-1}+PSB5kgha^{-1}+*Azoto*2.5kg ha^{-1}+*Azos* 15kg ha^{-1}) (Rs. 37468) and T_9-(30kgha^{-1}+PSB5kgha^{-1}+ *Azos* 15kg ha^{-1}) (Rs. 58094). However in terms of benefit: cost ratio was in T_{10}-(30kgha^{-1}+PSB5kgha^{-1}+*Azoto*2.5kg ha^{-1}+*Azos* 15kg ha^{-1})(1.3:1) followed by T_9-(30kgha^{-1}+PSB5kgha^{-1}+ *Azos* 15kg ha^{-1}) (1.0:1)and T_8-(30kgha^{-1}+PSB5kgha^{-1}+ *Azos*10kg ha^{-1})(1.0:1) and minimum in control (Rs. 18578) net return and (0.7:1)B:C ratio.

Table 4.11 Effect of sulphur and bio-fertilizers on benefit: cost of coriander.

Treatments	Benefit: Cost
T_1-Control	0.7:1
T_2 -S @30kg ha-^{1}	0.8:1
T_3-S @30kg + PSB @5kg ha-^{1}	0.7:1
T_4-S @30kg + Azoto @2.5 kg ha-^{1}	0.8:1
T_5-S @30kg + Azosp @10kg ha-^{1}	0.8:1
T_6-S @30kg + Azosp @15 kg ha-^{1}	0.9:1
T_7-S @30kg + PSB @5kg + Azoto @2.5kg ha-^{1}	0.9:1
T_8-S @30kg + PSB @5kg + Azosp @10kg ha-^{1}	1.0:1
T_9-S @30kg + PSB @5kg + Azosp @15 kg ha-^{1}	1.0:1
T_{10}-S @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha-^{1}	1.3:1

Chapter - V

DISCUSSION

The outcomes of the present study entitled **"Effect of Sulphur andBio-fertilizers onGrowth and Yield of Coriander (*Coriandrum sativum* L.)"** as shown in previous chapter has been discussed in the present section and discussed in the light of the research work reported from National and International organizations.The investigation was carried out with nine constant doses of sulphur @ 30 kg ha^{-1} with different doses bio-fertilizers (PSB @ 5 kg *Azotobacter 2.5 @ kg* and *Azospirillum* @ 10 & @ 15 kg ha^{-1}) were taken as treatments along with one untreated control plot.All the parameters were recorded at fixed interval of 30 days from days after sowing to harvest. The results of the present investigation are discussed under the following sub-headings.

5.1 Phenological parameter

The phenology of plants significantly varied with the application of sulphur and different doses of bio-fertilizer except days to 50% germination. The Table 4.1 and Figure 4.1 shown that the early germination (6.33), flowering (66.33) and maturity (95.67) were recorded in treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) and late germination (8.67), flowering (74.33) and maturity (113.00) under treatment T_1 – control at 30, 60, 90 days after sowing and at harvest respectively. The possible reason of early phenology of crop may be due to increased availability of nutrients leading to high accumulation of net photo-synthetics with optimum dose of sulphur along with biofertilizers and availability of energy sources for prolonged time. Thus, good proliferation of roots and enhance the uptake of nutrients and increased growth attributing characters (Meena *et al.,* 2014). Similar findings were also reported by Mandal and Sinha (2002). Improved field emergence and increased seedling vigour with *azospirillum* seed treatment in coriander was reported by Kalidasu *et al.* (2008).

5.1 Morphological attributes

All the morphological parameters were significantly influenced with the application of sulphur and bio-fertilizers at 30, 60, 90 days after sowing and at harvest except fresh weight at 60 days after sowing which was non-significant. This dissimilarity in morphological characteristics was arising due to constant dose of sulphur and different doses bio-fertilizers combinations. It is confirmed from the Table number 4.2, 4.3, 4.4 and 4.5 and Figure number 4.2, 4.3, 4.4 and 4.5 that the maximum plant height (9.87, 49.6, 106.67 and 109.67 cm $plant^{-1}$), number of branches (2.27, 5.27, 8.73 and 10.63 $plant^{-1}$), fresh weight (5.67, 69.67, 92.33 and 94.23 g $plant^{-1}$) and dry weight (1.39, 19.90, 26.38 and 31.41 g $plant^{-1}$) were recorded in treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) and minimum plant height (7.93, 41.93, 94.03 and 97.03 cm $plant^{-1}$), number of branches (0.87, 3.87, 6.60 and 8.50 $plant^{-1}$), fresh weight (3.2, 58.33, 79.33 and 81.23 g $plant^{-1}$) and dry weight (0.62, 16.67, 22.67 and 27.08 g $plant^{-1}$) under treatment T_1 – control at 30, 60, 90 DAS and at harvest respectively. The increased growth and its related attributes could be because of certain growth promoting substance, released through bio-fertilizers, besides increasing accretion of atmospheric nitrogen and stagnant phosphorus in soil, which may lead to finer root and seedling development, greater incorporation of water, nutrients and their convey reported by (Singh, 2014) in coriander. Among the bio-fertilizers azospirillum secret bioactive substances which have performed similar as that of growth hormones besides biological nitrogen fixation noted by Kalidasu *et al.* (2008) in coriander. Similarly, *azotobacter* which has secreted plant growth promoting ability to fix atmospheric nitrogen, antifungal and antibacterial substances that enhance plant growth. Whereas, PSB influenced the plant growth and development which may be due to the dissolved of fixed phosphorus by phosphate-emulsifiable microorganisms across the building of organic acids. noted by Meena *et al.* (2017) in coriander. Ashwath *et al.* (2012) reported the closer result as more branches with *azotobactor* or in combination with PSB. This may be because of biofertilizers secret metabolites such as plant growth hormones that directly encourage growth and facilitate nutrient uptake by plants. Further, application of sulphur improved growth and development of the crop plants in the present investigation may be the result of higher metabolic activities and photosynthetic rate leading to improvement in plant growth and ultimately the accumulation of dry biomass at successive growth stage. The findings are in accordance with Patel *et al.* (2013) in coriander.

5.2 Growth parameters

The entire growth attribution components statistically varied with the application of constant dose of sulphur and different doses of bio-fertilizers at 30, 60, 90 days after sowing and at harvest except leaf area at 90 days after sowing, leaf area index at 60-90 days after sowing, leaf area duration at 60-90 days after sowing, relative growth rate at 90 days after sowing to at harvest and crop growth rate at 90 days after sowing to at harvest. Leaf area express the functional unit of the crop stands on a unit land area, while its index is the proportion of assimilatory leaf surface area of plant. Leaf area duration expresses the magnitude and persistence of leaf area during the crop growth period. Relative growth rate is a measurement of the productivity dry mass per unit of plant mass over a specified period of time. Crop growth rate may be due to associated with the decrease in magnitude of photo assimilatory area of the plant. The result revealed from the Table 4.6, 4.7, 4.8, 4.9 and 4.10 and Figure 4.6, 4.7, 4.8, 4.9 and 4.10 that, leaf area, leaf area index and leaf area duration were shown sigmoid curve but relative growth rate and crop growth rate shown reverse sigmoid curve. However, the highest leaf area (30.83, 84.27, 182.87 and 40.83), leaf area index (0.182, 0.435 and 0.384), leaf area duration (16.40, 39.12 and 34.17), relative growth rate (0.0981, 0.0777 and 0.0913) and crop growth rate (0.207, 0.139 and 0.182) were accumulated in treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) and lowestleaf area (26.59, 71.07, 175.47 and 36.59), leaf area index (0.159, 0.416 and 0.353), leaf area duration (14.37, 38.04 and 31.65), relative growth rate (0.0875, 0.0573 and 0.0881) and crop growth rate (0.178, 0.0783 and 0.114) in T_1- control untreated plots at 30, 60, 90 days after sowing and at harvest respectively. The use of biofertilizers can raise the building of nutrients and the obtainable of growth hormones by bacteria that are straight intricate in increasing the width and length of leaves major to better foliose yield reported by Mounika *et al.* (2017). Alike results were apply by Sonali *et al.* (2012) in fenugreek. The current worldwide research to exploit bio-fertilization as an alternative to chemical fertilization especially in medicinal and aromatic plants has been reported by many researchers Darzi *et al.* (2012). The biofertilizer can directly increase plant growth by enhancing atmospheric nitrogen fixation, solubilization of minerals that sequester iron or secreting the plant growth hormones or due to phytohormones released by biological nitrogen fixers such as IAA (Taghavi *et al.,* 2009). This might be due to more availability and production of nutrients leading to high accumulation of net photosynthates with the application of optimum dose of sulphur along with biofertilizers. Thus, better proliferation of roots and higher uptake of nutrients increased growth attributing characters. *Azotobacter* which has the ability to fix atmospheric nitrogen, produce plant hormone and they increased plant growth. The possible reason for obtaining higher relative growth rate may be due to increase in cell elongation, cell multiplication and cell expansion throughout the entire growth period. This may be resulted in more production of photosynthates and their translocation to sink, which ultimately increased the plant growths observed by Meena *et al.,* 2013.

Yield parameters:

The yield and yield attributing parameters *viz.,* number of umbels, number of umbellate, number of seeds, seed yield, biological yield and dry matter content were significantly higher with the application of sulphur andbio-fertilizers except number of umbellate and harvest index which non-significant. The data are depicted in Table 4.11, 4.12 and 4.13 and diagrammatically Figure 4.11, 4.12 and 4.13. The highest number of umbels was recorded in (27.53 plant^{-1}), number of umbellate (6.47 umbel^{-1}), number of seeds (40.83 umbel^{-1}), seed yield (2.13 g plant^{-1}), seed yield (0.319 kg plot^{-1}), seed yield (10.64 q ha^{-1}), biological yield (40.72 q ha^{-1}), harvest index (30.2 %) and dry matter content in seed (87.88%) were found is T_{10}- (S @ 30kg + PSB @ 5kg + Azoto @ 2.5kg + Azosp @ 15kg ha^{-1}) while, minimum number of umbels (18.13 plant^{-1}), number of umbellate (5.40 umbel^{-1}), number of seeds (29.77 umbel^{-1}), seed yield (1.44 g plant^{-1}), seed yield (0.216 kg plot^{-1}), seed yield (7.19 q ha^{-1}), biological yield (25.96 q ha^{-1}) and harvest index (23.01 %) and dry matter content in seed (82.03%) in T_1- control at 30, 60, 90 days after sowing and at harvest respectively. The combined application of azotobacter + phosphate solubilizing bacteria + sulphur noted the significant high yield and yield components. This may be due to enhance availability and production of nutrients leading to high accumulation of net photosynthates with optimum dose of sulphur along with bio-fertilizers as compare to alone. Hence, higher proliferation of roots and increased absorption of nutrients from soil which enhanced growth and yield attributing traits (Meena *et al.,* 2013). The possible reason are that accessible of phosphorus improved by PSB, nitrogen fixed from atmosphere by azotobactor leads to balance supply of major nutrients and ultimately contributed into higher yield and yield attributing traits (Aishwath *et al.,* 2012). Sulphur is an essential secondary plant nutrient and it is necessary for synthesis of kind of vitamins and amino acids as well as it help in photosynthesis and nitrogen fixation. Uptake of nitrogen, phosphorous and sulphur from the soil by plants were also increased with the help of sulphur (Lal *et al.,* 2014).

Economics of the treatments

In the present investigation the data of benefit cost ratio were affected with the application of sulphur and different doses of bio-fertilizers. The net profit from the cultivation of coriander was calculated after subtracting the cost of cultivation from gross returns. In the present study, the economics of the different treatments were affected due to application of sulphur and different doses of bio-fertilizers.

The highest net returns (Rs. 37468) and benefit: cost ratio (1.3:1) was recorded in treatment in T_{10}-(30kgha^{-1}+PSB5kgha^{-1}+*Azoto*2.5kg ha^{-1}+*Azos* 15kg ha^{-1}) as compared to other treatments and the lowest in T_1-control (Rs. 18578) net returns and (0.7:1) B: C ratio. Thus, it can be concluded that the application of sulphur and different doses of bio-fertilizers through the highest system productivity and net monetary returns from coriander crops along with improvement in soil health of loamy sand soil under semi-arid plain of Madhya Pradesh.

Chapter - VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

The present field experiment on **"Effect of Sulphur and Bio-fertilizers on Growth and Yield of Coriander (*Coriandrum sativum* L.)"** was conducted at Horticulture Research Farm, department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.)during the year 2020-2021.

In this experiment application of effect of sulphur and bio-fertilizerswereassessed for phenological, morphological, growth and yield attributes under field condition. The investigation was carried out with nine constant doses of sulphur @ 30 kg ha^{-1} with different doses bio-fertilizers (PSB @ 5 kg *Azotobacter 2.5 @ kg* and *Azospirillum @ 10 & @ 15 kg* ha^{-1}) while the plants in the control plots were shown without any application of supplements. The research experiment was enclosing in a random block design with three replicates. All the parameters were recorded at 30, 60, 90 days after sowing and at harvest. The significant findings of the studies are summarized below.

Summary:

Among pre harvest and at harvest observations, the plant height (cm), number of branches per plant, fresh weight of plants (g), dry weight of plants (g) and phenological parameter days to 50% germination, days to 50% flowering and days to maturity were studied in coriander. All the morphological characteristics were significantly influenced except fresh weight at 60 days after sowing with the application of sulphur and bio-fertilizer. However, treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) was recorded highest values of plant height (7.93, 41.93, 94.03 and 97.03 cm $plant^{-1}$), number of branches (0.87, 3.87, 6.60 and 8.50 $plant^{-1}$), fresh weight (3.2, 58.33, 79.33 and 81.23 g $plant^{-1}$) and dry weight (0.62, 16.67, 22.67 and 27.08 g $plant^{-1}$)at 30, 60, 90 days after sowing and at harvest respectively. All the phenological characteristics were significantly influenced except days to 50% germination with the application of sulphur and bio-fertilizer. However, treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) was observed early germination (6.33), days taken to 50% flowering (66.33) and days to maturity (113) as compared to untreated plot.

Among growth parameter, leaf area (cm^2 $plant^{-1}$), leaf area index(%), leaf area duration (cm^2 $days^{-1}$), crop growth rate (g cm^2 $days^{-1}$)and relative growth rate (g g^{-1} $days^{-1}$) were significantly higher with the application of sulphur and bio-fertilizers except leaf area 90 days after sowing, leaf area index 60-90 days after sowing, leaf area duration 60-90 days after sowing, crop growth rate 30-60 days after sowing and growth relative rate 90 days after sowing - at harvest and significantly influenced by different treatments. However, treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) was registered the highest value of leaf area (30.82cm^2 $plant^{-1}$), leaf area index (0.182 %), leaf area duration (16.40 cm^2 $days^{-1}$), crop growth rate (0.200 g cm^2 $days^{-1}$) and relative growth rate (0.098 g g^{-1} $days^{-1}$) compared to control.

Among the yield and yield attributes, number of umbels, number of seeds, seed yield, biological yield and dry matter content in seed were significantly higher with the application of sulphur and bio-fertilizers before sowing except number of umbellate and harvest index. However, treatment T_{10}- (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}) was registered the highest value of number of umbels (27.53 $plant^{-1}$), number of umbellate (6.47 $umbel^{-1}$), number of seeds (40.83 $umbel^{-1}$), seed yield (2.13 g $plant^{-1}$), seed yield (0.319 kg $plot^{-1}$), seed yield (10.64 q ha^{-1}), biological yield (40.72 q ha^{-1}), harvest index (30.2 %) and dry matter content in seed (87.88%) as compared to control.

Under the economics of the treatment, it was found that, the highest net return (Rs. 37468) and benefit: cost ratio (1.3:1) were obtained from T_{10} - (S @ 30kg + PSB @ 5kg + *Azoto* @ 2.5kg + *Azosp* @ 15kg ha^{-1}).

Conclusion:

On the foundation of one year research it can be concluded that, out of 10 treatment combinations of sulphur and bio-fertilizers. The best performing combination is suphure @30kg + PSB @5kg + Azoto @2.5kg + Azosp @15kg ha^{-1} for enhanced growth and yield of coriander.

Suggestions for future work:

Based on the current study, the following line of work may be suggested for future investigation

1. Same analysis can be repeated to check the findings of present work.
2. Effect of bio-fertilizers and chemical fertilizers on phytochemical constituents of seeds may be carried out.
3. Some approximate analysis may be checked.

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Appendix I: Analysis of variance for thephenological traits of coriander under different treatments

Source ofVariation	D.F.	Mean sum of squares		
		Days to 50% germination	Days to 50% flowering	Days to maturity
Replications	2	2.23	15.23	50.83
Treatments	9	1.81	19.37	78.90
Error	18	1.01	5.23	15.98
Total	29	-	-	-

Appendix II: Analysis of variance for the morphological traits of coriander under different treatments

Source of Variation	D.F.	Mean sum of squares							
		Plant height (cm plant^{-1})				Number of branches (plant^{-1})			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Replications	2	1.75	5.90	4.17	4.17	0.04	0.06	0.09	0.09
Treatments	9	1.27	21.60	49.65	49.65	0.78	0.75	1.29	1.29
Error	18	0.44	8.44	18.49	18.49	0.18	0.27	0.46	0.46
Total	29	-	-	-	-	-	-	-	-

Significant at 5% probability

Appendix III: Analysis of variance for the morphological traits of coriander under different treatments

Source ofVariation	D.F.	Mean sum of squaresLeaf area (cm plant^{-1})			
		30 DAS	60 DAS	90 DAS	At harvest
Replications	2	0.99	5.74	25.64	0.99
Treatments	9	6.62	47.80	14.52	6.62
Error	18	1.82	24.77	41.38	1.82
Total	29	-	-	-	-

Appendix IV: Analysis of variance for the growth attributing traits of coriander under different treatments

Source of Variation	D.F.	Mean sum of squares							
		Fresh weight (g plant^{-1})				Dry weight (g plant^{-1})			
		30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Replications	2	0.33	29.03	2.03	2.03	0.01	0.70	0.17	0.23
Treatments	9	1.91	36.79	60.31	60.31	0.14	3.00	4.92	6.70
Error	18	0.17	18.76	1.56	1.56	0.05	1.19	0.13	0.17
Total	29	-	-	-	-	-	-	-	-

Significant at 5% probability

Appendix V: Analysis of variance for the growth attributing traits of coriander under different treatments

Source of Variation	D.F.	Mean sum of squares					
		Crop growth rate (g $cm^{-1}$of ground area day^{-1})			Relative growth rate (g g^{-1} day^{-1})		
		30-60 DAS	60-90 DAS	90 DAS-at harves	30-60 DAS	60-90 DAS	90 DAS-at harvest
Replications	2	0.0000002	0.00005	0.0000002	0.00017	0.00006	0.000001
Treatments	9	0.0000089	0.00015	0.0000069	0.00037	0.00039	0.000017
Error	18	0.0000034	0.00006	0.0000002	0.00010	0.00015	0.000009
Total	29	-	-	-	-	-	-

Appendix VI: Analysis of variance for the growth attributing traits of coriander under different treatments

Source ofVariation	D.F.	Mean sum of squares					
		Leaf Area Index			Leaf Area Duration (cm^2 $days^{-1}$)		
		30-60 DAS	60-90 DAS	90 DAS-at harvest	30-60 DAS	60-90 DAS	90 DAS-at harvest
Replications	2	0.000001	0.00008	1.495	0.009	0.905	0.483
Treatments	9	0.000161	0.00023	1.499	1.305	0.875	3.992
Error	18	0.000060	0.00009	1.483	0.489	1.285	1.426
Total	29	-	-	-	-	-	-

Significant at 5% probability

Appendix VII: Analysis of variance for yield attributing of coriander under different treatments

Source ofVariation	D.F.	Mean sum of squares		
		Number of umbles ($plant^{-1}$)	Number of umbellates ($umbel^{-1}$)	Number of seeds ($umbel^{-1}$)
Replications	2	0.01	0.60	9.1
Treatments	9	24.81	0.43	46.3
Error	18	5.77	0.57	18.7
Total	29	-	-	-

Appendix VIII: Analysis of variance for Yield and yield components of coriander under different treatments

Source of Variation	D.F.	Mean sum of squares		
		Seed yield (g $plant^{-1}$)	Seed yield (kg $plot^{-1}$)	Seed yield (q ha^{-1})
Replications	2	0.04	0.0009	0.96
Treatments	9	0.12	0.0026	2.89
Error	18	0.03	0.0006	0.71
Total	29	-	-	-

Significant at 5% probability

Appendix IX: Analysis of variance for Yield and yield components of coriander under different treatments

Source of Variation	D.F.	Mean sum of squares		
		Biological yield (q ha^{-1})	Harvesting index %	Dry matter content in seed (%)
Replications	2	8.80	15818.4	6.0
Treatments	9	66.81	2907.9	10.8
Error	18	20.97	21060.7	3.1
Total	29	-	-	-

Significant at 5% probability

VITA

The author of this thesis **Mr.Himalay Chandel** was born on 1thAugust 1996 at Village- Budhan Bhath, Post- Chhuikhadan Tehsil+District- Rajnandgaon (C.G.).

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